ENVIRONMENTAL PLANNING STRATEGIES FOR URBAN RIVER: A CASE STUDY OF GURUPURA RIVER IN THE COASTAL CITY OF MANGALURU

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DECLARATION

I, K S Ananya, the author of the thesis titled, **"Environmental Planning Strategies for Urban River: A Case Study of Gurupura River in the Coastal City of Mangaluru"** hereby declare that the thesis work submitted for the partial fulfilment of the award of the degree of Master of Planning (with specialization in Environmental Planning) is the outcome of my own work, bona-fide and authentic to the best of my knowledge.

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CERTIFICATE

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List of Maps

Map 1 Netravati and other's sub river basin of the larger Tadri to Kanyakumari River Basin.. 4
Map 2 Dakshin Kannada District and its Watersheds 4
Map 3 White River Basin 35
Map 4 River Reaches of the White River 37
Map 5 Ganga Basin 39
Map 6 Connectivity to the region 44
Map 7 Dakshin Kannada located on Koppen's climate classification of India 45
Map 8 Dakshin Kannada located on Biogeographic zone of India 46
Map 9 Dakshin Kannada located on the Agro-climate zones of India 47
Map 10 Dakshin Kannada located on the Champion & Seth's forest Classification map of India 48
Map 11 Physiographic region of Karnataka 50
Map 12 Netravati & the others Sub-basin of Tadri to Kanyakumari River basin 51
Map 13 Dakshin Kannada District located on Netravati & the others Sub-basin 52
Map 14 Dakshin Kannada district & its Watershed 52
Map 15 Sub-watersheds encompassing the Dakshin Kannada district 53
Map 16 Rivers & Waterbodies of Dakshin Kannada District 54
Map 17 Contour 55
Map 18 Elevation 56
Map 19 Slope 57
Map 20 Faults & Lineaments 58
Map 21 Forest Cover 59
Map 22 Scoped Environmental Region 60
Map 23 Tehsil Boundary of Dakshin Kannada District 61
Map 24 Village boundary 62
Map 25 Mangaluru Planning Area & Municipal Corporation Boundary 62
Map 26 Urban Centres in Dakshin Kannada District 63
Map 27 Road Network of Dakshin Kannada District 64
Map 28 Tourist locations in the district 65
Map 29 Industries 66
Map 30 Scoped Man-made region 67
Map 31 Overlay of Environmental & Man-made region 68
Map 32 Scoped Region 69
Map 33 Decadal Isohyets 1992-2021 74

Map 34 Geology map of the region 77
Map 35 Geomorphology of the region 78
Map 36 Soil map of the region 79
Map 37 Watersheds, sub-watersheds & Rivers 80
Map 38 Stream Order 81
Map 39 Infrastructure built on surface water 82
Map 40 Micro-watersheds of the Region 85
Map 41 Watersheds & Sub-Watersheds of the region 86
Map 42 Stream Order 87
Map 43 Micro-watershed Bifurcation Ratio 87
Map 44 Sub-watershed Bifurcation Ratio 87
Map 45 Micro-watershed - Length of Overland flow 88
Map 46 Sub-watershed Length of Overland flow 88
Map 47 Micro-watershed Circularity Ratio 89
Map 48 Sub-watershed Circularity Ratio 89
Map 49 Micro-watershed Stream Frequency 90
Map 50 Sub-watershed Stream Frequency 90
Map 51 Micro-watershed Drainage Density 90
Map 52 Sub-watershed Drainage Density 90
Map 53 Micro-watershed Texture Ratio 90
Map 54 Sub-watershed Texture Ratio 90
Map 55 Micro-watershed Infiltration Number 90
Map 56 Sub-watershed Infiltration Number 90
Map 57 Micro-watershed - Basin Relief 91
Map 58 Sub-watershed - Basin Relief 91
Map 59 Micro-watershed Relief Ratio 92
Map 60 Sub-watershed Relief Ratio 92
Map 61 Micro-watershed Ruggedness number 92
Map 62 Sub-watershed Ruggedness number 92
Map 63 Pre-Monsoon Flow 93
Map 64 Post-Monsoon Flow 93
Map 65 Monsoon Flow 93
Map 66 Cumulative flow of sub-watersheds 94
Map 67 Pre-Monsoon Depth to water level in the region 1990-1999 95
Map 68 Post-Monsoon Depth to water level in the region 1990-1999 95
Map 69 Decadal (1990-1999) Pre-Monsoon Depth to water level in the region 96



Map 70 Decadal (1990-1999) Post-Monsoon Depth to water level in the region 96
Map 71 Seasonal Fluctuation in depth to water levels in the region 1990-1999 96
Map 72 Decadal (1990-1999) Seasonal Fluctuation in depth to water levels in the region 96
Map 73 Decadal (1990-1999) Standard deviation in fluctuation in the region..... 96
Map 74 Pre-Monsoon Depth to water level in the region 2000-2009..... 97
Map 75 Post-Monsoon Depth to water level in the region 2000-2009 97
Map 76 Decadal (2000-2009) Pre-Monsoon Depth to water level in the region..... 97
Map 77 Decadal (2000-2009) Post-Monsoon Depth to water level in the region 97
Map 78 Seasonal Fluctuation in depth to water levels in the region 2000 - 2009 98
Map 79 Decadal (2000-2009) Seasonal Fluctuation in depth to water levels in the region 98
Map 80 Decadal (2000-2009) Standard Deviation in fluctuations in the region 98
Map 81 Pre-Monsoon Depth to water level in the region 2010-2019..... 99
Map 82 Post-Monsoon Depth to water level in the region 2010-2019 99
Map 83 Decadal (2010-2019) Pre-Monsoon Depth to water level in the region..... 99
Map 84 Decadal (2010-2019) Post-Monsoon Depth to water level in the region 99
Map 85 Seasonal Fluctuation in depth to water levels in the region 2010 - 2019 100
Map 86 Decadal (2010-2019) Seasonal Fluctuation in depth to water levels in the region .. 100
Map 87 Decadal (2010-2019) Standard Deviation in fluctuations in the region 100
- Map 88 Rock formation & Lineaments in the region 101

Map 89 Low recharge potential zones 102
Map 90 Forest Area..... 103
Map 91 Forest Area in the region..... 103
Map 92 LULC 2015 106
Map 93 LULC 2024 106
Map 94 NDVI - Pre-Monsoon & Post-Monsoon for 2015 & 2024 107
Map 95 NDWI Analysis..... 108
Map 96 NDWI April 2015 108
Map 97 NDWI April 2024 108
Map 98 NDWI December 2015 108
Map 99 NDWI December 2024 108
Map 100 Total population of the region – Tehsil wise 110
Map 101 Total population of the region – Village wise 110
Map 102 Total Urban Population..... 110
Map 103 Total Urban Population - village wise 110
Map 104 Class of Settlements as per URDPFI 110
Map 105 Sex ratio in the region..... 111



Map 106 Literacy rate 112
Map 107 % SC Population 112
Map 108 % ST Population 112
Map 109 Workers population 113
Map 110 Access to tap water 116
Map 111 % HH with access to Improved Latrine 116
Map 112 % HH with Septic Tank 116
Map 113 % HH connected with drainage network 116
Map 114 Settlement Hierarchy 117
Map 115 River Ecosystem Service Dependency 119
Map 116 Forest Buffer & Villages 120
Map 117 Forest - Provisioning Services 121
Map 118 Forest - Regulating Services 121
Map 119 Forest - Supporting Services 121
Map 120 Forest – Cultural Services 121
Map 121 Forest – Ecosystem Service Dependency 121
Map 122 River Zones 122
Map 123 Micro-watersheds and the buffers 122
Map 124 Flood extent 123
Map 125 River - Provisioning Services 123
Map 126 River - Regulating Services 123
Map 127 River - Supporting Services 123
Map 128 River - Cultural Services 123
Map 129 River - Ecosystem Service Dependency 123
Map 130 Forest Ecosystem - Natural Capital 126
Map 131 Forest Ecosystem - Human Capital 126
Map 132 Forest Ecosystem - Physical Capital 126
Map 133 Forest Ecosystem - Social Capital 126
Map 134 Forest Ecosystem - Financial Capital 126
Map 135 Forest Ecosystem - Cumulative Livelihood Dependency Map 127
Map 136 River Ecosystem - Natural Capital 128
Map 137 River Ecosystem - Human Capital 128
Map 138 River Ecosystem - Physical Capital 128
Map 139 River Ecosystem - Social Capital 128
Map 140 River Ecosystem - Financial Capital 128
Map 141 River Ecosystem - Cumulative Livelihood Dependency Map 129



Map 142 LULC 2015 130
Map 143 LULC 2024 130
Map 144 Land Use Change Detection 131
Map 145 Topographic Wetness Index 134
Map 146 Rainfall 2022 134
Map 147 Bifurcation Ratio 135
Map 148 Elevation 135
Map 149 Soil Type 135
Map 150 NDWI Dec 2024 135
Map 151 NDVI Dec 2024 135
Map 152 Distance from the River 135
Map 153 Drainage Density 135
Map 154 LULC 2024 135
Map 155 Flood Susceptibility 136
Map 156 Sub-watersheds wise - Very high & High flood susceptibility 136
Map 157 Stakeholder mapping 137
Map 158 Industries in the Region 143
Map 159 Mining locations in region 144
Map 160 Sand bar mining 144
Map 161 Tourism Network in the Region 145
Map 162 Critical Watersheds 150
Map 163 River Corridors in the region 151
Map 164 Slope 152
Map 165 River & Mangrove in Mangaluru Planning Area 152
Map 166 Encroached Mangrove Area 153
Map 167 Flow 153
Map 168 2022 Post Monsoon DTWL 153
Map 169 Parameters determining the ground water & their levels 155
Map 170 Settlement Hierarchy in Mangaluru Planning Area 156
Map 171 Mangaluru Planning Area Landuse Map 157
Map 172 Sensitivity 160
Map 173 Adaptive Capacity 160
Map 174 Vulnerability 160
Map 175 Exposure 160
Map 176 Hazard 160
Map 177 Risk 160



Map 178 Contour and evolution of Mangaluru City 162
Map 179 Evolution of Mangaluru City 163
Map 180 Micro-watersheds within 2, 5 & >5km buffer of Gurupura River 165
Map 181 Wards within micro-watersheds of 2 & 5km buffer 165
Map 182 Provisioning Ecosystem Services - Mangrove Ecosystem 165
Map 183 Regulating Ecosystem Services - Mangrove Ecosystem 165
Map 184 Supporting Ecosystem Services - Mangrove Ecosystem 165
Map 185 Cultural Ecosystem Services - Mangrove Ecosystem 165
Map 186 Cumulative dependency on Mangrove Ecosystem Services 166
Map 187 CRZ Map 167
Map 188 CRZ Detail at A 168
Map 189 CRZ Detail at B 168
Map 190 CRZ Detail at C 169
Map 191 CRZ Detail at D 169
Map 192 CRZ Detail at E 170
Map 193 CRZ Detail at F 170
Map 194 Shoreline change map 172
Map 195 Fluvial & Coastal flooding zones 173
Map 196 Key map of Mangaluru City 173
Map 197 Lakes of Mangaluru City 173
Map 198 Kavoor Lake and Landuse in 50m buffer 174
Map 199 Total Population 176
Map 200 Population density 176
Map 201 Sex Ratio 176
Map 202 Literacy Rate 176
Map 203 SC population % 176
Map 204 ST population % 176
Map 205 WFPR 176
Map 206 Land Use map of Mangaluru Municipal Corporation Area 178
Map 207 Water Sample points on Gurupura River 180
Map 208 180
Map 209 Industries and Port 181
Map 210 MSEZ Mangaluru 181
Map 211 New Mangalore Plan Layout 183
Map 212 River Corridors in Mangaluru City 185
Map 213 Usage of tap water 186



Map 214 Water supply duration 186
Map 215 Tanker water supply 186
Map 216 Septic tank 186
Map 217 Sewage network 186
Map 218 Door to door collection 186
Map 219 Sewerage 187
Map 220 Water Logging 187
Map 221 Open & green spaces 187
Map 222 Housing sub-systems 187
Map 223 Housing Typology 187
Map 224 Slums 187
Map 225 Solid waste management zones 188
Map 226 Ward wise solid waste generation - 2011 188
Map 227 Water Supply Zones 191
Map 228 % HH with tap water from treated sources 191
Map 229 STP Command Areas 192
Map 230 STP and Wet wells 192
Map 231 Stormwater drain connection and network 194
Map 232 Micro-watershed wise run-off 194
Map 233 Location of Pluvial flooding areas 194
Map 234 Road network and road density ward wise 199
Map 235 Educational Facilities 200
Map 236 Healthcare facilities 200
Map 237 Open spaces 201
Map 238 Physical Infrastructure 202
Map 239 Flood Risk 202
Map 240 Coastal Hazard 203
Map 241 Water Stress 203
Map 242 Land Use 203
Map 243 Critical Wards 203
Map 244 Land use of ward 13 204
Map 245 Land use of Ward 27 205
Map 246 Region Land Suitability 214
Map 247 Planning Area Land Suitability 214
Map 248 Proposed Development Zones 216
Map 249 villages identified for Regenerative Agricultural Practices 217



Map 250 Conceptual plan for an Eco-Village 218
Map 251 Kenjar Census Town - Proposal map 223
Map 252 City proposals 226
Map 253 Proposals for River corridor 3 233
Map 254 Key map of Ward 13 240
Map 255 Proposed location for DEWATS 240

List of Figures

Figure 1 Timeline and partnership under Global River Cities Alliance (GRCA) 2
Figure 2 Flooding types in Mangaluru 4
Figure 3 Methodology 8
Figure 4 Meander Belt 11
Figure 5 Key IWRM actions to support integration 13
Figure 6 IUWM planning process 14
Figure 7 WSUDP: Integrating water-cycle management 15
Figure 8 Interface between the elements of the basin plan and supporting thematic plans 16
Figure 9 The objectives of the URMP Framework 17
Figure 10 Instruments and tools for making river-sensitive plans 18
Figure 11 Various Scales of River Management Plans 19
Figure 12 Phases of IAdapt Framework 22
Figure 13 Indicators of ClimateSmart Cities Assessment Framework 3.0 23
Figure 14 UN Sustainable Development Goals 24
Figure 15 Power dynamics amongst stakeholders 26
Figure 16 An example of stakeholder mapping 28
Figure 17 City Blue Print Approach Framework 31
Figure 18 Various Scales of River Management Plans 34
Figure 19 Conceptual framework 42
Figure 20Daskhin Kannada located on the Agro-Ecological zones of India 49
Figure 21 Aspects considered for scoping of region 50
Figure 22 Temperature over the years - 1992 to 2022 70
Figure 23 Maximum Temperature 70
Figure 24 Minimum Temperature 70
Figure 25 Deviations in Maximum Temperature 71
Figure 26 Deviations in Minimum Temperature 71
Figure 27 Decadal seasonal mean temperature – Isotherms 1992-2021 71
Figure 28 30 Year Annual Precipitation 72
Figure 29 30 Year monsoon trend 73
Figure 30 30 Year rainfall variability 73
Figure 31 Rainfall variability 73
Figure 32 30 Year Isohyets 1992-2021 74
Figure 33 Wind speed 75
Figure 34 Wind direction & speed 76

Figure 35 Annual Relative Humidity 76
Figure 36 Average monthly relative humidity 1992-22 76
Figure 37 Annual Solar Radiation 77
Figure 38 Monthly average solar radiation 1992-2022 77
Figure 39 Stream length in km 82
Figure 40 Hypselobarbus lithopidos 83
Figure 41 Garra mullya 83
Figure 42 Garra stenorhynchus 83
Figure 43 Forest Administration & Hierarchy 102
Figure 44 Endangered species in the region 103
Figure 45 Forest Area 2015 106
Figure 46 Forest Area 2024 106
Figure 47 Growth rate over the years 109
Figure 48 Population composition 110
Figure 49 Sex ratio 111
Figure 50 Age sex pyramid of Dakshin Kannada District 111
Figure 51 Literacy rate 112
Figure 52 SC Population 112
Figure 53 ST Population 112
Figure 54 WFPR 113
Figure 55 Workers' composition 113
Figure 56 Gender composition in work force 113
Figure 57 Occupation of workers 113
Figure 58 Occupation of the main "other workers" of Dakshin Kannada district 113
Figure 59 Duration of migration as per gender 114
Figure 60 Place of migration 114
Figure 61 Reason for migration 114
Figure 62 Score of Ecosystem service indicators as per primary survey & research observation 119
Figure 63 Ecosystem services 120
Figure 64 Livelihood dependency table for Forest ecosystem 127
Figure 65 LULC change 131
Figure 66 Watershed wise flood susceptibility 136
Figure 67 Stakeholders influence on Gurupura River 138
Figure 68 Sectoral contribution of Dakshin Kannada District 139
Figure 69 Number of Workers 139



Figure 70 Primary sector workforce in the region 140
Figure 71 Cultivated area statistics for Dakshin Kannada District 140
Figure 72 Production of crops 140
Figure 73 Agricultural Calendar in the region 141
Figure 74 Season wise crop production 141
Figure 75 Area under major crops 141
Figure 76 Production of major crops 141
Figure 77 Gross irrigated area: Irrigation sources 142
Figure 78 Net irrigated area: Irrigation sources 142
Figure 79 % Agricultural area in Watersheds 142
Figure 80 Scale of industries 143
Figure 81 Pollution classification 143
Figure 82 Scale wise pollution potential 143
Figure 83 Employment 143
Figure 84 Category wise tourist footfall in the region 2024 145
Figure 85 Category wise tourist footfall in the region 145
Figure 86 Tourist locations in the region 146
Figure 87 Accommodation in the region 146
Figure 88 Occupancy in the peak season 146
Figure 89 Monthly tourist footfall trend in 2024 146
Figure 90 Impact Matix of economic activities in the region 147
Figure 91 Impact Matrix - Observations 148
Figure 92 Prioritization of Sub-watersheds 149
Figure 93 Mangrove species in the Planning Area 153
Figure 94 Aquifer disposition of Mangaluru Taluk 154
Figure 95 Fence Diagram of Mangaluru Tehsil 154
Figure 96 Landuse of Mangaluru Planning Area 158
Figure 97 Landuse of Built-up areas of Mangaluru Planning Area 158
Figure 98 multi-framework approach for Urban River Management 161
Figure 99 Gurupura River in Mangaluru City 161
Figure 100 Evolution of Mangaluru City 162
Figure 101 CRZ zones within Region, Planning Area & Municipal Area 167
Figure 102 Sea Level Rise for the year 2050 172
Figure 103 Shoreline retreat for the year 2050 172
Figure 104 Section of Kavoor Lake 174
Figure 105 Kavoor Lake Post monsoon and pre-monsoon 174



Figure 106 Growth rate of Mangaluru M. Corp compared to State and district 175
Figure 107 Workers' composition..... 177
Figure 108 Composition of main workers..... 177
Figure 109 Industrial main workers occupation in the district..... 177
Figure 110 Mangaluru Municipal Corporation - Population estimation for 2025 177
Figure 111 Built-up lad use of Mangaluru city 178
Figure 112 Land use of wards in micro watersheds of 2 km buffer around Gurupura River 179
Figure 113Detail Land use at A 179
Figure 114 Detail Land use at B..... 179
Figure 115 Land use of wards in micro watersheds of 5 km buffer around Gurupura River 179
Figure 116 113Detail Land use at C..... 179
Figure 117 113Detail Land use at D 179
Figure 118 Fishing boats FY 2018 - 2019..... 184
Figure 119 % waste from various sources 188
Figure 120 Landfill Location 189
Figure 121 Pachanady Landfill in Mangaluru City..... 189
Figure 122 % HH water supply source 190
Figure 123 Section of existing stormwater drains..... 193
Figure 124 Fluvial & Pluvial Flood Prone Areas..... 195
Figure 125 Physical aspects of water stress 196
Figure 126 Existing Water balance in Mangaluru City..... 198
Figure 127 % Road Network..... 199
Figure 128 Land use share of ward 13 204
Figure 129 Landuse share of ward 27 206
Figure 130 Key dimensions and indicators of URM Index 207
Figure 131 Governance structure for Gurupura River 210
Figure 132 SWOC Analysis for the Region and Mangaluru City..... 211
Figure 133 Region population projection..... 214
Figure 134 Mangaluru Planning Area Population Projection 214
Figure 135 Multi-scalar River Management Framework..... 215
Figure 136 Components of Regenerative Agriculture 217
Figure 137 Intercropping - component of Regenerative Agriculture..... 217
Figure 138 River bank zoning in identified villages to enusre minimal impact of agricultural run-off into the river..... 218
Figure 139 River corridor..... 220
Figure 140 Riparian buffer and commonly found riparian species in the region 220



Figure 141 Bio-swale 221
Figure 142 Farm ponds 221
Figure 143 Kattas 221
Figure 144 Bio-fencing 222
Figure 145 Constructed wetland 222
Figure 146 Retention & detention ponds 222
Figure 147 Fish ponds 224
Figure 148 Mangrove belt 224
Figure 149 Schematic early warning system 225
Figure 150 Components of the proposed CETP 227
Figure 151 Industrial Symbiosis concept applied to some industries in Baikampady 228
Figure 152 Components of DEWATS 229
Figure 153 Permeable paving for internal roads 229
Figure 154 Rain water harvesting for public buildings in the ward 229
Figure 155 Zoning strategy proposed for agricultural area within Mangaluru city 230
Figure 156 Plants for Phytoremediation zone 231
Figure 157 Bio-swale 232
Figure 158 NEERI's ecological unit 233
Figure 159 Suggested Mangrove species for afforestation 234
Figure 160 Bamboo board walk in a Mangrove Park 235
Figure 161 River precinct visualization 235
Figure 162 Proposed water balance for Mangaluru city 238
Figure 163 Section of ground water recharge trench 239
Figure 164 Rain Garden section 239
Figure 165 Section f constructed wetland 239
Figure 166 Treatment modules of the proposed DEWATS facility 240
Figure 167 Components of DEWATS 240
Figure 168 Development plan integration 243



List of Tables

Table 1 Coastal line erosion in Karnataka 3
Table 2 Parameters taken forward 20
Table 3 Parameters taken forward 25
Table 4 Parameters taken forward 29
Table 5 Parameters taken forward 32
Table 6 State and District Documents 33
Table 7 Associating River Management Scales with Spatial Planning Scales 34
Table 8 Parameters taken forward 43
Table 9 SPI 73
Table 10 Geology of the scoped region 78
Table 11 River & Watershed details 81
Table 12 Overview of Basin Morphometric parametric 84
Table 13 Details of Sub-basins 85
Table 14 Bifurcation ratio & flood susceptibility 87
Table 15 Length of Overland Flow 87
Table 16 Linear aspects of Watersheds co-related with the Table 16 & 17 88
Table 17 Circularity ratio & its relation to flood potential & erosion susceptibility 89
Table 18 Stream frequency & its relation to permeability 89
Table 19 Drainage density & its relation with infiltration, run-off & flood risk 89
Table 20 Texture ratio & its relation with Infiltration & run-off 89
Table 21 Infiltration number & its relation to Run-off 89
Table 22 Aerial aspects of Watersheds co-related with the Table 19 & 23 91
Table 23 Range on which the relief aspects are assessed 91
Table 24 Co-relation of the relief aspects with terrain, infiltration & Run-off 91
Table 25 Relief aspects of watersheds co-related with table 25-26 92
Table 26 Seasonal flow decision matrix 93
Table 27 Cumulative flow decision matrix based on seasonal flow 93
Table 28 High recharge potential zones 101
Table 29 Moderate recharge potential zones 102
Table 30 List of Flora found in the region 104
Table 31 List of Fauna found in the region & their status 105
Table 32 Forest change 106
Table 33 NDVI Analysis 107
Table 34 Population over the years 109

Table 35 Migration in Dakshin Kannada district 114
Table 36 Population estimation of Study Region (excluding LPA & M. Corp) 115
Table 37 Population estimation of Mangaluru Planning Area (Including Mangaluru M. Corp) 115
Table 38 Population estimation of Mangaluru Municipal Corporation 115
Table 39 Population estimation of other urban centres in the region 115
Table 40 Forest Ecosystem Service Dependency 118
Table 41 Primary survey & research observation - River & Forest Ecosystem Comparative 119
Table 42 Number of villages within the defined buffers 120
Table 43 Normalized score for forest ecosystem services 121
Table 44 Number of villages within the defined buffers 122
Table 45 Normalized score for River ecosystem services 124
Table 46 Livelihood Capital & indicators 125
Table 47 Livelihood dependency table for Forest ecosystem 128
Table 48 LULC Change detection table 132
Table 49 Pair wise comparison matrix of flood susceptibility indicators 133
Table 50 Normalized matrix & weightage of flood susceptibility indicators 133
Table 51 Flood susceptibility Indicators - Class, Rating & weightage 134
Table 52 Agriculture Land Use Change 139
Table 53 Land utilization of Dakshin Kannada District FY 2021 - 22 140
Table 54 Area (Ha) under cultivation FY 2021-22 140
Table 55 Fertilizers types and % run-off 142
Table 56 Details of industrial Area 144
Table 57 Mining statistics 144
Table 58 Identified Critical Sub-watersheds 150
Table 59 Aquifer wise resource availability and extraction (2022) – Mangaluru Tehsil 155
Table 60 Comparison of ground water availability and draft scenario in Mangalore tehsil 155
Table 61 Demographic statistics of Mangaluru Planning Area 156
Table 62 Estimated population of Mangaluru Planning Area 2025 156
Table 63 Land Use of Mangaluru Planning Area 157
Table 64 Sector wise analysis and their implications on the Gurupura River 158
Table 65 Normalized values and risk calculation for critical sub-watersheds 159
Table 66 Mangrove ecosystem service dependency 164
Table 67 CRZ Zones 2011 & 2019 166
Table 68 Coastal erosion statistics of Karnataka's coastal districts 171
Table 69 Prominent lakes in Mangaluru 174



Table 70 Population of Mangaluru Municipal Corporation 175
Table 71 Land use of Mangaluru city 178
Table 72 Water quality of Gurupura River for samples collected by author in February 2025 180
Table 73Water Sample points 2022 on Gurupura River 180
Table 74 Number of industries in Baikampady Industrial Cluster 181
Table 75 GIDC Sustainability Standards calculated for Baikampady Industrial Area 182
Table 76 Environmental Quality and indicators as per GIDC Sustainability Standards 183
Table 77 GIDC Sustainability Standard score range 183
Table 78 Impact matrix for Mangaluru City 184
Table 79 Storage reservoirs in water supply zones 190
Table 80 Water supply source, Demand, Supply & Gap 191
Table 81 Existing treatment capacity and gap 192
Table 82 Stormwater drain details 193
Table 83 Calculation of discharge of Stormwater drains 194
Table 84 Indicators for 4 aspects of water stress and their range for scores 196
Table 85 Water stress for Domestic sector 197
Table 86 Water stress for Industry sector 197
Table 87 Water stress range 197
Table 88 Gaps in Educational facility 200
Table 89 Gaps in Healthcare facilities 200
Table 90 Open spaces and gaps 201
Table 91 Critical ward identification - Normalized values 202
Table 92 Land use of ward 13 204
Table 93 Land use of Ward 27 206
Table 94 URMP Monitoring indicators and the respective score for Gurupura River 207
Table 95 Status of Gurupura River Management in Mangaluru city with respect to URM Index score 208
Table 96 CRZ Compliance Score 209
Table 97 Range of CRZ Compliance score 209
Table 98 Mangrove and Estuarian Habitat Health score 209
Table 99 Range of Mangrove and Estuarian Habitat Health score 209
Table 100 Urban Flood Resilience score 209
Table 101 Range of Urban Flood Resilience score 209
Table 102 Score of additional URRI indicators 209



Table 103 Status of Gurupura River Management in Mangaluru city with respect to URRI score 210
Table 104 Region - Normalized pairwise comparison matrix and weightage for each layer 213
Table 105 Region - Buffers for suitability 213
Table 106 Planning Area - Normalized pairwise comparison matrix and weightage for each layer 213
Table 107 Planning Area - Buffers for suitability 213
Table 108 Water supply gap 237
Table 109 Waste water treatment gap 238
Table 110 Total project cost 241
Table 111 Funding and Subsidies 241
Table 112 Annual O & M costs 241
Table 113 Revenue Mechanisms 241
Table 114 Impact summary 242
Table 115 Species for Planted gravel filter module 242
Table 116 Project timeline - Gantt chart 242
Table 117 Phasing & Governance 243



Abbreviations

NIUA – National Institute of Urban Affairs

NMCG – National Mission for Clean Ganga

URDPFI – Urban and Regional Development Plan Formulation and Implementation

RADPFI – Rural Are Development Plan Formulation and Implementation

CRZ – Coastal Regulation Zone

LULC – Land use land cover

NDVI – Normalized difference vegetation index

NDWI – Normalized difference wetness index

URMP – Urban River Management Plan

IUWM – Integrated Urban Water Management

IWRM – Integrated Water Resource Management

URRI – Urban River Resilience Index

Table of Content

1. Introduction 1

1.1 Understanding Urban Rivers 1

1.2 Need of the Study 3

1.3 Aim and Objectives 7

1.3.1 Aim 7

1.3.2 Objectives 7

1.3.3 Scope and Limitations 7

1.3.4 Methodology 8

2. Literature Study 10

2.1 Basic Concepts and Terminologies 10

2.1.1 River Ecology 10

2.1.2 River and Human Settlements 12

2.1.3 Impact of human activities on rivers 12

2.1.4 River Basin 12

2.2 River Basin Frameworks, Watershed Management and Planning Concepts 13

2.2.1 Integrated Water Resource Management (IWRM) 13

2.2.2 Integrated Urban Water Management (IUWM) 14

2.2.3 Water Sensitive Urban Design and Planning (WSUDP). 15

2.2.4 River Basin Planning (Asian Development Bank) 16

2.2.5 Urban River Management Plan (URMP) 17

2.2.6 River-Sensitive Master Planning (NIUA) 18

2.2.7 The Compendium of River Management Plans 19

2.2.8 Inference 19

2.3 Climate Resilience and SDG's 21

2.3.1 City Resilience Profiling Toolkit (UN-Habitat) 21

2.3.2 IAdapt (Adaptation of Catchment to Climate Change) 21

2.3.3 ClimateSmart Cities Assessment Framework 3.0 (NIUA) 22

2.3.4 Sustainable Development Goals (SDG's) 24

2.3.5 Inference 25

2.4 Stakeholder & Livelihood analysis, Ecosystem Services 26

2.4.1 Stakeholder Analysis and Power Dynamics 26

2.4.2 Stakeholder Mapping Tool 27

2.4.3 The Economics of Ecosystems and Biodiversity (TEEB) 28

2.4.4 Inference 29

2.5 Spatial Planning Approaches 30

2.5.1 Urban and Regional Development Plans Formulation and Implementation Guidelines (URDPFI) 30

2.5.2 RADPFI- Rural Area Development Plan Formulation and Implementation Guidelines. (RADPFI) 30

2.5.3 Green City Toolkit 31

2.5.4 City Blueprint Approach 31

2.5.5 Inference 32

2.6 State and District Documents 33

2.7 Associating River Management Scales with Spatial Planning Scales 34

2.8 Case Study 35

2.8.1 White River Plan, Indianapolis 35

2.8.2 River Ganga, India 39

2.9 Conceptual Framework 42

3. Regional Study 44

3.1 Regional Setting 44

3.1.1 Connectivity 44

3.1.2 Climate Zone (As per Koppen's Classification) 45

3.1.3 Biogeographic Zone 46

3.1.4 Agro Climatic Zone 47

3.1.5 Champion & Seth Forest Classification 48

3.1.6 Agro-ecological zone 49

3.1.7 Physiographic Region 50



3.2 Scoping of Region 50

3.2.1 Scoping of Environmental Region 51

3.2.2 Water Environment 51

3.2.3 Land Environment 55

3.2.4 Biotic Environment 59

3.2.5 Scoped environmental region 60

3.2.6 Scoping of Man-made region 61

3.2.7 Scoped Man-made Region 67

3.2.8 Scoped Region 68

3.3 Environmental Resources 70

3.3.1 Climate 70

3.3.2 Land Environment 77

3.3.3 Water Environment 80

3.3.4 Biotic Environment 102

3.3.5 Normalised Difference Vegetation Index (NDVI) 107

3.3.6 Normalized Difference Water Index (NDWI) 108

3.4 Settlement Analysis 109

3.4.1 Demographic & Socio-economic profile 109

3.4.2 Scalogram & settlement hierarchy 117

3.4.3 Ecosystem Service Dependency & Livelihood Analysis 118

3.4.4 Land Use Land Cover (LULC) 130

3.4.5 Flood susceptibility 133

3.5 Stakeholder Mapping 137

3.6 Economic Activities in the Region 139

3.6.1 Economic profile of Dakshin Kannada District 139

3.6.2 Primary Sector – Agriculture 139

3.6.3 Secondary Sector – Industries 143

3.6.4 Secondary Sector – Mining 144

3.6.5 Tertiary Sector – Tourism 145



3.6.6 Impact Matrix 147
3.6.7 Prioritization of Sub-watersheds 148
4. Mangaluru Planning Area 152
4.1 Environmental Resources 152
4.2 Demography & Socio-economics 156
4.3 Land Use and Development Plan Analysis 157
4.4 Fluvial Flood Risk 159
5. Mangaluru City 161
5.1 Evolution of the City 161
5.2 Environmental Resources 164
5.2.1 Mangrove Ecosystem Service Dependency 164
5.2.2 Coastal Regulation Zone 166
5.2.3 Coastal Hazard 171
5.2.4 Water Body Analysis 173
5.3 Demography 175
5.4 Land Use of Mangaluru Municipal Corporation Area 178
5.5 Water Quality 180
5.6 Economic Activities 181
5.6.1 Industries 181
5.6.2 Port 183
5.6.3 Fishing 184
5.6.4 Impact Matrix 184
5.7 Identification of River Corridors 185
5.8 Primary Survey 186
5.9 Housing & Solid waste 187
5.10 Physical Infrastructure 190
5.10.1 Water Supply 190
5.10.2 Sewerage 192
5.10.3 Stormwater Drainage 193



5.10.4 Water Stress 196
5.10.5 Water Balance 198
5.10.6 Road 199
5.11 Social Infrastructure 200
5.11.1 Education & Healthcare 200
5.11.2 Open Spaces 201
5.12 Identification of critical wards 202
5.13 Critical Ward Analysis 204
5.13.1 Ward 13 204
5.13.2 Ward 27 205
5.14 Urban River Resilience Index (URRI) 207
6. Governance 210
7. SWOC 211
8. Proposals 212
8.1 Land Suitability 212
8.2 Population Projections 214
8.2.1 Region 214
8.2.2 Mangaluru Planning Area 214
8.3 Multi-scalar River Management Framework 215
8.4 Development Zones 216
8.5 Region Proposals 216
8.5.1 Agriculture zone 216
8.5.2 River Corridor 219
8.6 Planning Area Proposals 223
8.7 City Proposals 226
8.7.1 River corridor 1 226
8.7.2 River corridor 2 231
8.7.3 River corridor 3 233
8.7.4 City wide strategies 237

8.8 Detail Project Report (DPR) for DEWATS 240

8.9 Phasing & Governance 242

8.10 Development plan integration 243

Conclusion 244

Summary 245

Recommendations 248

Chapter-wise summary 248

Key Recommendations 249

Way Forward 251

References 252

Annexure i



Abstract

Gurupura River, also termed as the Phalguni River, is a west flowing river that originates from the Western Ghats of Karnataka, runs through Dakshina Kannada district, and flows into the Arabian Sea. It is an important freshwater source and ecological corridor and contributes to rural livelihoods, agriculture, industries, and urban settlements - coastal city of Mangaluru. However, urbanization, industrialization, and unregulated land use along the river have increased environmental pressures such as water pollution, habitat destruction, loss of biodiversity, and greater flood risk.

This thesis examines the Gurupura River at multiple scales - starting from the region (recognizing the entire watershed), to the planning area and finally down to the city scale (with high urban and industrial activity). Since the river flows through various administrative boundaries, there is a need for integrated environmental planning approaches that appreciate the river as a continuous ecological system.

Although the Coastal Regulation Zone (CRZ) norms protect the river within the city and at the estuarine stretch, they were not particularly effective in terms of upstream and midstream stresses. This research illustrates the lack of efficacy for the river to be treated in such fragmented jurisdictions, and subsequently recommends a river basin perspective based on spatial considerations, field observations and surveys, and stakeholder mapping. It also incorporates Urban River Management Plan (URMP) with land-use planning, livelihood resilience, and ecological restoration.

The outcomes of the thesis, pursuant to the navigation of multiple scales, are space-based differentiated management strategies that address the river's ecological health, focus on reducing pollution from industrial and agricultural practices, improve water retention through nature-based solutions, and empower local communities engaged in sustainable livelihoods. The strategies were guided by national frameworks like the Urban River Management Plan (URMP), the NMCG and NIUA, and the socio-ecological circumstance of the Gurupura River.



सारांश

गुरुपुरा नदी, जिसे फाल्गुनी नदी भी कहा जाता है, एक पश्चिम की ओर बहने वाली नदी है जो कर्नाटक के पश्चिमी घाटों से उत्पन्न होती है, दक्षिण कन्नड़ जिले से होकर बहती है और अंततः अरब सागर में मिल जाती है। यह नदी एक महत्वपूर्ण मीठे पानी का स्रोत और पारिस्थितिक गलियारा है, जो ग्रामीण आजीविका, कृषि, उद्योगों और शहरी बस्तियों — विशेष रूप से तटीय शहर मंगलूरु — के लिए महत्त्वपूर्ण योगदान देती है। हालांकि, शहरीकरण, औद्योगीकरण और अनियंत्रित भूमि उपयोग ने नदी पर पर्यावरणीय दबाव बढ़ा दिए हैं, जैसे जल प्रदूषण, आवासीय क्षरण, जैव विविधता की हानि, और बाढ़ का बढ़ता जोखिम।

यह शोध गुरुपुरा नदी का विश्लेषण कई स्तरों पर करता है — क्षेत्रीय स्तर (जहां पूरे जलग्रहण क्षेत्र को मान्यता दी गई है), नियोजन क्षेत्र स्तर, और अंततः शहर स्तर (जहां उच्च शहरी और औद्योगिक गतिविधियाँ देखी जाती हैं) । चूँकि नदी विभिन्न प्रशासनिक सीमाओं से होकर गुजरती है, इसलिए इसे एक निरंतर पारिस्थितिक प्रणाली के रूप में देखने वाले एकीकृत पर्यावरणीय नियोजन दृष्टिकोण की आवश्यकता है।

हालाँकि शहर और मुहाना क्षेत्र में नदी की रक्षा के लिए **सी.आर.ज़ेड.** के मानदंड लागू होते हैं, वे ऊपरी और मध्य प्रवाह क्षेत्रों में पर्याप्त प्रभावी नहीं पाए गए। यह शोध स्पष्ट करता है कि खंडित प्रशासनिक सीमाओं में नदी का प्रबंधन इसकी पारिस्थितिकीय स्थिति को कमजोर करता है। अतः, यह शोध एक नदी बेसिन आधारित दृष्टिकोण प्रस्तुत करता है, जो स्थानिक विश्लेषण, क्षेत्र सर्वेक्षण, और हितधारक मानचित्रण पर आधारित है। इसमें **यू.आर.एम.पी.** को भूमि उपयोग नियोजन, आजीविका सुदृढ़ता और पारिस्थितिक पुनर्स्थापन के साथ जोड़ा गया है।

शोध के निष्कर्ष बहु-स्तरीय, स्थान आधारित प्रबंधन रणनीतियाँ प्रस्तुत करते हैं, जो नदी के पारिस्थितिक स्वास्थ्य में सुधार, औद्योगिक एवं कृषि प्रदूषण को कम करने, प्रकृति-आधारित समाधानों द्वारा जल संचयन बढ़ाने, और स्थानीय समुदायों को सतत आजीविकाओं के माध्यम से सशक्त बनाने पर केंद्रित हैं। ये रणनीतियाँ राष्ट्रीय स्तर की रूपरेखाओं जैसे **यू.आर.एम.पी.** और **एन.आई.यू.ए.** से प्रेरित हैं और गुरुपुरा नदी की सामाजिक-पारिस्थितिक परिस्थितियों पर आधारित हैं।

1. Introduction

1.1 Understanding Urban Rivers

What is an Urban River?

Urban rivers are defined in a descriptive sense as **"Rivers that flow through cities,"** and in an analytical sense as **"those rivers that have been folded into the process of urbanization, whether flowing through urban centres or not"** (NIUA, 2021)

Global Context

Rivers have historically supported many great cities and consistently provided crucial resources for the sustenance of human settlements. They have served as lifelines for water, food, trade, and economic advancements. The connectivity and the livable conditions offered by the rivers have often been a primary deciding factor for humans to choose their locations to settle, enabling the towns and cities to flourish along their banks

Rivers still contain the potential to make sustainable cities today. However, biodiversity, ecosystem and the overall environmental health of the rivers continue to be threatened by the unchecked and rapid urbanisation. Furthermore, cities along these rivers are especially vulnerable to the effects of climate change given their close linkage to nature.

According to recent discussions at the World Urban Forum, cities are urged to reconnect with their rivers, to tackle issues such as pollution, and habitat destruction while fostering economic growth and climate resilience. The concept of sustainable management of urban rivers is gaining momentum worldwide, as the cities are recognizing the need to integrate river management with urban planning (Uribe, 2024).

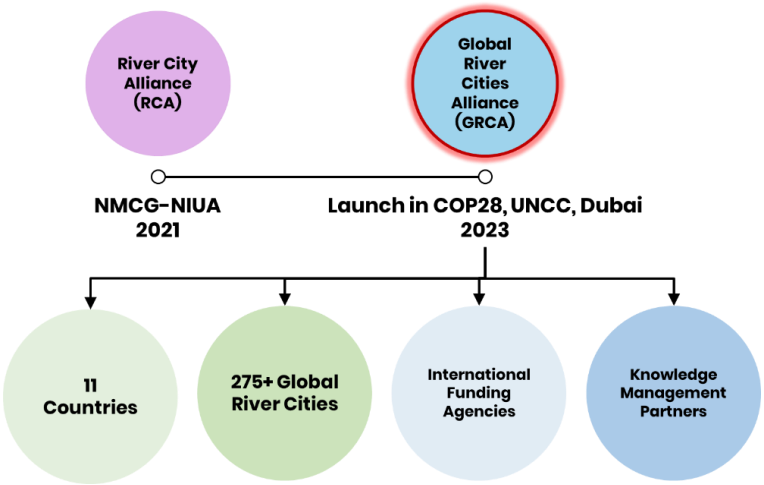
In the global context, India leads the Global River Cities Alliance, an International Collaboration, where the signatory countries and their cities work together to manage, protect and conserve their rivers.

National Context

In India, Rivers are not only central to cultural identity but also important for sustaining livelihood. The National Mission for Clean Ganga (NMCG) along with **National Institute of Urban Affairs (NIUA)** has made significant efforts in creating **"Urban River Management Plan"** highlighting its need, especially in densely populated cities that face ecological degradation, and serves as a framework for the cities to develop policies that are tailored to local concerns while also promoting sustainable development.

India's position as a leader in the Global River Cities Alliance, enables it to create standards for river-centric policies that align with both the management of rivers to ensure its ecological balance and sustainable development of human settlements.

Figure 1 Timeline and partnership under Global River Cities Alliance (GRCA)



Source 1 Author

The Gap

The **River Cities Alliance and URMP** has so far focused on the **Inland cities** along **East flowing river basins** such as the Ganga, Godavari, Krishna, and Cauvery basins

The **West Flowing** Rivers of the West flowing river basins from **Tapi to Tadri** and **Tadri to Kanyakumari** are often overlooked in discussions about river management and conservation, for various reasons such as they are fewer in number, shorter in length, have smaller catchments and steep gradient as they originate form the western ghats.

This thesis addresses the gap by providing actionable planning and management strategies for West Flowing Urban Rivers in the context of a coastal city through the case study of **Gurupura River** in the **Coastal City of Mangaluru.**

1.2 Need of the Study

Why the Coastal City of Mangaluru?

1. **Location:** Mangalore is 2nd largest urban centre along the coast in the Tadri to Kanyakumari River Basin after Kochi, Kerala. It is also the largest Urban area located along the west coast in Karnataka

Population of Mangaluru M. Corp - 499487 (Census 2011) & Mangaluru UA – 6,23841, Estimated 2021 population of the Mangaluru UA – 8,84,000 and Estimated 2025 population of Mangaluru UA - 9,10,000

2. **Rivers and the Urban Area:** The Mangaluru Planning Area has four west flowing rivers, two of which – **Gurupura & Netravati Rivers** flow through the Municipal corporation limits. The Mangaluru Planning area stretches along the entire coastal length of the district, - **62 km**, indicating the urban development all along its coastal length
3. **Economic activities** – Special Economic Zone, including Mangalore Refineries and Petrochemical Limited, Manufacturing, BASF, Food processing and IT sector, making it the 2nd largest business centre after Bangalore, all of which are located on the northern banks of **Gurupura river.**
4. **Export hub:** Exports approximately **75%** of India's coffee, timber, & Cashew signifying that it is critical player in trade
5. **Port Size & Capacity:** It is the 6th largest in India and the only port of Karnataka, and has the deepest inner harbour on the entire west coast which is strategically significant for larger vessels and diverse cargo types.
6. **Coastal Erosion:** As per a study by National Centre for Coastal Research, Mangaluru covering the entire coastal length of the district, faces the highest percentage of coastal erosion among the three coastal districts of Karnataka (R.S. Kankara, 2018).

Table 1 Coastal line erosion in Karnataka

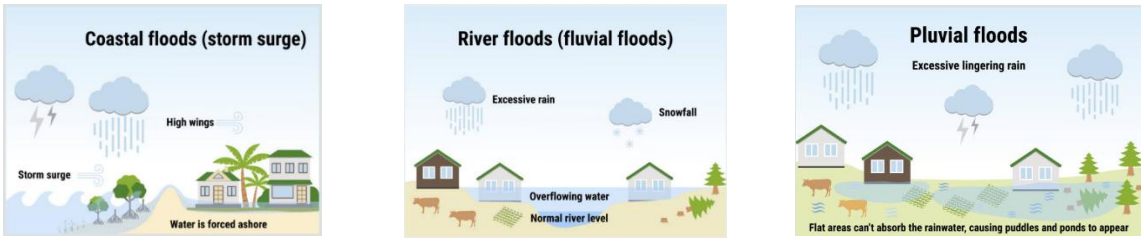
District	Coastline (km)	% of total coastline	Coastal erosion - % of district coastline
Uttar Kannada	160	50	12.3%
Udupi	98	30.6	34.7%
Dakshin Kannada	62	19.4	48.4%
Total	**320**	**100**	

Source 2 National Centre for Coastal Research

7. **Flooding:** Located 21.9m ASL, the Mangaluru city also has a history of flooding. Sea Level Rise causing Coastal floods with **5%** of Land in Mangaluru expected to be submerged by **2040**

Gurupura River flooding has displaced settlements along its banks & damaged infrastructure (*TOI Aug 2 2024)*. **Overwhelmed drainage** causes flooding in low-lying areas in Mangalore (*TOI Jul 9 2024)*

Figure 2 Flooding types in Mangaluru



Source 3 Canada water portal

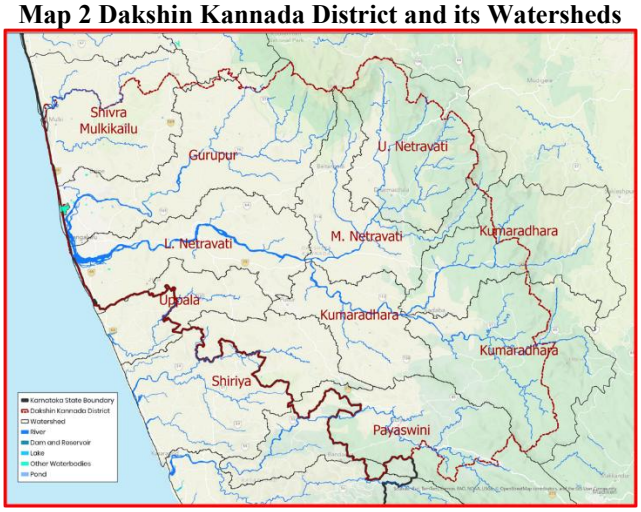
Why Gurupura River in the Coastal City of Mangaluru?

Map 1 Netravati and other's sub river basin of the larger Tadri to Kanyakumari River Basin



Source 4 India WRIS

Map 2 Dakshin Kannada District and its Watersheds



Source 5 Author

As per **India WRIS,** the River Basin is Tadri to Kanyakumari WFR Basin, **Sub-River Basin** include Netravati & Others Sub-Basin and the origin of Gurupura river is in Western Ghats, Udupi District

Dakshin Kannada District is drained by 3 major river systems – **Shambhavi River, Gurupura, Netravati & their tributaries**. These watersheds and their sub- watershed will further be used to scope the region.

Parameters	Gurupura River	Netravati River
River Length	87 km	103 km
Length in urban area	11.7 km (M. Corp) (13.44%)	8.8 km (M. Corp) (8.54%)
Watershed area	874.6 Sq.km	3498.18 Sq.km
Tributaries	Kela, Gurupura	Kumaradhara, Aniyur Hole, Shishla Hole, Gogri Hole, Netravati, Mundaje hole, Gundya Hole, Neriya Hole
No. of Tehsils	4 (Mangaluru, Mudabidri, Bantwal, Beltangadi)	6 (Bantwal, Beltangadi, Ullal, Puttur, Kadaba, Sulya)
Total Population	5,62,494	10,09,975
No. of Villages	81 (722.49 Sq.km) 2.7 PPH	154 (2573.93 sq.km) 2.07 PPH
No. of Urban Area	14	23
Mangaluru M. Corp	32 Wards (78.25 Sq.km) 33.24 PPH	20 Wards (34.53 Sq.km) 44.86 PPH
Other urban centres	13 (133.20 Sq.km) 8.00 PPH	22 (213.19 Sq.km) 15.11 PPH
Urban population	3,66,825 (M'lore M. Corp 2,60,142 + 1,06,683)	4,77,078 (M'lore M. Corp 1,54,935 + 3,22,143)
Rural Population	1,95,669	5,32,897
Industrial Area	Baikampady Industrial Area, New Mangalore Port	-
Tourist Locations	9	6

Although, the Netravati River watershed takes care of the larger share of population, the economic activities such as the Industrial area, port and tourism activities are largely depended on Gurupura river, indicating higher potential for anthropogenic changes in the Gurupura watershed. The Gurupura River also has 13.44% of its length within the urban area compared to 8.54% of Netravati River.

The need

Significance:

a. **Historical importance:** Served as a trade and transportation route; evidenced by structures like the **Bangla Gudde dam** built by Tipu Sultan.
b. **Cultural Importance:** Temples and worship sites located along the river, supporting important festivals like **Gurupur Teru**, and **Venur Mahamasthakabhisheka**
c. **Rural Livelihoods:** Supports agriculture by providing irrigation for crops like rice, coconut, Arecanut, and spices, and is also a source of drinking water.
d. **Economic Hub:** Critical for Mangalore as a center of economic activity. Gurupura River currently supports navigation of small boats, ferries and has potential for further development as it has a designation of National Waterway 43

Complexity:

a. **Transition from Rural to Urban:** Serves agriculture in rural areas, but transitions to supporting urban industries as it enters Mangalore, including the New Mangalore Port and chemical industries, impacting several stakeholders – Farmers, Industries and Residents.
b. **Supports diverse ecosystem:** Coastal, Estuarian and Riverine with dependency economic activities dependent on it.

Issues:

a. **Pollution:** Industrial effluents, domestic wastewater, and solid waste affecting the water quality
b. **Critically polluted industrial area:** Baikampady industrial area is identified as **Critically polluted industrial area with CEPI score 73.68 by CPCB in the year 2018,** which located on the northern bank of the river along the coast.
c. **Environmental Concerns:** Fish deaths reported in Gurupura river due to industrial effluent discharge, mangrove destruction, The NGT report (OA 151/2023) stresses the urgency of effective river basin management to address these issues.

1.3 Aim and Objectives

1.3.1 Aim

To devise **Environmental Planning Strategies** for Gurupura River Basin that support sustainable River Basin Management Principles and encourage River Centric Urban Planning for reinstating the ecological health of the Gurupura River.

1.3.2 Objectives

Objective 1

Understand the interface between Basin Wide (River) & Spatial Planning Approach w.r.t WFR in Karnataka's coastal ecosystem.

Objective 2

Delineate study area based on environmental & anthropogenic parameters & establish baseline for prioritizing ecosystem services that bare a connect with environmental resources, human settlements & land use within the study area

Objective 3

Arrive at critically degraded watersheds & sub-watersheds containing urban settlements that have a bearing on the river water ecology & develop River Centric Urban Plans

Objective 4

Develop Environmental planning strategies & guidelines that are multi scalar, encouraging green field development that support symbiotic relation between the river & human settlements.

1.3.3 Scope and Limitations

Scope

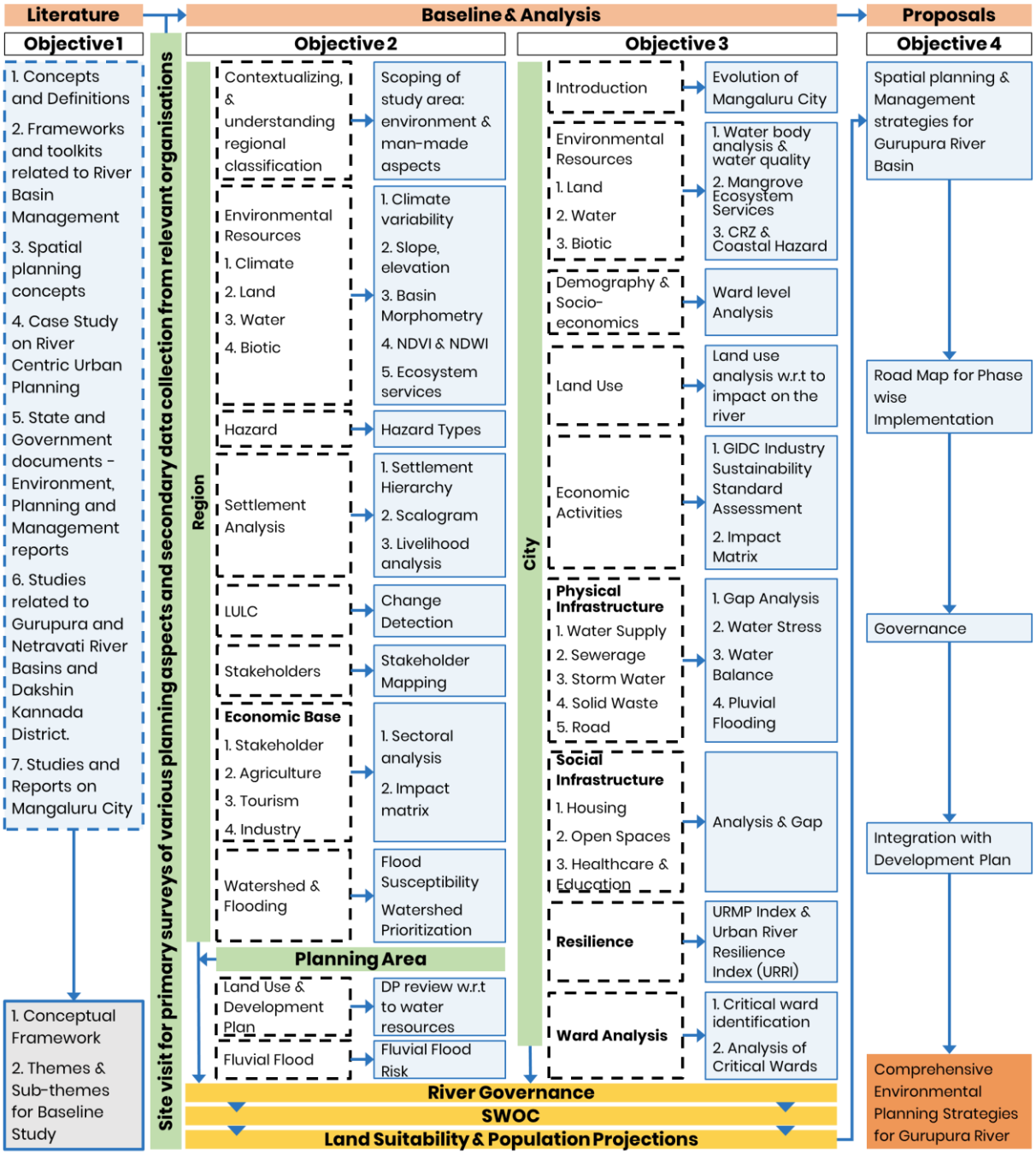
The interventions will be focused on various scales that aligns with both **Spatial planning and Watershed based planning** within the identified critically degraded watersheds.

Limitation

The limitations include data gaps and time frame, Solar intensity & solar radiation, Evaporation & evapotranspiration, Inland fishing is absent, Hydrology Modelling, River carrying capacity – Sediment load, Velocity & Discharge, Ecosystem service valuation, Water related health data, Water Stress at region scale, Tourism & Carrying capacity, Social Governance

1.3.4 Methodology

Figure 3 Methodology



Source 6 Author

The study is conducted following structured methodology around the four objectives that study planning and analysis at various levels.

The first objective is to conduct a literature review to establish a conceptual framework for the study. This literature review has explored topics dealing with integrated river basin management, spatial planning, and urban river management, which is further fed into creating the baseline under objective two and three.

The second objective is to define the study area and conduct an extensive analysis of land-use change, climatic conditions, water resources, biodiversity, settlement patterns and economic activities within the Gurupura River Basin, provide insights regarding existing environmental and socio-economic conditions, Economic activities, and their impact on Gurupura River at the regional scale & flood susceptibility. All these feed into the identification of critical sub-watersheds, which takes care of the Mangaluru Planning area, where a flood risk assessment has been carried out.

The third objective shifts to the city scale, concentrating on Mangalore and its urban milieu. Environmental resources, Urban land use, the gaps existing in the infrastructure and the economic activities are analysed, and the said effect of urbanization and economic activities on the watershed. Economic sectors like agriculture, fisheries, industry, and tourism are analysed to find the challenges and opportunities for sustainable development.

The final objective is to propose strategies and actions for the sustainable management and conservation of the Gurupura River Basin is the last and fourth objective, which involves the physical planning strategies, integrating policies with the development plans, engaging the stakeholders, identification of governance roles needed to make the implementation functional.

By using such a methodology, a multiscale approach to regional and urban assessments is attempted to provide a foundation for sustainable river basin management and conservation.

2. Literature Study

2.1 Basic Concepts and Terminologies

Understanding the fundamental concepts and terminologies related to river systems is essential for determining their ecological, hydrological, and socio-economical relevance. The following are some of the important concepts and associated terminologies that align with river-based planning and management.

2.1.1 River Ecology

River ecology is the study of the ecosystem that consists of the flowing river itself, and its interactions with the biotic environment that includes flora, fauna and micro-organisms. These ecosystems play a pivotal ecological role but are also amongst the most stressed due to anthropogenic activities and interventions. Understanding this will guide in river management and conservation.

Key terminologies

1. **Basin Morphometry:** It is the measurable aspect of the physical dimensions and shape of the drainage basin. It includes measurements of **Linear aspect** (Stream order, Stream length, Bifurcation Ratio), **Aerial aspect** (Drainage density, Stream frequency, Form factor) and **Relief aspect** (Basin relief, Relief Ratio).
    a. **Stream Order:** A measure of the position of a stream in the hierarchy of streams (Mahala, 2019)
    b. **Stream Length:** Total length of the stream of a particular order (Mahala, 2019)
    c. **Bifurcation Ratio:** The ratio of number of streams in one order to the number of streams in the next order. (Mahala, 2019)
    d. **Drainage density:** Ratio of total length of streams of all order within a drainage basin to the area of the drainage basin (Mahala, 2019).
    e. **Stream frequency:** The number of streams per unit area. A higher stream frequency points to a larger surface runoff, steeper ground surface, impermeable subsurface sparse vegetation, and high relief conditions. Low stream frequency indicates high permeable geology and low relief (Mahala, 2019).
    f. **Form Factor:** A ratio that describes the shape of a drainage basin by calculating the ratio of the basin's area to the square of its length, essentially indicating how elongated or circular a watershed is; a smaller form factor signifies a more elongated basin, while a larger one indicates a more circular basin, with significant implications for peak flow and runoff patterns within the watershed (Mahala, 2019).

h. **Basin Relief:** The elevation difference of the highest and lowest point of the valley floor (Mahala, 2019).

i. **Relief ratio:** The ratio between the total relief of a basin i.e. elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Mahala, 2019).

Relief Ratio = Maximum Basin Relief (H)/Maximum Basin Length (Lb)

2. **Spatial Dimensions (WWF, River Ecology):**

a. **Length** – The longitudinal extent of a river, covering headwaters, midstream sections, and estuaries (Stoyan Mihov, 2011).

b. **Width** – The lateral expanse, including the river channel and its floodplain (Stoyan Mihov, 2011).

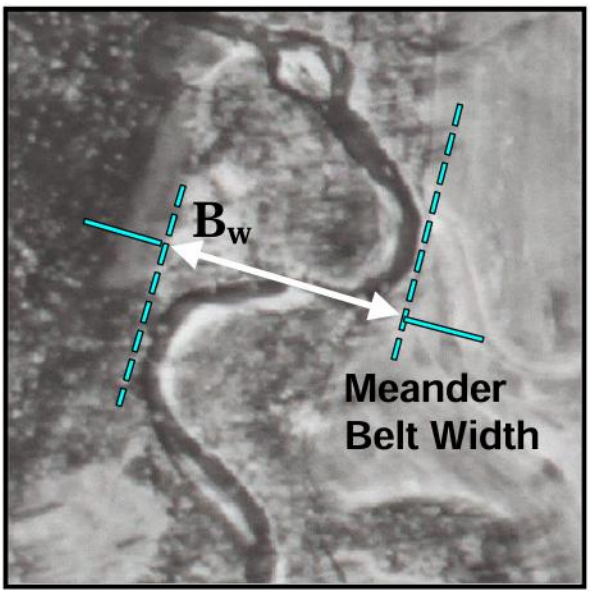
c. **Height** – The vertical profile of the river, including the depth and structure of the riverbed (Stoyan Mihov, 2011).

d. **Time** – The temporal variation in river flow, including seasonal changes (floods and droughts) and long-term alterations due to climate change and human interventions (Stoyan Mihov, 2011).

River Meander Belt

The lateral extent of river meandering, defining the corridor width within which the river migrates naturally over time.

Figure 4 Meander Belt



Source 7 Defining River Corridors, Fact Sheet, Vermont DEC River Management Program

2.1.2 River and Human Settlements

Rivers have influenced the growth of human settlements, it has enabled early civilisations to flourish along their banks due to its crucial resources such as water, fertile soil, and navigational advantages. Overtime the human settlements have moved inland due to advancements in technology and increased risks of flood.

Key Terminology:

River Corridor: The land adjacent to and including the river course is referred to as a **river corridor**. It supports ecological functions such as habitat connectivity, flood plain management, and water quality regulation. Protecting the river corridors helps preserve these natural processes and biodiversity (Vermont).

2.1.3 Impact of human activities on rivers

Rapid growth of urban areas and anthropogenic activities greatly impact the river ecosystems and alter the hydrology, water quality and biodiversity it supports. The effects of industrialization, infrastructural expansion, and pollution need long-term river management techniques.

Key Terminology:

River Precinct: It is a designated area surrounding a river that is strategically planned and managed to enhance its ecological function & processes, cultural and recreational values, and balances human interventions with environmental sustainability (Shire of Augusta, 2020).

2.1.4 River Basin

A River basin is the geographical area drained by a river and its tributaries. It is a land area that collects and channels water into a river system, including all the land, water bodies, and groundwater that drain into a particular river or river system.

Key Terminology:

River basin: A hydrological unit that collects and channels water into a particular river system. It serves as a fundamental unit for watershed management, ensuring the sustainable use of water resources while minimizing environmental degradation.



2.2 River Basin Frameworks, Watershed Management and Planning Concepts

Integrated river basin and watershed management requires planning approaches that meet the needs of sustainability, water security, urban resilience, and stakeholder participation. This section presents the guiding frameworks for a sustainable water resources management process and urban river design.

2.2.1 Integrated Water Resource Management (IWRM)

Integrated Water Resource Management (IWRM) is a water resource management approach that focuses on coordinated management across sectors with due considerations given to ecological, social, and economic sustainability.

The broad aspects of IWRM include coordinated management across sectors, ecological sustainability, social inclusivity, economic efficiency, and participation by stakeholders.

Figure 5 Key IWRM actions to support integration



Source 8 An Integrated Water Resource Management Framework to Support Implementation of the Cartagena Convention

Components of IWRM included water resource assessment, consumption efficient in-sector management of domestic, agricultural, and industrial water, environmental sustainability, institutional frameworks and capacity building, the strengthening of governance for effective management of water, development of infrastructure for supply systems-aspects of storage, treatment, and distribution-and flood management through planning and infrastructure interventions to counter the flooding risks.

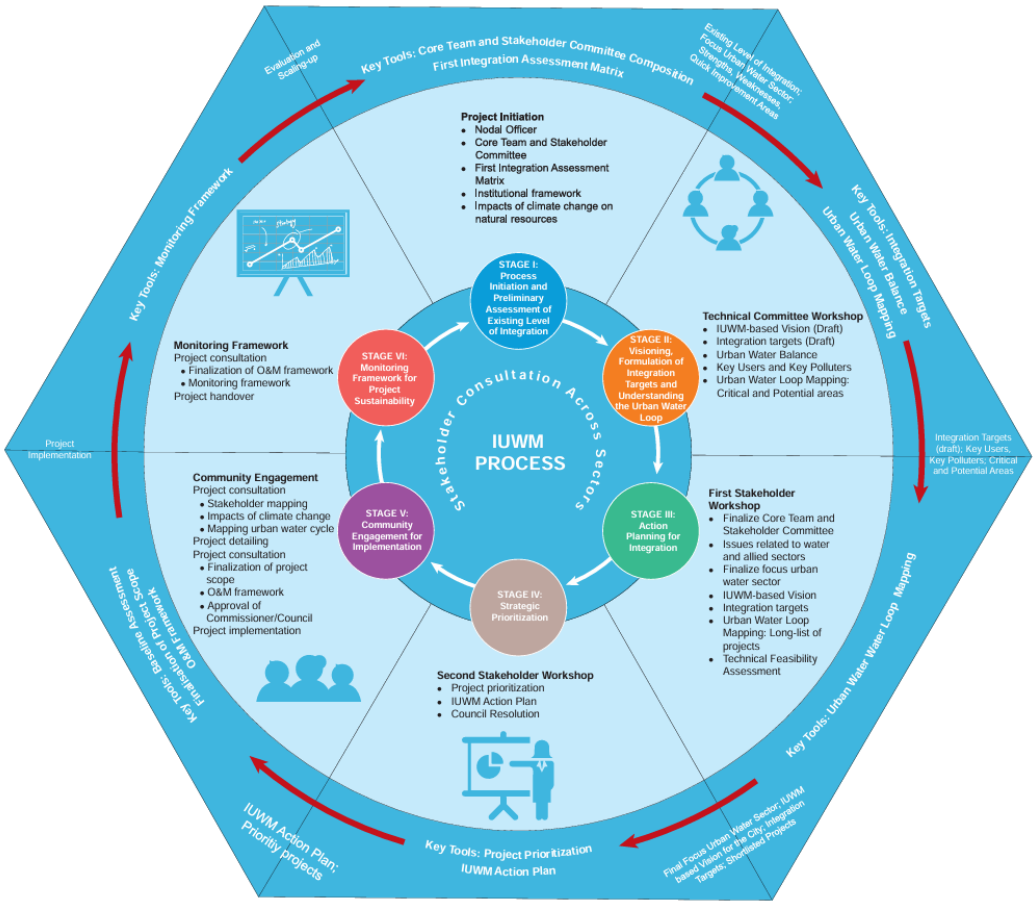
2.2.2 Integrated Urban Water Management (IUWM)

IUWM integrates water supply, wastewater management, and stormwater control within urban environments to ensure water security, environmental protection, and climate resilience.

Broader aspects of IUWM include a higher degree of water security, environmental protection, and resilience.

The components of IUWM include the urban water and wastewater, management of stormwater with flood prevention, water recycling and reuse, pollution control and green infrastructures, climate adaptation measures, stakeholder participation in urban water planning (ICLEI, 2013-2016).

Figure 6 IUWM planning process



Source 9 IUWM Toolkit for Indian Cities

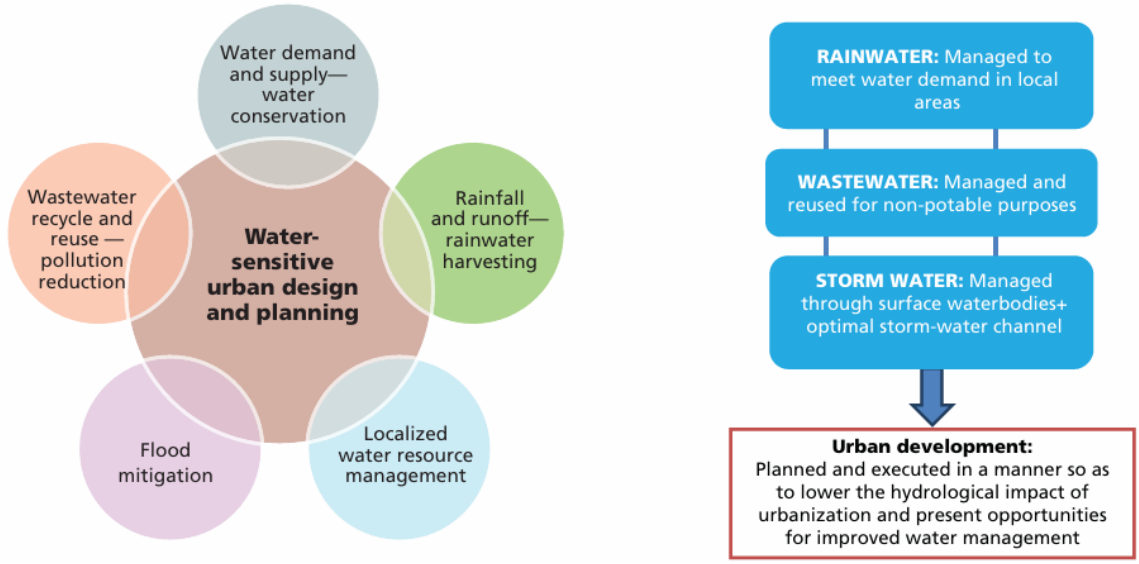
2.2.3 Water Sensitive Urban Design and Planning (WSUDP).

Water sensitive urban design and planning integrates water management into urban design in a manner that is sustainable, restorative to ecosystems and resilient to climate variation.

Some of the key features in relation to WSUDP include that of **integrated water management, sustainable urban development, climate resilience**

Core components of WSUDP includes Rainwater harvesting and sustainable urban drainage systems, green infrastructure for storm water absorption, Decentralized resource management: storm water and wastewater recycling, Natural resource restoration and management, Stakeholder involvement in sustainable water planning (Mahreen Matto, Shivali Jainer, Chhavi Sharda, & Suresh Kumar Rohilla, 2017)

Figure 7 WSUDP: Integrating water-cycle management



Source 10 Water Sensitive Urban Design and Planning-Practitioners Guide

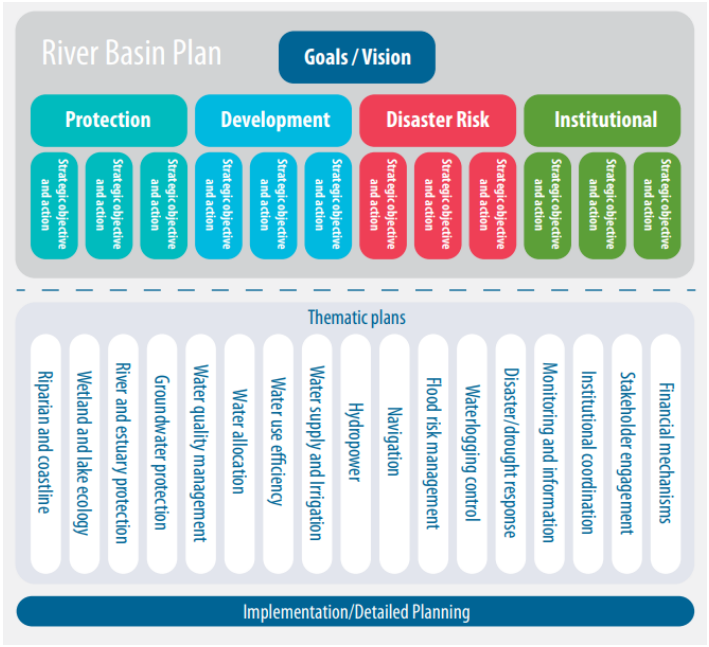
2.2.4 River Basin Planning (Asian Development Bank)

Basin Planning is a systematic process that outlines strategies for management of water resources in a river basin. It involves the establishment of objectives, modelling the future, determining current conditions, and preparing action plans considering social, economic, and environmental priorities. Effective basin planning is a requisite for answering challenges related to over-extraction, pollution, and habitat degradation.

Broad Aspects of River Basin Planning Environmental sustainability, Water resource optimization, Disaster risk management, Governance, and socio-economic development

Key Components of River Basin Planning comprises of Water resource management and ecosystem protection, Water allocation and utilization, Infrastructure development, Flood risk management, Stakeholder engagement, Livelihood support and poverty reduction (Pegram, et al., 2013)

Figure 8 Interface between the elements of the basin plan and supporting thematic plans



Source 11River Basin Planning

2.2.5 Urban River Management Plan (URMP)

National Institute of Urban Affairs (NIUA) has developed this framework for managing urban rivers in an integrated way, incorporating flood control, biodiversity conservation, and community involvement.

Main components of the Urban River Management Plan include **Urban flood management** that focus on Drainage and retention measures, **riverbank management** focusing on Stabilization of river edges to prevent erosion with riparian plantings, b**iodiversity conservation** which highlights the protection of aquatic ecosystems, **management of resources (urban water cycle)** to ensure sustainable use of urban water, **ecosystem services for economic development** which promotes river-based tourism and recreation and **community engagement** that focuses on participation of local stakeholders in river restoration programs (NIUA & NMCG, Urban River Management Plan, 2020).

Figure 9 The objectives of the URMP Framework

DESIGN PHILOSOPHY	Environmentally responsible	Economically beneficial	Socially inclusive
ELEMENT	ENVIRONMENTAL	ECONOMIC	SOCIAL
VISION	The river will be able to support a habitat for biodiversity to thrive	The river will provide opportunities for economic development	The river will be celebrated among the citizens
OBJECTIVES	1. To ensure effective regulation of activities in the floodplain 2. To keep the river free from pollution 3. To rejuvenate waterbodies and wetlands in the city 4. To enhance the riparian buffer along river banks 5. To adopt increased reuse of treated wastewater 6. To ensure maximum good quality return flow from the city into the river	7. To develop eco-friendly riverfront projects 8. To leverage on the economic potential of the river	9. To inculcate river-sensitive behaviour among citizens 10. To engage citizens in river management activities

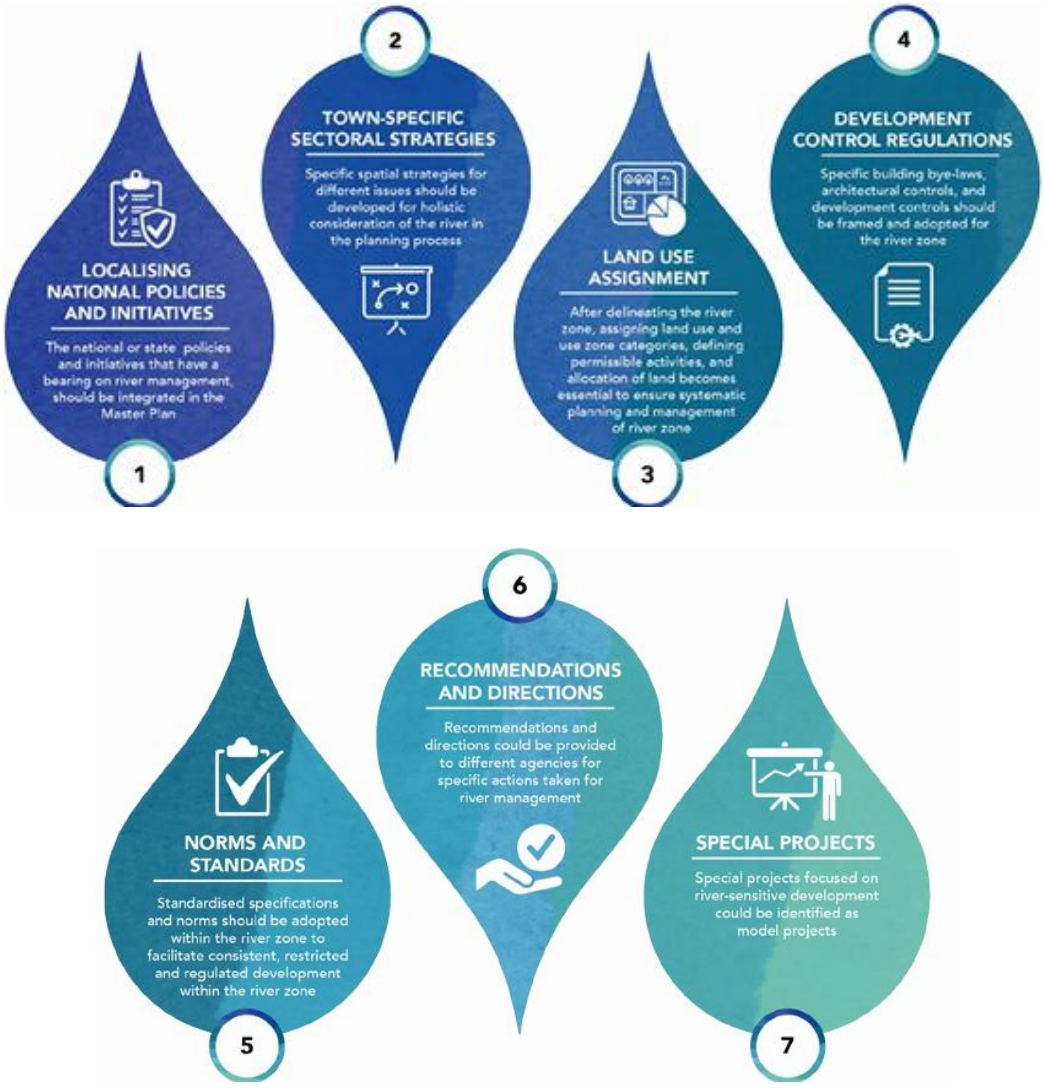
Source 12 The Urban River Management Framework

2.2.6 River-Sensitive Master Planning (NIUA)

This planning framework integrates river health into urban development, ensuring that cities grow without compromising the ecological and hydrological functions of rivers.

Key Components of River-Sensitive Master Plans includes **Ecological** assessment that focuses on monitoring water quality and ecosystem health, **Urban planning integration** that recommends aligning city expansion with river conservation, **Community engagement** with focus on Encouraging participatory planning and **Flood risk management** that focuses on Implementing flood-resilient infrastructures (NIUA & NMCG, Making River Sensitive Master Plan, 2021)

Figure 10 Instruments and tools for making river-sensitive plans



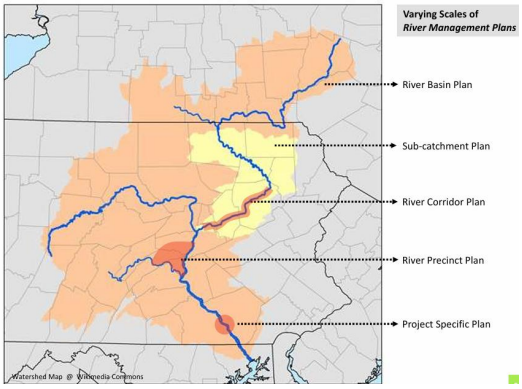
Source 13 Making river-sensitive master plans

2.2.7 The Compendium of River Management Plans

"The Compendium of River Management Plans," published by the National Institute of Urban Affairs (NIUA), is a guidance to diversify river management approaches towards unified and sustainable options in urban settings of river management. It highlights seriously the role of rivers in supporting ecosystems, economies, and communities, while meeting the challenges posed by urbanization, pollution, and degradation of ecosystems (NIUA & NMCG, A Compendium of River Management Plans, 2022).

Key components include **River Management Framework** under which the compendium sets out a rigorous framework for devising effective River Management Plans (RMPs), taking into full consideration, ecological, social, and economic aspects. It further establishes the need for a **long-term vision** for the health of the river agreed upon by all stakeholders, **Ecological health** which focuses on maintaining water quality and biodiversity, **community engagement** to strengthen public participation in river conservation, **urban planning integration** to ensure river-sensitive development, **flood risk management** to Mitigate urban flood hazards and **water supply and wastewater management** to promote sustainable resource use.

Figure 11 Various Scales of River Management Plans



Source 14 The compendium of River Management Plans

2.2.8 Inference

These frameworks provide structured approaches for managing river basins and watersheds. By incorporating these principles, we can bring about a change in terms of sustainable development in urbanization, climate change, and water security contexts. Also, these frameworks underscore the importance of ecosystem preservation, participatory governance, and resilience planning, providing essential tools for river and watershed management in both urban and rural settings.

Table 2 Parameters taken forward

Broad aspects	Components	Indicators
Water	**River Basins & Watershed -** Spatial units defining the hydrological system and catchment areas.	▪ River discharge & flow variation ▪ Drainage density
	Surface Water & Groundwater – Availability & Quality – Sustainable water quantity and quality maintenance.	▪ Groundwater recharge rates ▪ Surface water quality indices (Ph, BOD, COD, TDS) ▪ Aquifer water level fluctuations
	Morphometric Parameters – Physical watershed characteristics affecting hydrology.	▪ Aerial aspects ▪ Linear aspects ▪ Relief aspects
Climate Resilience	**Climatic Conditions & Variability -** Temperature, precipitation, and seasonal hydrological changes	▪ Annual rainfall variation ▪ Temperature fluctuations
	Flood Susceptibility - Risk assessment due to precipitation, land use, and watershed characteristics.	Flood frequency & intensity
	Water Scarcity - Ability to meet water demand under climate stress.	▪ Drought frequency & severity (SPI - Standardized Precipitation Index) ▪ Water demand vs. supply ratio
Socio-Economic	**Communities Living Within Watersheds** - Population dependency on river resources.	▪ Population density in watershed areas (persons/km²) ▪ Household water access (%)
	Sectoral Activities – Domestic, Agricultural, Industrial - Water consumption patterns in different sectors.	▪ Percentage of agricultural land use (%) ▪ Water consumption per sector (m³/day) ▪ Industry-specific pollution levels (BOD, COD)
Physical Infrastructure	Water Supply	Per capita water supply
	Storm Water Management	Stormwater drainage coverage (%)
	Sewerage	▪ Sewerage connectivity (%) ▪ Wastewater treatment efficiency

Source 15 Author

2.3 Climate Resilience and SDG's

This section discusses frameworks that build climate-resilient systems in cities while remaining aligned with the Sustainable Development Goals (SDGs). Each of these framework presents a structured approach to assess and enhance resilience while examining different components of urban systems: water resource management, biodiversity, disaster resilience, and socio-economic equity.

2.3.1 City Resilience Profiling Toolkit (UN-Habitat)

Conceived by UN-Habitat, the City Resilience Profiling Toolkit (CRPT) provides cities with a systematic way of determining and building resilience capacities across shocks and stressors. It adopts a multi-dimensional approach to **climate resilience, urban systems, social equity, and economic sustainability** (UN-Habitat, 2012)**.**

The framework contains five major components:

1. **City Identification (ID)** – Collection of information related to demographic and geographic features, providing a baseline information from which resettlement assessment could proceed.
2. **Stakeholder Engagement** – The principle of inclusiveness and diversity is recognized in this component, which provides an avenue for all affected communities to voice out their perspectives in the resilience-building strategies.
3. **Shocks and Stressors** – Reference and location on risks and vulnerabilities, involving extreme weather events, wildfires, and social instability.
4. **Quality of Infrastructure** – It is imperative to assess the durability and efficiency of city and community infrastructure to ensure climate resilience in the long run.
5. **Equitable Access to Service** – Equitable distribution of resources and services, particularly to marginalized communities, is an important indicator of resilience planning.
6. This framework enables cities to identify vulnerabilities, risks, and long-term resilience strategies in compliance with SDG targets for urban sustainability (SDG 11), economic sustainability (SDG 8), and climate action (SDG 13).

2.3.2 IAdapt (Adaptation of Catchment to Climate Change)

The initial focus of the IAdapt framework is climate adaptation at river, watershed, and urban drainage levels. Such adaptation is vital for sustainable water management, addressing flood mitigation, and achieving climate resilience in river cities (ICLEI, 2023).

The framework includes a four-step process:

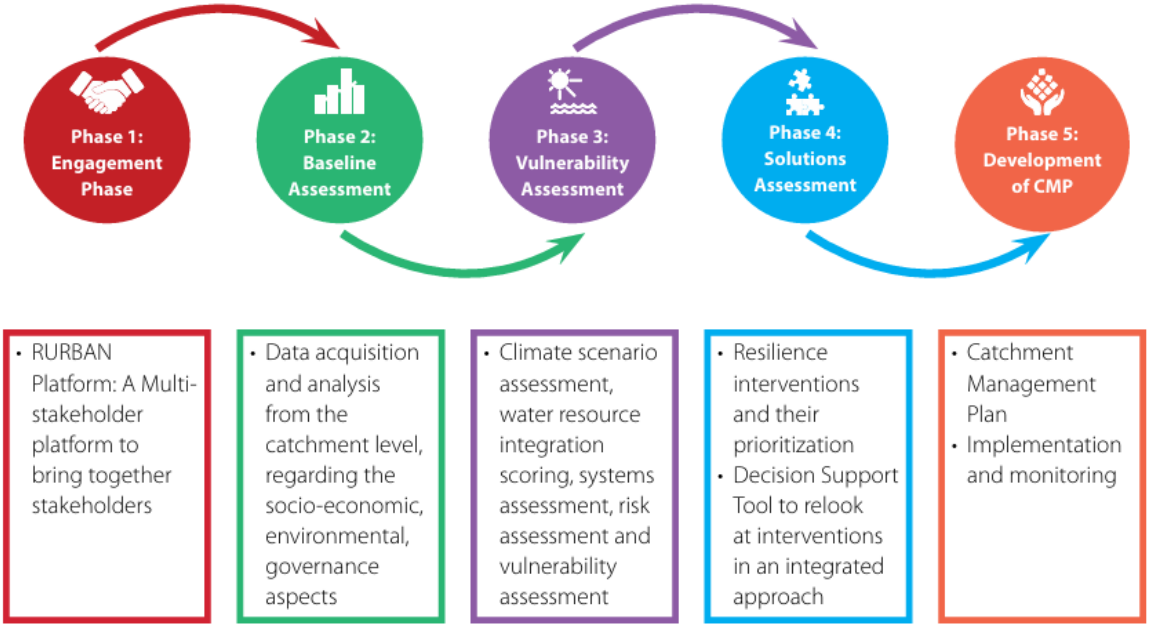
Stakeholder Engagement: It includes participatory planning involving local communities and local government and environmental organizations to adopt an inclusive approach.

Baseline Assessment: Involves collecting information on social and economic conditions, environmental parameters, and governance structures to characterize existing vulnerabilities.

Vulnerability Assessment: Identifies zones subject to extremely high threats regarding climate hazards, such as flood zones, water-scarce areas, or pollution hotspots.

Solution Assessment and Prioritization: Calls for adaptation solutions involving ecosystem-integrated approaches, enhancement to drainage systems, and climate-resilient infrastructure to be proposed and ranked.

Figure 12 Phases of IAdapt Framework



Source 16 IAdapt Framework

This framework integrates hydrology with ecological and socio-economic factors and strongly supports the achievement of climate action-related SDGs (SDG 13), clean water and sanitation (SDG 6), and cities (SDG 11) objectives.

2.3.3 ClimateSmart Cities Assessment Framework 3.0 (NIUA)

The ClimateSmart Cities Assessment Framework 3.0 under development at the NIUA intends to assess and enhance the climate resilience of Indian cities. This framework is aligned with India's urban sustainability goals and emphasizes urban biodiversity, energy efficiency, water conservation, and waste management (Dr. Umamaheshwaran Rajasekar, et al., 2022).

It focuses on five aspects that includes **Urban planning, green cover, and biodiversity** - This includes conservation of natural spaces, afforestation, and urban biodiversity for strengthening resilience, **Energy and green buildings** - To promote energy-efficient infrastructure and adoption of renewable energy to minimize carbon footprint, **Mobility and air quality** - Which deals with sustainable transport systems, air pollution mitigation, and non-motorized transport solutions, **Water management** - This includes water resource consumption efficiency, flood risk reduction, recycling of wastewater, and non-revenue water losses, **Waste management** - Advocating for the scientific disposal of waste, recycling initiatives, and circular economy approaches.

The framework includes indicators like urban biodiversity, flood risk management, and disaster preparedness, which make it consistent with SDGs on sustainable cities (SDG 11), responsible consumption and production (SDG 12), and climate action (SDG 13).

Figure 13 Indicators of ClimateSmart Cities Assessment Framework 3.0



Source 17 ClimateSmart Cities Assessment Framework 3.0

2.3.4 Sustainable Development Goals (SDG's)

The SDGs comprise a set of goals built to push for a broader cause of sustainability and resilience in social, economic, and environmental domains. These goals can be grouped into several categories that include **Social Development (SDGs 1,2,3,4,5,10,11)** – emphasizes the reduction of poverty, hunger, and inequalities and the improvement in education, health, and urban liveability, **Economic Development (SDGs 8,9,12)** – encourages sustainable industrialization, creation of jobs, innovation, and responsible consumption, **Environmental Protection (SDGs 6,7,13,14,15)** – focuses on climate resilience, clean water management, biodiversity conservation, and sustainable energy, **Global Partnership and Governance (SDGs 16,17)** – gives importance to policy reform, global cooperation, and institutional systems with respect to sustainability.

The SDGs then provide an overarching direction that ensures that urban resilience strategies are integrated, inclusive, and in-sync with the global views.

Figure 14 UN Sustainable Development Goals



Source 18 UN Sustainable Development Goals

2.3.5 Inference

These frameworks can be used as structured approaches toward climate resilience, each focusing on diverse urban and environmental aspects. The City Resilience Profiling Toolkit highlights urban systems and equity, while IAdapt focuses on catchment-based climate adaptation. These frameworks give a comprehensive assessment for Indian cities in areas such as biodiversity, water, and waste management. The SDGs constitute the general sustainability framework. These frameworks, provide a multi-layered view on resilience make sure that urban planning strategies are inclusive, data-driven, and aligns with climate objectives. By integrating these frameworks, cities stand to develop strong and data-driven strategies aligned with the UN SDGs for long-term resilience and sustainability.

Table 3 Parameters taken forward

Broad Aspect	Component	Indicators
Environment – Land, Water & Biotic	▪ Conservation of waterbodies ▪ Open areas ▪ Urban biodiversity to maintain ecological balance	▪ % of green cover ▪ Waterbody area ▪ Biodiversity index
Climate Resilience	▪ Climatic condition ▪ Flood risk to enhance urban resilience.	▪ Temperature trends ▪ Flood frequency ▪ Climate variability
Utility – Water supply, sewage, sanitation	▪ Infrastructure gap ▪ Usage of water by various sectors ▪ Wastewater Treatment & its repurposing	▪ Per capita water consumption ▪ % of treated wastewater ▪ Sanitation coverage
Demography & Socio-economics	Literacy rate, Workers population & Economic activities	▪ Literacy rate ▪ Employment rate ▪ GDP
SDGs	Aligning urban resilience and sustainability strategies with global SDG targets.	▪ **SDG 6** (Clean Water & Sanitation) ▪ **SDG 10** (Reduced Inequalities) ▪ **SDG 11** (Sustainable Cities & Communities) ▪ **SDG 13** (Climate Action) ▪ **SDG 15** (Life on Land) ▪ **SDG 17** (Partnerships for the Goals) ▪ Indirectly **SDG 8** (Decent Work & Economic Growth) ▪ **SDG 9** (Industry, Innovation & Infrastructure)

Source 19 Author

2.4 Stakeholder & Livelihood analysis, Ecosystem Services

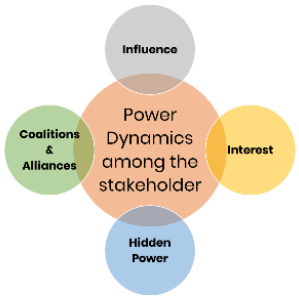
Stakeholder analysis, livelihood analysis, and ecosystem services are the basic building blocks of environmental planning that help ensure inclusive decision-making, sustainable resource management, and the associated long-term ecological and social benefits. **Stakeholder analysis** helps in identifying key players, their influence, and the power dynamics within environmental projects. **Livelihood analysis** targets the understanding of how communities rely upon natural resources, and **ecosystem services valuation** ensures that development planning evaluates the benefits derived from nature, like water purification, climate regulation, and biodiversity conservation.

2.4.1 Stakeholder Analysis and Power Dynamics

Stakeholder Analysis in Environmental and Conservation Planning

Stakeholder analysis is a very important tool in environmental and conservation planning, helping categorize stakeholders according to their influence, interest, and role in the decision-making process. The power dynamics of stakeholders can be understood under 4 aspects that include Influence which is the ability of stakeholders to directly influence decisions or motivate projects somehow, **Coalitions & Alliances** which is a range of partnerships that stakeholders build to substantiate their position or advance common goals, **Hidden Power** which identifies unrecognized or indirect influence some stakeholders wield on decision-making and **Interest** that captures the degree of concern or stake that a particular group has in the project or agreement made (Suzanne Macey, Donna Vogler, & Amanda Sigouin, 2017).

Figure 15 Power dynamics amongst stakeholders



Source 20 Author

2.4.2 Stakeholder Mapping Tool

The stakeholder mapping tool developed by the **Centre for Creative Leadership** places stakeholders according to their level of trust as well as their level of agreement with a project or policy. This place is very important in analysing stakeholder relationships and coming up with engagement strategies.

The **four broad areas of stakeholders** in the mapping tool are:

1. **Allies (high trust, high agreement):** These stakeholders are open to supporting environmental and conservation efforts and are trusted partners in planning.

Example: Environmental NGOs actively promote conservation and sustainable management practices. Local communities (farmers, fishermen) subsist through the utilization of resources and hence back conservation efforts.

2. **Associates (Low Trust, High Agreement**): Stakeholders who may be in agreement with environmental objectives have poorer trust relations due to bureaucratic processes or differing priorities.

Example: Municipal authorities and urban planners support sustainable development, there may be other competing interests, such as urban growth, that conflict somehow with conservation goals.

3. **Opponents (High Trust, Low Agreement):** These stakeholders typically hold high decision-making positions and will oppose conservation because of economic or industrial premises.

Example: Industrial stakeholders and real estate developers often put economic growth and infrastructure development ahead of environmental concerns and thus may directly conflict with conservation and sustainable resource management goals.

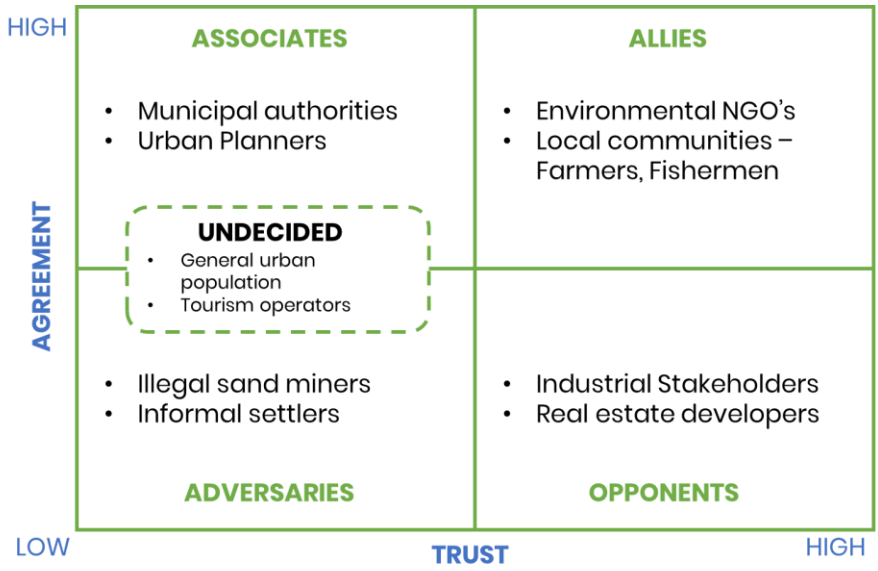
4. **Adversaries (Low Trust, Low Agreement):** These stakeholders are, technically and practically direct opponents of the environmental agenda and have no trust relations with planners, and sometimes, they cause immense environmental damage that persists.

Example: Illegal sand miners and informal settlers unsustainably exploit the resources and, at times, are in direct confrontation with conservation work.

Undecided Stakeholders: Some do not belong to any of these previous categories, being neutral or dependent on external conditions for their stand.

Example: General urban population and tourism operators may support or oppose conservation efforts based on how they perceive economic and environmental trade-offs.

Figure 16 An example of stakeholder mapping



Source 21 Author

2.4.3 The Economics of Ecosystems and Biodiversity (TEEB)

This TEEB-adapted model by GIZ provides methodical approach for integrating ecosystem service consideration within development planning. Hence, this framework enables policies and decision making for a sustainable and resilient development by taking ecological benefits into consideration.

Scope Definition and Making the Scene: It identifies major environmental and development issues, relevant stakeholder groups, milestones, and resource needs; Planning starts to include ecosystem considerations.

Screening and Prioritizing Ecosystem Services: Engages different sectors in dependency assessments based on service provision from ecosystems. Development activities impact assessment against ecosystem services. This screening thus prioritizes ecosystem services requiring urgent conservation/restoration measures.

Identifying States, Trends, and Trade-offs: Basically, assesses the present status of any ecosystem services and future expected trends under different development scenarios. It contrasts trade-offs between economic growth and environmental sustainability.

Appraising Institutional and Cultural Frameworks: Examine existing policies and regulations, as well as cultural factors impacting ecosystems' management. This will enable identification of gaps and opportunities for strengthening governance.

Healthy Decision Making: Identifying risks and opportunities for ecosystem services. Integrate scientific, social, and economic considerations, providing policy recommendations.

Changing the System: Establishing strategies for stakeholder involvement into activities that will ensure sustainable ecosystem management. Encourages adaptive governance where policies evolve depending on environmentally and socio-economically based feedback.

This framework ensures that ecosystem services such as water regulation, climate resilience, and biodiversity are integrated systemically into any development plans with sufficient consideration for environmental protection and social-economy.

2.4.4 Inference

Stakeholder analysis is essential to understanding the various perspectives and power relationships that come into play in river management & planning strategies. It will allow decision-makers to identify whom they need to engage with and develop a targeted engagement strategy in building alliances with supporters and disarming opponents. Ecosystem services should be included in developments so that the contribution of the environment would be recognized and valued to ensure a more sustainable and resilient urban and rural development strategy. All these strategies are laying a comprehensive foundation for a consolidated environmental and socio-economic sustainability in the long run.

Table 4 Parameters taken forward

Broad Aspect	Component	Indicators
Stakeholder Assessment	▪ Power dynamics amongst stakeholder ▪ Identifying & grouping stakeholder	▪ Number of stakeholders identified ▪ Level of influence.
Stakeholder Mapping	▪ Identifying concerns and interest of stakeholder ▪ Resources/Strategies needed to align the interests of Stakeholders	▪ Trust levels ▪ Conflict resolution strategies.
Ecosystem Services	Evaluating benefits ecosystems provide and their role in planning.	▪ Ecosystem dependency ▪ Economic valuation.

Source 22 Author



2.5 Spatial Planning Approaches

Spatial planning is essential for creating sustainable and resilient urban and rural environments by combining land use, infrastructure, environmental factors, and socio-economic growth. To assist planners and policymakers in executing effective planning strategies, various guidelines and toolkits have been developed. The table below outlines four key frameworks that tackle spatial planning issues, including climate resilience, disaster risk reduction, infrastructure planning, and integrated water management.

2.5.1 Urban and Regional Development Plans Formulation and Implementation Guidelines (URDPFI)

The URDPFI Guidelines offer a systematic method for developing urban and regional development plans. They create a hierarchy of plans to ensure that development strategies are in line with national, state, and local policies. These guidelines focus on **Environmental sustainability** which encourages urban green spaces, conservation of natural resources, and the protection of ecosystem, **Infrastructure planning** covering transportation systems, utilities, and essential urban services and **Disaster resilience** with emphasis on climate-related risks such as floods and severe climatic events.

Components include regional planning approach, Urban planning approach, Infrastructure planning, Conservation of natural resources, Urban greens and ecosystem preservation, Watershed as a fundamental unit of development, Climate, and flood risk management.

2.5.2 RADPFI- Rural Area Development Plan Formulation and Implementation Guidelines. (RADPFI)

These guidelines are aimed at inclusive rural development through equitable access to resources, services, and economic opportunities. It promotes the participatory approach where local communities are involved in decision-making. Also addresses other aspects that emphasize further on **Capacity building** by enhancing local skills as well as institutional support for rural communities, **Infrastructure development**, especially pointed toward basic services like water supply, sanitation, and connectivity, **Livelihood opportunities** through sustainable agriculture, skill development, and rural employment.

Components include stakeholder engagement, Training programs and workshop, Connectivity, water supply and sanitation, Skill development, SHGs and agricultural support

2.5.3 Green City Toolkit

The Green City Toolkit helps cities implement the adaptation and mitigation strategies to strengthen urban resilience towards climate change. It highlights on **green infrastructure** with a focus on parks, permeable pavements, and green corridors to foster air quality and urban biodiversity, **Disaster risk reduction** through flood management infrastructure and early warning systems, **Water-sensitive urban design**, integrating stormwater and wastewater management into urban planning, **Sustainable waste management** promoting recycling, composting, and resource recovery (Asian Development Bank, 2015).

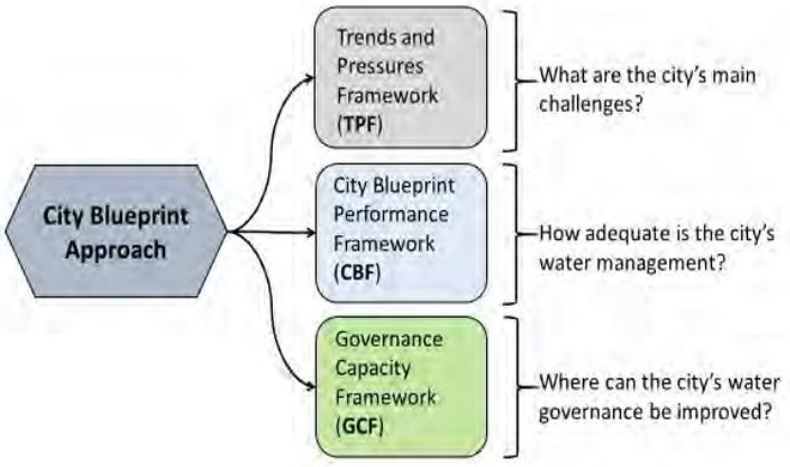
Components include Climate adaptation-green roofs, urban cooling solutions and flood management, Disaster risk reduction-early warning systems, all resilient building codes, green infrastructure-parks, green corridors, and permeable pavements, WSUD stormwater and wastewater management, Waste reduction and management

2.5.4 City Blueprint Approach

The City Blueprint is a comprehensive water management frame that assesses urban water performance and governance capacity. It has **three complementary frameworks**:

1. **Trends and Pressure Framework**-Assesses socio-economic and environmental pressures (water scarcity, heat stress, urbanization).
2. **City Blueprint Performance Framework**-Assesses the performance of water infrastructure to identify the bottlenecks in Integrated Water Resource Management.
3. **Governance Capacity Framework**-To check institutional, financial and governance capabilities to implement water and climate resilience strategies.

Figure 17 City Blue Print Approach Framework



Source 23 The City Blueprint Approach

2.5.5 Inference

The guidelines and toolkits referred to bring out the importance of integrated spatial planning in achieving environmental sustainability, disaster resilience, and infrastructure development. **URDPFI and RADPFI** provide structured cities and rural planning, intending that the growth process keeps in mind the regional and local demands. **The Green City Toolkit** focuses on climate adaptation and green infrastructure to make the cities capable of responding to environmental challenges. **City Blueprint Approach** creates a data analysis-based assessment of water management and governance capacity to ensure a truly sustainable urban water cycle. Cumulatively, these frameworks provide a holistic perspective to spatial planning, which guarantees that both urban and rural spaces are sustainable, resilient, and inclusive.

Table 5 Parameters taken forward

Broad Aspect	Component	Indicators
Environment	▪ Climate ▪ Land ▪ Water ▪ Biotic	▪ Climate conditions ▪ Land use ▪ Water availability ▪ Biodiversity
Climate Resilience	▪ Climatic condition ▪ Flood risk	▪ Flood-prone areas, temperature variations ▪ Precipitation trends
Utility – Water supply, sewage, sanitation	▪ Infrastructure gap, Usage of water by various sectors ▪ Wastewater Treatment & its repurposing	▪ Water demand-supply gap ▪ Wastewater treatment facilities ▪ Sanitation coverage
Demography & Socio-economics	▪ Literacy rate ▪ Workers population ▪ Economic activities	▪ Literacy rate ▪ Employment rate ▪ Economic activity types

Source 24 Author

2.6 State and District Documents

Table 6 State and District Documents

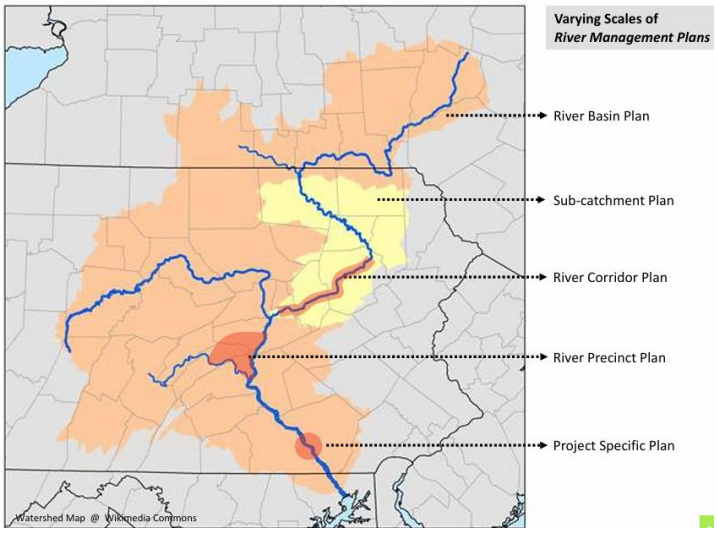
Document	Description
Karnataka State Action Plan on Climate Change 2021	**Climate Projections and Risks** **Rainfall and Drought:** Increase in very high-intensity rainfall events annually. Decline in the frequency of drought years by two under the RCP 4.5 scenario. **Coastal Vulnerability:** Significant risk of coastal erosion, particularly at Ullal beach, losing more than 1 meter of shoreline annually.
	Fisheries and Coastal Management **Impacts on Fisheries:** Sea level rise, ocean acidification, and changes in precipitation affecting marine and freshwater fish productivity. Fishing infrastructure, such as jetties and harbors, may require climate-adaptive modifications.
Dakshin Kannada District Disaster Management Plan 2019-2020	**Meteorological Hazards:** Cyclones, heavy rainfall, floods, and lightning. **Geological Hazards:** Earthquakes and landslides. **Industrial Hazards:** Toxic releases, fires, and explosions in Major Accident Hazard (MAH) industries. **Biological Hazards:** Epidemics and food poisoning. **Miscellaneous Hazards:** Forest fires, road and rail accidents, and stampedes.
Dakshin Kannada District Environmental Plan 2022	Provides a comprehensive overview of the district's environmental profile, waste management strategies, and action plans for sustainability. **Area: 4,859 sq. km**, with a diverse geography of coastal and forested regions. 9 Tehsils
	Waste Management: Solid, plastic, biomedical, hazardous, e-waste, and C&D waste management systems are under development. Focus on segregation at source, awareness campaigns, and recycling infrastructure.
	Air and Water Quality: **Air:** Monitoring stations and pollution control measures. **Water:** Sewage treatment and conservation efforts for rivers and lakes.
	Industrial and Mining Regulation: Policies to mitigate environmental impacts from industries and mining activities.
Madhav Gadgil report	The **Ecologically Sensitive Zones (ESZs)** in Dakshina Kannada, as outlined in the WGEEP report, include **Beltangadi and Sulya** are designated as **ESZ1,** indicating the highest ecological sensitivity. **Puttur** is classified as ESZ2, where moderate ecological sensitivity requires regulation but allows some developmental activities
Kasturi Rangan Report	46 villages in Dakshina Kannada district are included in the ESAs. Recommends that these villages adopt **village-level management plans** to balance conservation and sustainable development. **1. Participatory Approach:** Involvement of local communities and stakeholders in planning and implementation. **2. Developmental Regulations:** Restrictions on activities like mining, large construction projects, and industrial development that could harm the ecological balance. Promotion of sustainable agricultural practices and eco-tourism. 3. Biodiversity Protection: Safeguarding biodiversity hotspots and critical habitats within these villages. Preserving riparian zones, forested areas, and other natural ecosystems

Source 25 Author

2.7 Associating River Management Scales with Spatial Planning Scales

River management is a multi-scalar process that requires coordination at various levels of planning to implement sustainable water resource management, ecological conservation, and disaster resilience. The following table presents the alignment of various river management planning scales with spatial planning scales as defined in the Urban and Regional Development Plans Formulation and Implementation (URDPFI) Guidelines. Integrating each level's interventions—from the river basin down to project-specific plans—into broader urban and regional development strategies helps achieve sustainability, localized interventions, and coordinated governance for riverine ecosystems.

Figure 18 Various Scales of River Management Plans



Source 26 The compendium of River Management Plans

Table 7 Associating River Management Scales with Spatial Planning Scales

River management plan	URDPI Planning scale	Rational
River Basin Plan	Perspective/Regional Plan	Long-term vision for river
Sub-Catchment plan	Sub-Regional Plan	Focus on smaller catchments, Localised water resource management & Land use strategies
River Corridor plan	District Development plan/ Regional Plan	- District-level planning for managing river corridors, - Disaster risk reduction, economic development
River Precinct Plan	Development Plan/Zonal Plan	Focus on urban areas and specific urban interventions
Project Specific Plan	Local Area Plans	Microlevel interventions such as Embankments, WTP, etc

Source 27 Author

2.8 Case Study

2.8.1 White River Plan, Indianapolis

Document: White River Plan, 2019

Hierarchy of plan: Precinct Level

Vision: The White River will soon embody all our aspirations as a clean, natural, historic, connected, and active asset for the Central Indiana region to enjoy (NMCG & NIUA, 2022)

River basin profile

The Location is Indianapolis and has a River length of 583 kms. The Catchment Area is 14,880sq.km and supports a Population of 2 million. The Precinct River Length is 78kms and Precinct Area is 249 Sq.km.

Core issues

Issues include Water pollution, Flooding, Sewage influences, Loss of biodiversity, Invasion by non-native plants, Sedimentation

Map 3 White River Basin



Source 28 A Compendium of River Management Plans

The White River Plan (2019) follows an organized framework within which nine key guiding principles, six river reaches, and river anchors are established.

Guiding Principles: The guiding principles are the foundational pillars that evaluate all strategies and actions of the White River Plan. They act to ensure that river management puts sustainability and community engagement and ecosystem health in the forefront. The nine guiding principles are:

1. **Sustainability:** An emphasis on long-term ecological health and social equity in managing river resources.
2. **Integrated Management:** Holistic approaches relating the river to land use, water management, and the needs of communities.
3. **Community Engagement:** Fostering the active participation of local communities and stakeholders within decision-making processes.
4. **Resilience:** Designing strategies that improve the ability of the river to adapt to climate change and human impacts.
5. **Scientific Framework:** Carrying decision-making on the basis of scientific efforts and empirical data that are to guide management care.
6. **Transparency:** The building of trust among stakeholders through open planning and decision-making processes.
7. **Cultural Heritage:** Recognition of the cultural and historical importance of the river to local communities.
8. **Biodiversity Conservation:** The conservation and enhancement of biodiversity within river ecosystems must be prioritized.
9. **Economic Viability:** Balancing interests of economic development and ecological conservation so the livelihoods of local people are supported.

River Reaches: The White River is subdivided into six different reaches, with a characteristic ecological, social, and hydrological feature. The division applies different strategies and is tailored for the different conditions and challenges that apply to every reach. The six reaches would generally be:

Map 4 River Reaches of the White River



Source 29 A Compendium of River Management Plans

1. **Upper Reach:** That area with headwaters generally less influenced by urban development and with high ecological integrity.
2. **Middle Reach:** It is a transitional zone where the quality of the ecology starts deteriorating but some natural features persist.
3. **Lower Reach:** This will comprise the heavily urbanized zone undergoing very strong anthropogenic impacts. This will require focused management intervention.
4. **Floodplain Reach:** These are flood-prone areas; therefore, flood management and habitat restoration strategies must be devised in for the same.
5. **Ecological Corridor**: It connects fragmented habitats towards enhancing biodiversity conservation efforts.
6. **Urban Interface:** It is an area directly impacted by urbanization concerning river systems, with efforts to integrate different green infrastructures in areas.

River Anchors: River anchors comprise crucial locations or features along the river that need to be recognized during the implementation of management strategies and community mobilization. These anchors serve as locus for different activities, including restoration work, public access, and educational initiatives.

Examples:

1. **Restoration Sites:** These include areas designated for ecological restoration in improving biodiversity and river health.
2. **Public Space:** Parks or waterfronts granting access to the river for recreation and community activities.
3. **Cultural Sites:** The areas of historical or cultural interest that help reinforce the importance of the river to local heritage.
4. **Monitoring Stations:** Stations measuring water quality, biodiversity, and other ecological indicators important for adaptive management.

Conclusion

The White River Plan is its guiding principles, river reaches, and river anchors takes a well-patterned approach towards river management. Such a system provides custom tailored strategies for the varied challenges and opportunities presented by different sections of the river and hence ensures that ecological health, community involvement, and sustainable development remain at the centre stage of decision making.

2.8.2 River Ganga, India

Document: Ganga River Basin Management Plan (GRBMP), 2015

Hierarchy of plan: Basin Level

Vision – To restore the ecological balance of the national river Ganga and provide an enabling environment for endemic flora, fauna, and microorganisms to thrive in the Ganga River network (NMCG & NIUA, 2022)

River basin profile

The Location of the river is India and has a Length of 2525 km. The Basin Area is 8,61,404 km^2 and supports a population of 48.5 Crores. Population Density is 563 persons/km^2, and it observes Urbanization Rate of 30%

Core issues

Issues include Water pollution, Flooding, Drought, Fragmented management, Deteriorating groundwater levels

Map 5 Ganga Basin



Source 30 A Compendium of River Management Plans

The Ganga River Basin Management Plan (GRBMP) defines core measures over **three dimensions: environmental, social and economic**, towards restoration and sustainable management of the river.

Environmental Strategies:

1 **Management of Environmental Flow; Agricultural Runoff:** Ensures appropriate flow of water for health in the river in terms of ecology as well as livelihoods attached to it. Reduced agricultural runoff-polices because of practices implemented to reduce contamination of water bodies from fertilizers and pesticides-protects water quality.

2 **Sewage Treatment Plant (STP) Capacity Augmentation:** This strategy intends to increase the existing capacity and effectiveness of STPs and provide an outlet to the waste. This is the improved new waste from STP and reduces the volumes of untreated sewage entering the river.

3 **GIS-based spatial planning and monitoring:** GIS technology for spatial analysis, mapping, and monitoring of land use and water resources. have helped plan and implement management interventions and more easily report environmental change across the river basin.

4 **Afforestation (Medicinal, Native Species) and Biodiversity Conservation:** Afforestation will be achieved through planting native and medicinal species which help habitat restoration, contribute to improvement in biodiversity, and strengthen soil and water conservation activities. This would enhance the ecological resilience of the river basin.

5 **Abatement of Industrial Pollution:** It seeks to find strict regulations for industrial discharges into the Ganga and encourages cleaner production processes, which minimizes the impact of industrial activity on water quality.

Social Strategies

1 **Development of Ganga Grams:** The llaga model villages, such as Ganga Grams, advocate sustainable development practices with improved sanitation, better waste and solid waste management, and eco-friendly practices. This is intended to relieve the housewife's existence and increase welfare, thus improving the livelihood of local communities while conserving the river.

2 **Communication and Public Outreach Activities:** Using awareness campaigns and outreach programs, including the Ganga Vahini and Praharis, people will be educated about river conservation. This will build a sense of ownership and responsibility for all stakeholders.

3 **Creation of Modern Dhobi Ghats:** Modernizing and upgrading the old facilities of washing places under the dhobi ghats will significantly improve the practices of waste management associated with laundry activities and cut down on their pollution. The livelihoods of the washermen will be improved. Their operations will carry on without depleting the water quality of the river into which they wash.

Economic Strategies

1 **Setting River Requirements:** This strategy advocates the development of riverfront infrastructure and facilities that are ecologically beneficial and accessible to the community. In this way, economic growth will not be at the expense of the river's ecosystem.

2 **Public Amenities in Char Dham and Ganga Yatra:** To develop the amenities for pilgrims and tourists along the Ganga to make their experience better; improve the livelihood of the surrounding communities; give a boost to responsible tourism; generate revenue to support conservation 'services such as sanitation'; meet specific needs of visitors.

3 **Implementation framework:** The entire strategy is framed in an implementation framework linking all strategies to the roles of various stakeholders, timelines, monitoring mechanisms, and funding sources that will facilitate the efficient execution of the strategies. This ensures coordinated efforts between governmental and non- governmental and community levels.

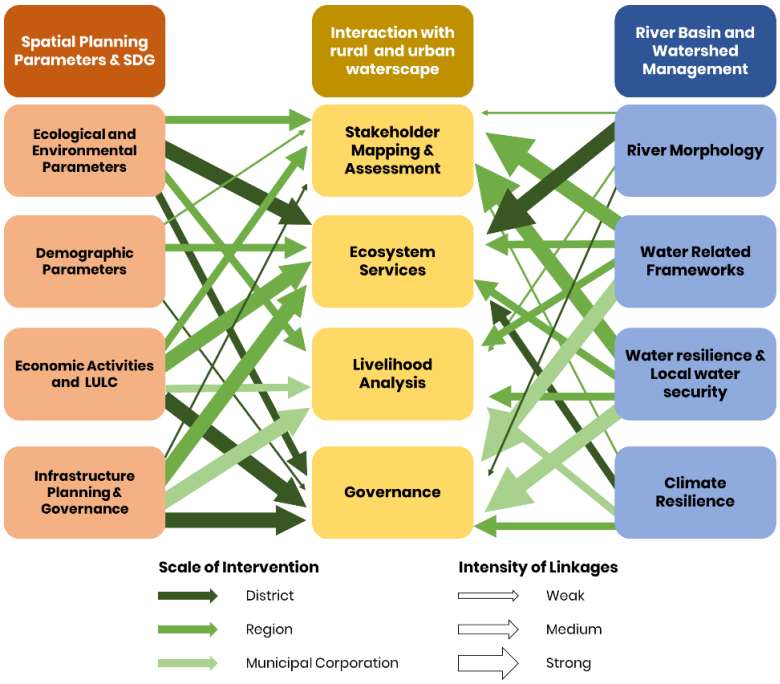
Conclusion

These strategies of the GRBMP are an integrated approach to the management of Ganga River Basin. Environmental protection, social equity, and economic development-not only a single individual action but an interlinked action form the main message from these strategies. The current plan will restore river health while supporting the life of local communities and build a sustainable model for river basin management.

2.9 Conceptual Framework

The conceptual framework for this thesis integrates 3 key dimensions: **Spatial planning parameters & SDG's, River basin & watershed management parameters and Political ecology.**

Figure 19 Conceptual framework



Source 31 Author

Spatial planning parameters & SDG'S: Captures how ecological, demographic, land use, infrastructure, resource allocation decisions should align with the Sustainable Development Goals & influence the river systems.

River basin & watershed management: This is the core component of the thesis, includes river & basin morphometry, water & river related frameworks, considers understanding the local water security & water resilience and integrates climate resilience.

Political ecology: Focuses on the flow of the river, Helps identify key stakeholders, their access to water, use of water and its availability. It addresses the access, control & the cultural & economic value of water, reveals the power dynamics & social relations in water management

Linkages & interactions: The coloured arrows indicate the scales of interventions and the size of the arrows indicate the intensity of linkages.

For example, *Economic Activities and LULC* from, and *Water Resilience & Local Water Security* from, both influence Livelihood Analysis in the centre. Together, they help us understand how land use and water access shape people's livelihood sources, such as agriculture, industrial activities etc in river-dependent areas.

So, the framework shows how planning and hydrology converge through people, guiding integrated river-sensitive strategies.

Based on the literature study & the conceptual framework below is a table of final parameters that are taken forward in this thesis and the scale of their intervention is marked.

Table 8 Parameters taken forward

Domain	Aspect	Parameter	Sub parameter	Indicator	Scale		
					District Level	Region	Mangaluru M.Corp
Climate Resilience	Ecology	Environmental resources (Abiotic)	Land & Water	- Geomorphological & soil feature - Surface water - Ground water			
		Biotic	Forest Cover & Biodiversity	Change in biodiversity			
	Climate	Climatic condition	Temperature & Rainfall trends	Change in climate			
		Hazard	Inland & Coastal	- Coastal erosion - Flood & Drought susceptibility			
Utility	Basic infrastructure	Water	Regional & Local level water security	- Water supply - Sewage - Stormwater - Water extraction & allocation - Waste water repurposing			
		Soil waste	Urban & Household level condition	- Waste collection - Handling & disposal			
		Transportation	Regional & Local connectivity	- Road network & Density			
		Industry	Types of industries	- Impact of industries on water			
	Built environment	Urban form	Settlement pattern & hierarchy	- LUCL - Urban centres - Change in density pattern			
			Land use classification & open spaces	Run-off intensity & infiltration			
		Housing & Built assets	Condition & Level of amenities	Level of surface water run-off during extreme precipitation			
Water Resilience	Health & Wellbeing	Governance & Access to social services	Local Governance Socio-economic profile Healthcare and Education facilities	- Responsibility & schemes - Literacy rate - WFPR - Sex ratio - Basic Social Structure			
Political Ecology	Stakeholder & their connect to Rivers	Political Ecology of Water & Urban Water	Stakeholder Assessment	- Identifying & categorizing the stakeholder			
			Stakeholder Mapping Local Water Security	- Identified concerns and interest of stakeholder - Resources/Strategies needed to align the interests of stakeholders			
		Livelihood Analysis	- Natural Capital - Human Capital - Physical Capital - Social Capital - Financial Capital	- Natural resources - Male & Female Literacy rate & WFPR - Access to water based on Social Construct (Rich vs Poor, Caste & Community, Gender based, economic groups) - Housing & Infrastructure - Social Infrastructure - Financial resources (Banks, People APL, Etc)			
	Ecology	Ecosystem Services	Provision	Agriculture, Fishing			
			Supporting	Biodiversity			
			Cultural	Recreational, Spiritual, Tourism			
Sustainability	SDG	1. Social development 2. Economic development 3. Environment Protection 4. Global partnerships & Governance	Direct - SDG **6, 10, 11, 13, 15 & 17**, Indirect - SDG **8 & 9**	Respective UN-SDG 2030 Indicators			

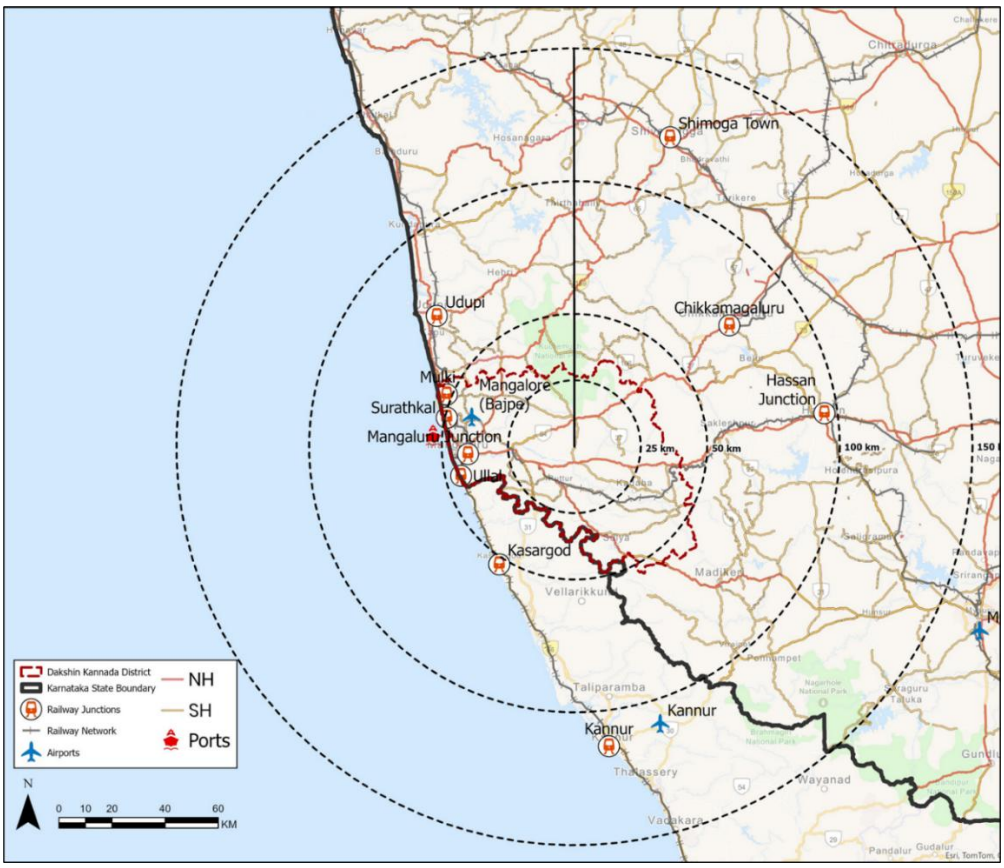
Source 32 Author

3. Regional Study

3.1 Regional Setting

3.1.1 Connectivity

Map 6 Connectivity to the region



Source 33 Generated by author

Road Connectivity: NH 66 connects Mangalore to Goa and Kerala along the west coast, NH 169 from Mangalore to Chikmangaluru via Karkala, SH 88 connects Mangalore to Madikeri and Mysore and SH 37: Bantwal to Belthangady and Charmadi Ghat.

Airports: Mangalore International Airport (IXE) & Kannur International Airport (Kerala)

Major Railway Junctions:

The major railway junctions include Mangalore Junction (Kankanadi), Ullal, Surathkal, and Mulki stations, Udupi, Kundapura Along the West Coast in Karnataka and Kannur & Kasaragod in Kerala, Chikkamangaluru, Shivamogga & Hassan Junctions

3.1.2 Climate Zone (As per Koppen's Classification)

The Koppen-Geiger climate classification has **5 categories.**

Mangalore falls under Group: A (Tropical Humid) climate classification

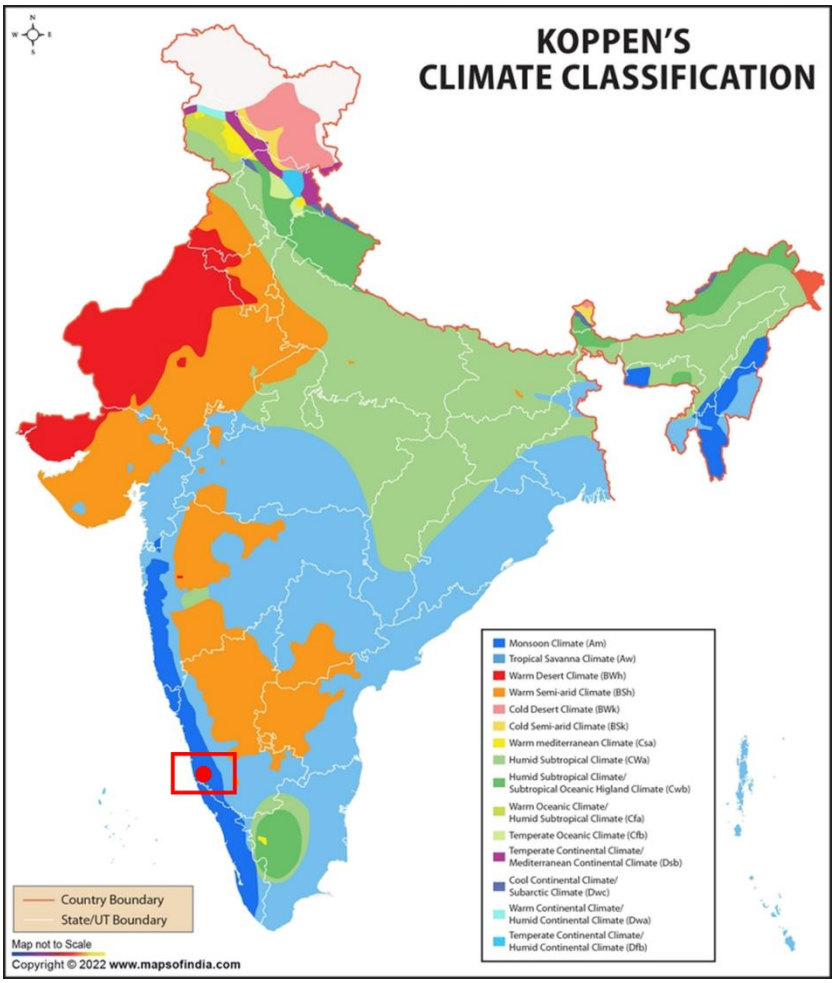
Type: Monsoon Climate, **Code:** Am

Key Characteristics:

The Annual rainfall is between **3,000–4,000 m**m June–September and has Distinct monsoon (wet) and post-monsoon (dry) periods. **Warm temperatures,** ranging between 24°C to 34°C year-round, and has **high humidity**

These characteristics is due to the location of Mangaluru, between the Arabian Sea coast on the west and the Western ghats on its east

Map 7 Dakshin Kannada located on Koppen's climate classification of India



Source 34 Koppen's climate classification

3.1.3 Biogeographic Zone

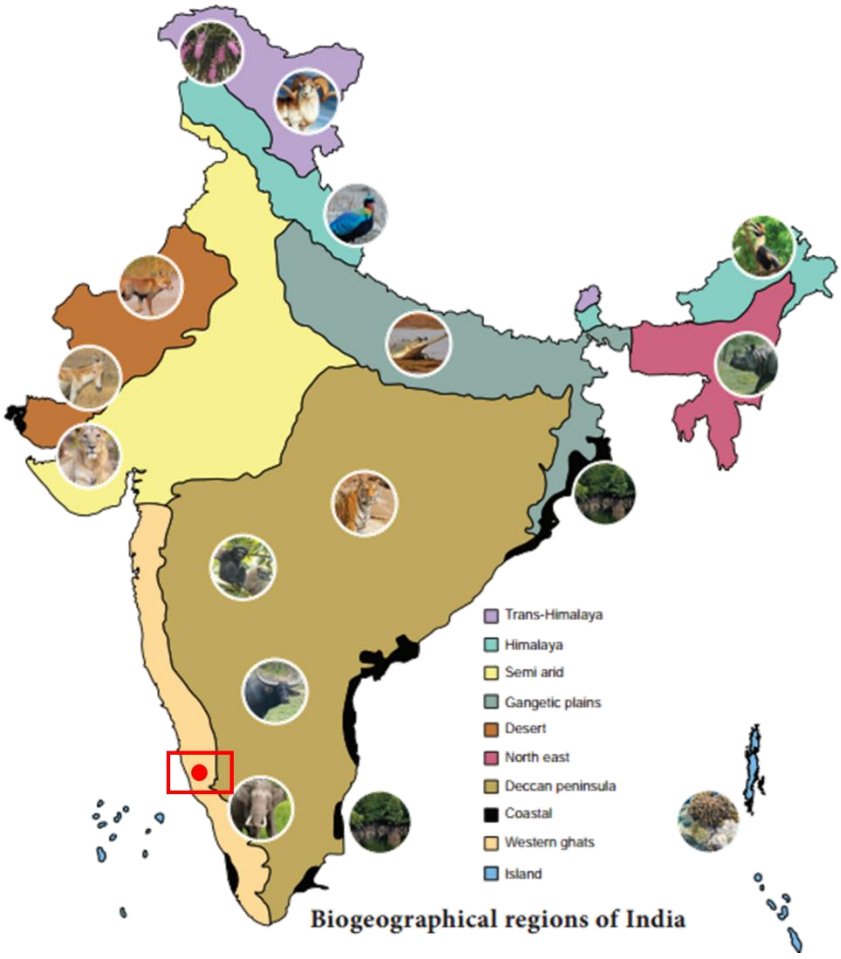
Biogeographic Zone India is divided into 10 biogeographic zones and 27 provinces.

Mangaluru falls within the **Western Ghats Zone**

Fall in the Subcategory of **Malabar Coast**

The key Characteristics are that it is a **biodiversity hotspot** with **tropical evergreen forests, high rainfall, fertile soils,** and **rich aquatic and terrestrial ecosystems** shaped by **rivers and estuaries.**

Map 8 Dakshin Kannada located on Biogeographic zone of India



Source 35 India Flora Online

3.1.4 Agro Climatic Zone

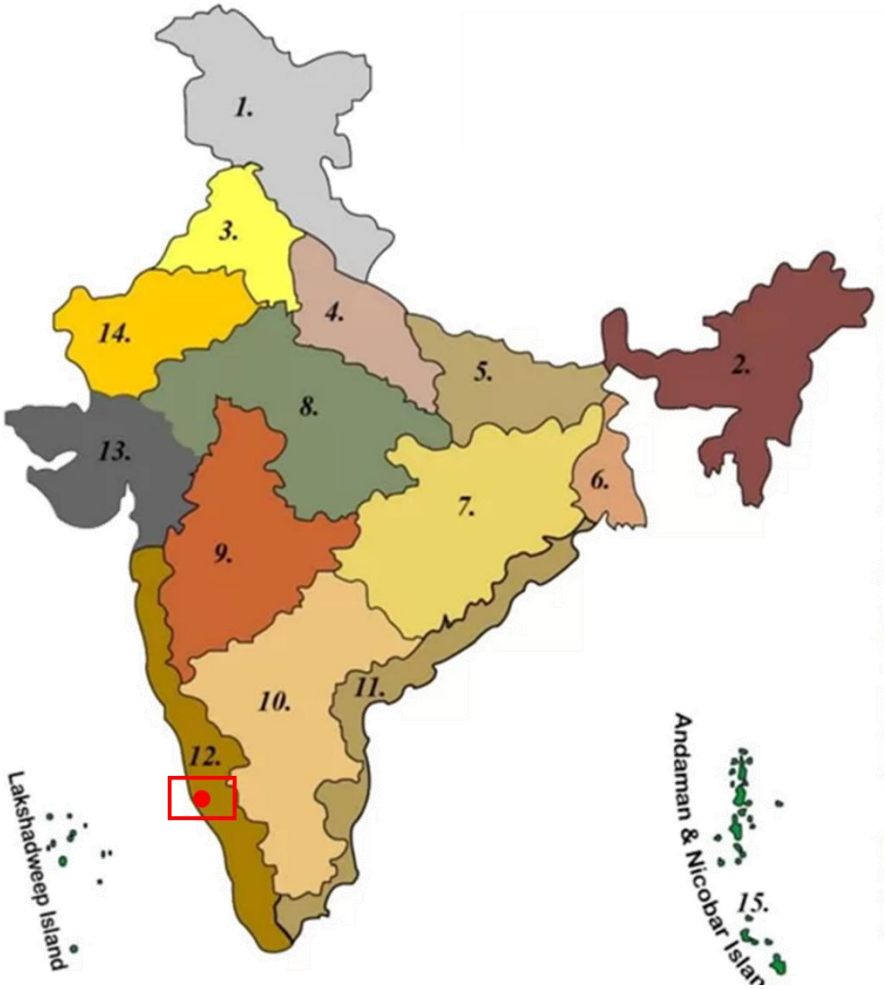
India is divided into 15 agro-climatic zones, and Mangaluru falls in **Coastal and Western Ghats Region (XII)Climate:** Hot and humid.

1. **Average Annual Rainfall:** 250–400 cm.
2. **Crops:** Rice, coconut, Arecanut, cashew, black pepper, ginger, cardamom, and horticultural crops like banana, jackfruit, and mango.
3. **Special Features:** Known for extensive plantations of **coconut and Arecanut,** along with **spices and cashew.**

Problems:

The region has high soil erosion due to heavy rainfall and undulating terrain, Limited groundwater resources in lateritic soils and salinity intrusion in coastal areas affecting agriculture.

Map 9 Dakshin Kannada located on the Agro-climate zones of India



Source 36 Geography4u

3.1.5 Champion & Seth Forest Classification

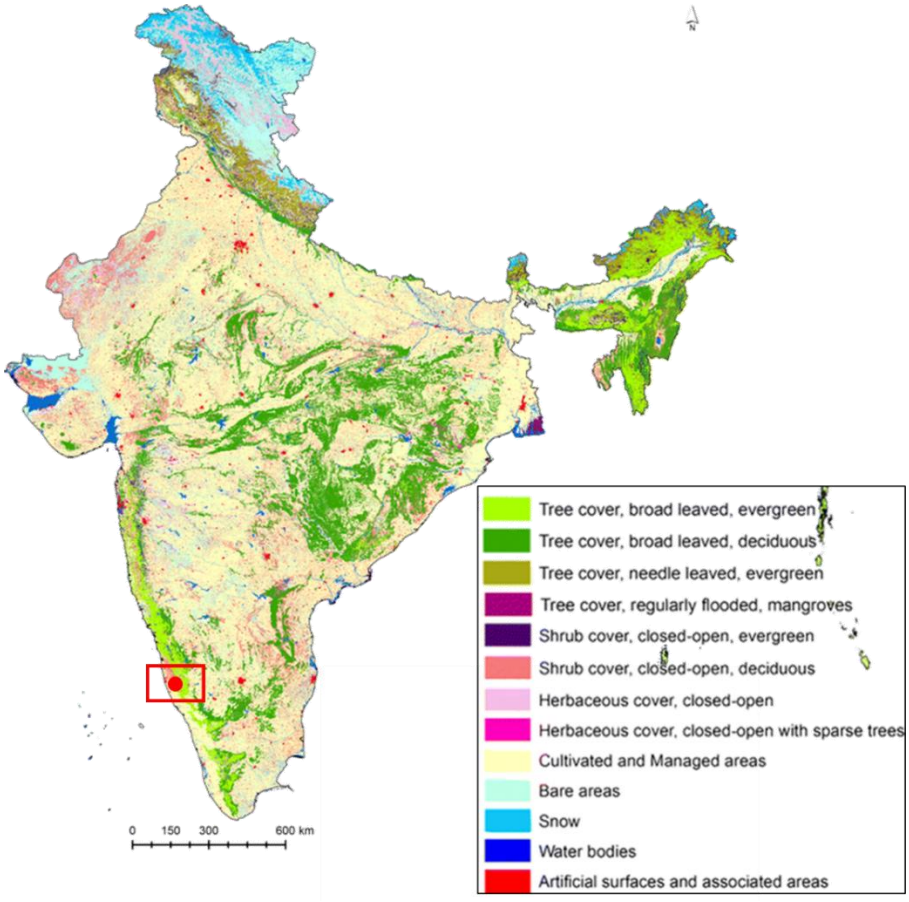
Forests are classified into **6 major groups** based on climatic factors, which are further divided into **16 type groups** based on temperature and moisture conditions. Dakshin Kannada district falls under **Group 1A -** Tropical Wet Evergreen Forests and Group 2A - Tropical Semi-Evergreen Forests.

Local sub-types found: West Coast Tropical Evergreen Forests (1A/C4) - Southern Hill Top Tropical Evergreen Forests (1A/C3) & West Coast Semi- Evergreen Forests (2A/C2)

The forests range from mangrove and coastal vegetation in lowlands to semi-evergreen forests in the hinterlands, with key species including **teak, rosewood, ebony, mangroves, and jackfruit trees.**

The area supports diverse wildlife, including species like black panther**, lion-tailed macaque, slender loris, and various birds** like **Malabar pied hornbill and white-bellied sea eagle.**

Map 10 Dakshin Kannada located on the Champion & Seth's forest Classification map of India



Source 37 Forest survey of India

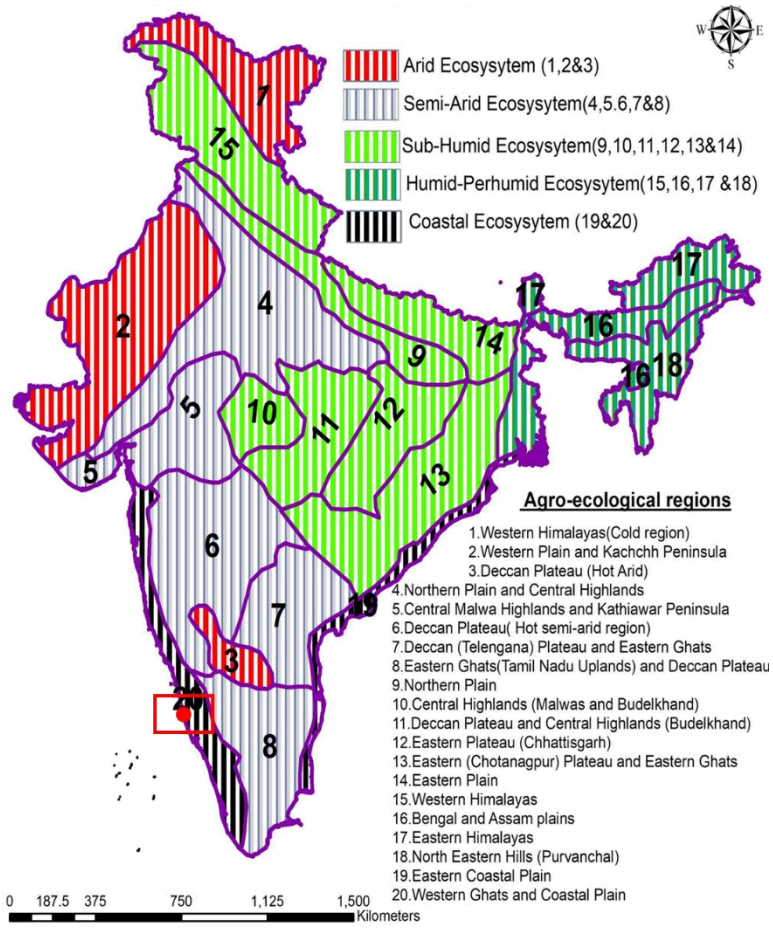
3.1.6 Agro-ecological zone

The Agro Ecological Zone classification under the National Bureau of Soil Survey & Land Use Planning has 20 zones

Dakshin Kannada falls in the Coastal ecosystem, and the Agro-ecological zone is Western ghats & coastal plains.

The Subregion is identified as hot humid to per humid, Soil type is shallow and medium, Clayey to Loamy acidic coastal alluvium, Available water Capacity (AWC) is Low to Medium and the Length of Growing Period (LGP): 240-270 days indicating that it is feasible for double cropping.

Figure 20Daskhin Kannada located on the Agro-Ecological zones of India

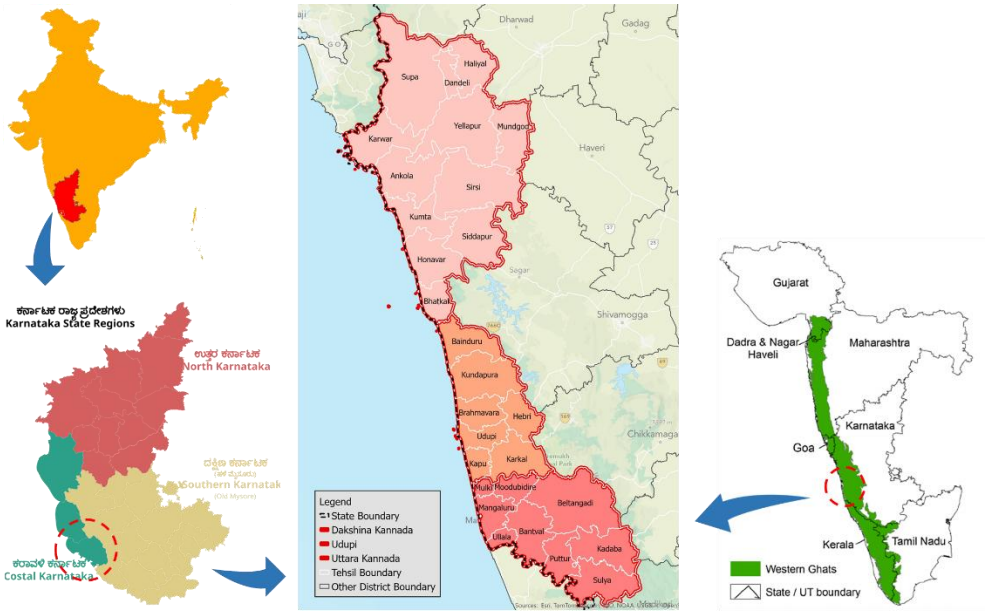


Source 38 NBSSLUP

3.1.7 Physiographic Region

Dakshin Kannada District is part of the Western Ghats & Larger Karavali Region (Coastal) of Karnataka. The Geographical Area is 4859 Sq.km

Map 11 Physiographic region of Karnataka

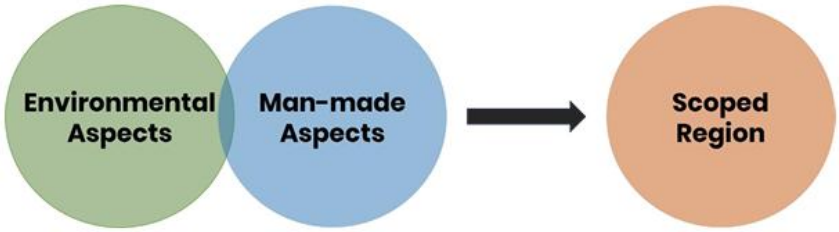


Source 39 Envis

3.2 Scoping of Region

To establish the final scoped region for the thesis, both environmental aspects and man-made aspects are considered. This comprehensive approach ensures that all relevant elements are integrated into the scoping process, ultimately leading to a well-informed and balanced evaluation of the region.

Figure 21 Aspects considered for scoping of region



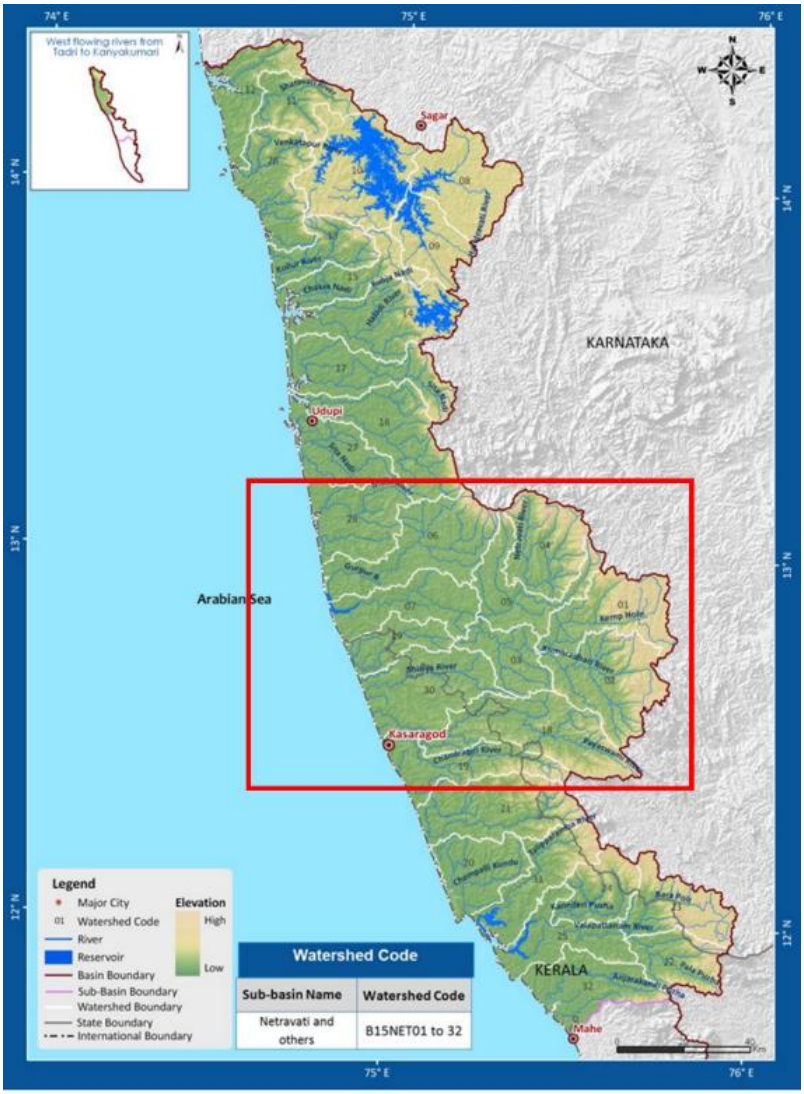
Source 40 Author

3.2.1 Scoping of Environmental Region

The Environmental aspects considered in the scoping process encompasses **Water, Land and the Biotic aspects**. The Water environment focuses on **sub-basins, sub-watersheds, rivers,** ensuring the hydrological framework is accurately represented. The Land environment includes **contours, elevation, slope, Geology, Geomorphology, Soil, Faults, and lineaments**, which are essential for understanding terrain characteristics and geological stability. Additionally, Biotic aspects such as forest area, forest types, and biodiversity hotspots are incorporated to highlight the ecological significance of the region.

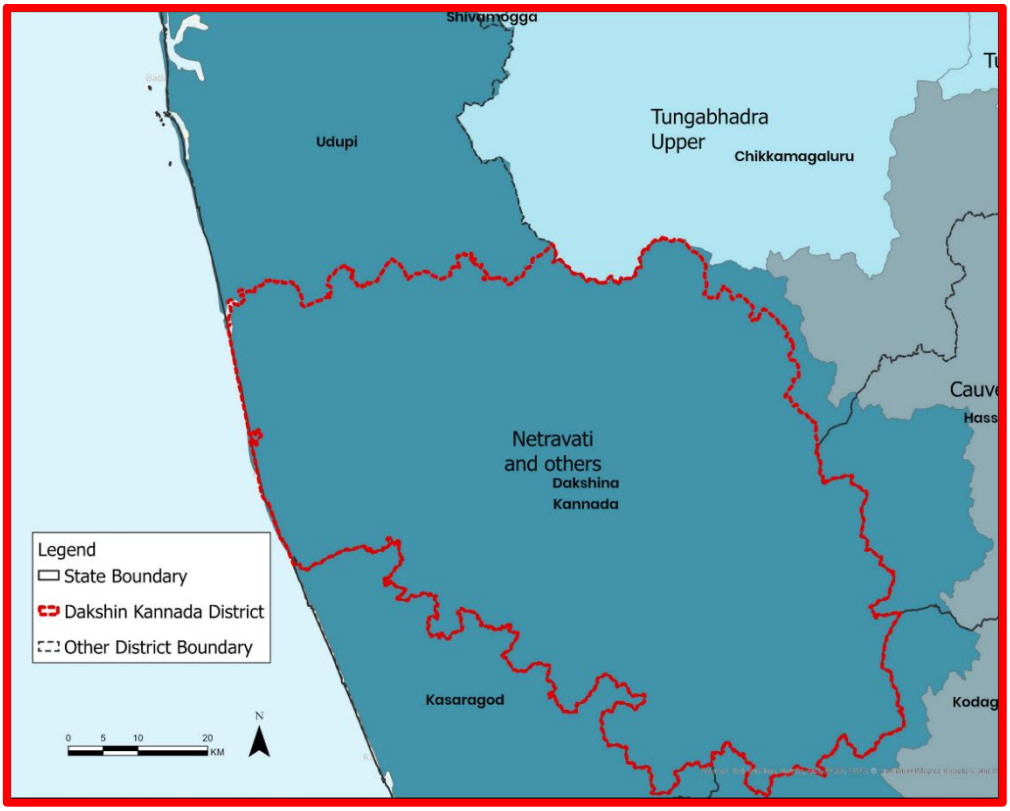
3.2.2 Water Environment

Map 12 Netravati & the others Sub-basin of Tadri to Kanyakumari River basin



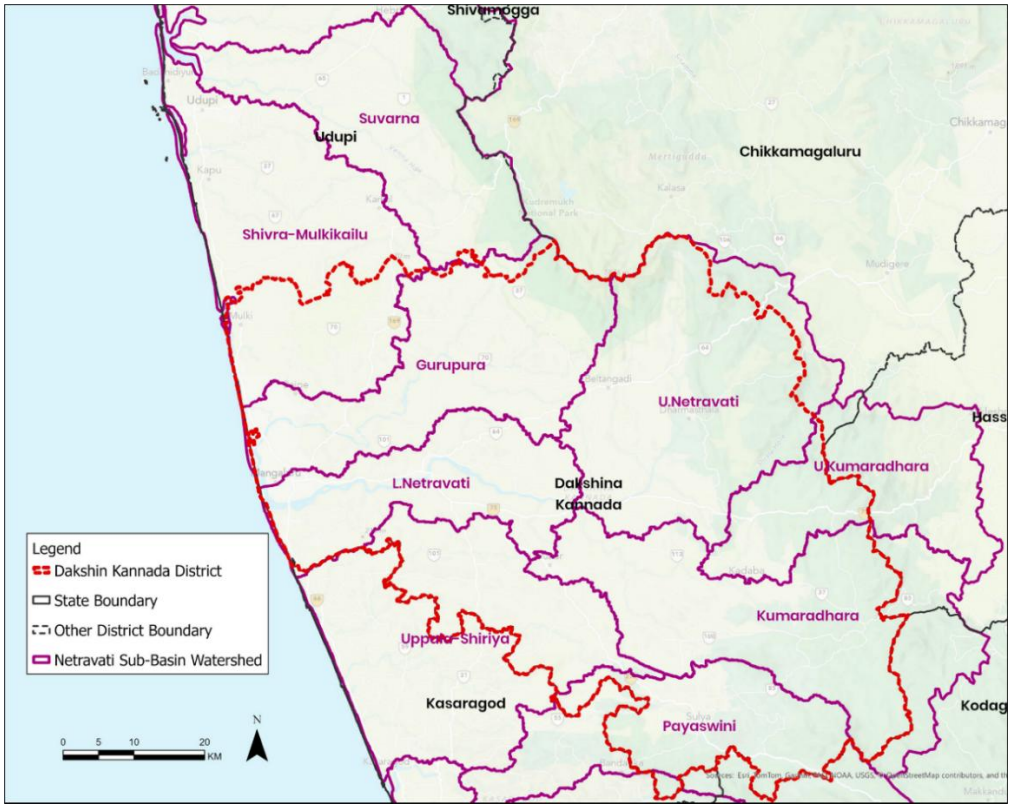
Source 41 India WRIS

Map 13 Dakshin Kannada District located on Netravati & the others Sub-basin



Source 42 Generated by Author

Map 14 Dakshin Kannada district & its Watershed

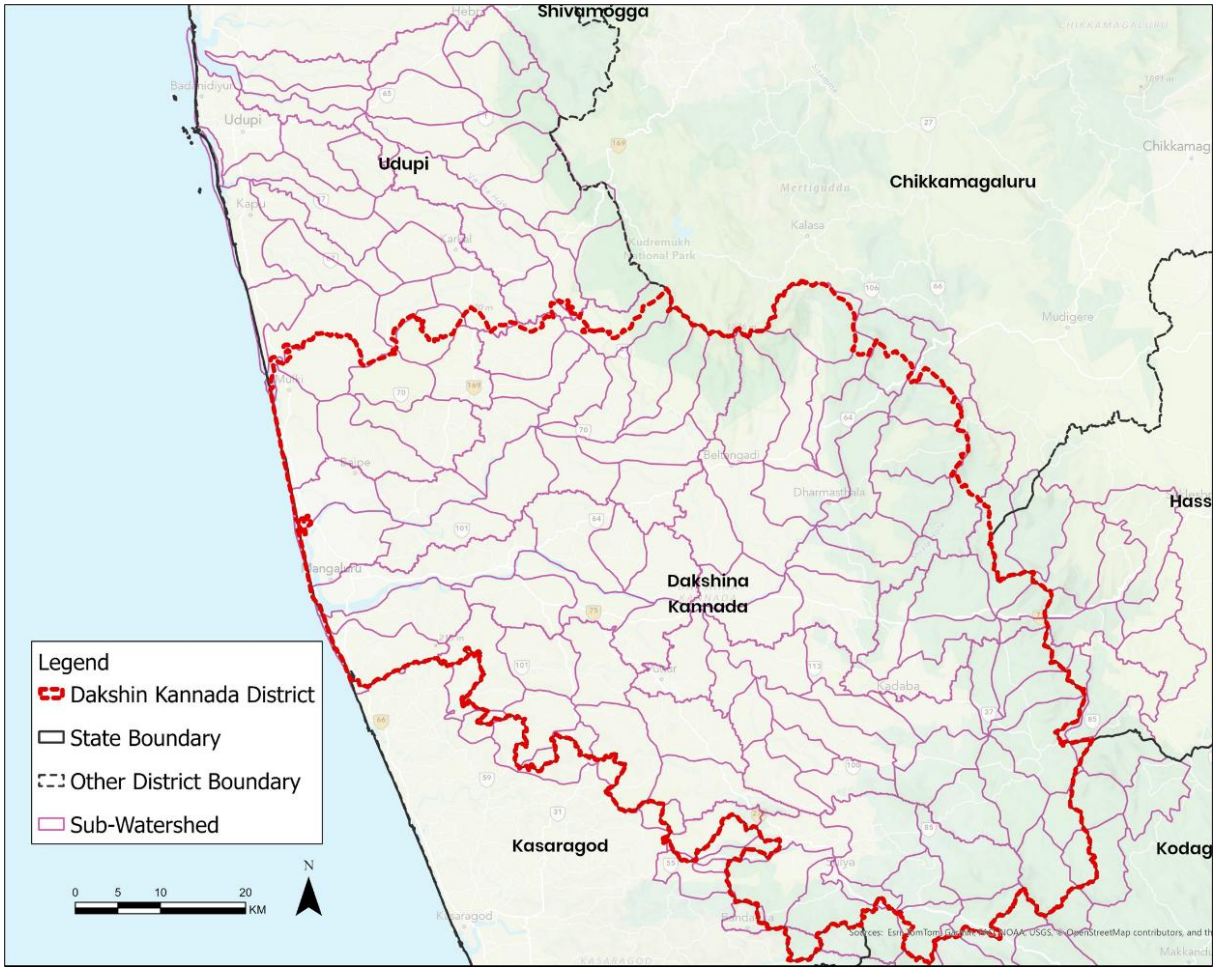


Source 43 Generated by Author

Basins & Watersheds

Dakshin Kannada district lies entirely on the Netravati & others sub-basin of the larger Tari to Kanyakumari River basin. Upper & Lower Netravati, Upper Kumaradhara & Kumaradhara, Gurupura, Uppala-Shiriya, Payaswini and Shivra-Mulkikailu are the watersheds that contain the district. Further the sub-watersheds are considered for the purpose of scoping the environmental region.

Map 15 Sub-watersheds encompassing the Dakshin Kannada district



Source 44 Generated by author using SLUSI sub-watersheds

Rivers & waterbodies

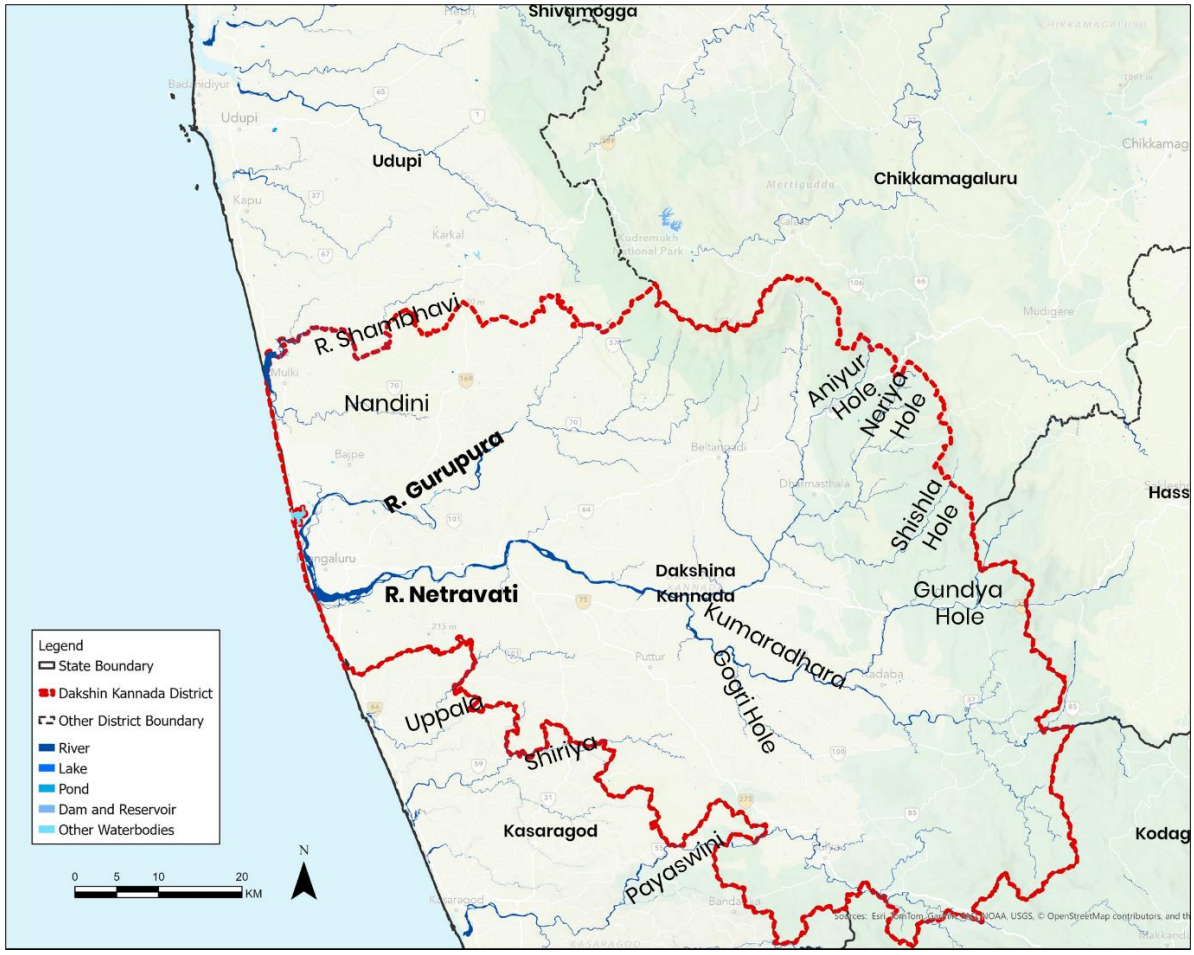
The district is drained by the River Netravati & its tributary- Kumaradhara both originating from the Western ghats from the west of the district into the Arabian sea.

Gurupura River originates from the western ghats in the Udupi district and flows through Dakshin Kannada district from the north western part into the Arabian sea.

The north-eastern edge of the district is drained by Shambhavi & Nandini Rivers that are a part of the Shivra & Mulkikailu watershed shared between the Udupi & Dakshin Kannada Districts.

South western parts of the district are drained by Uppala, Shiriya & Payaswini rivers that flows into the Arabian sea via Kasaragod district in Kerala.

Map 16 Rivers & Waterbodies of Dakshin Kannada District



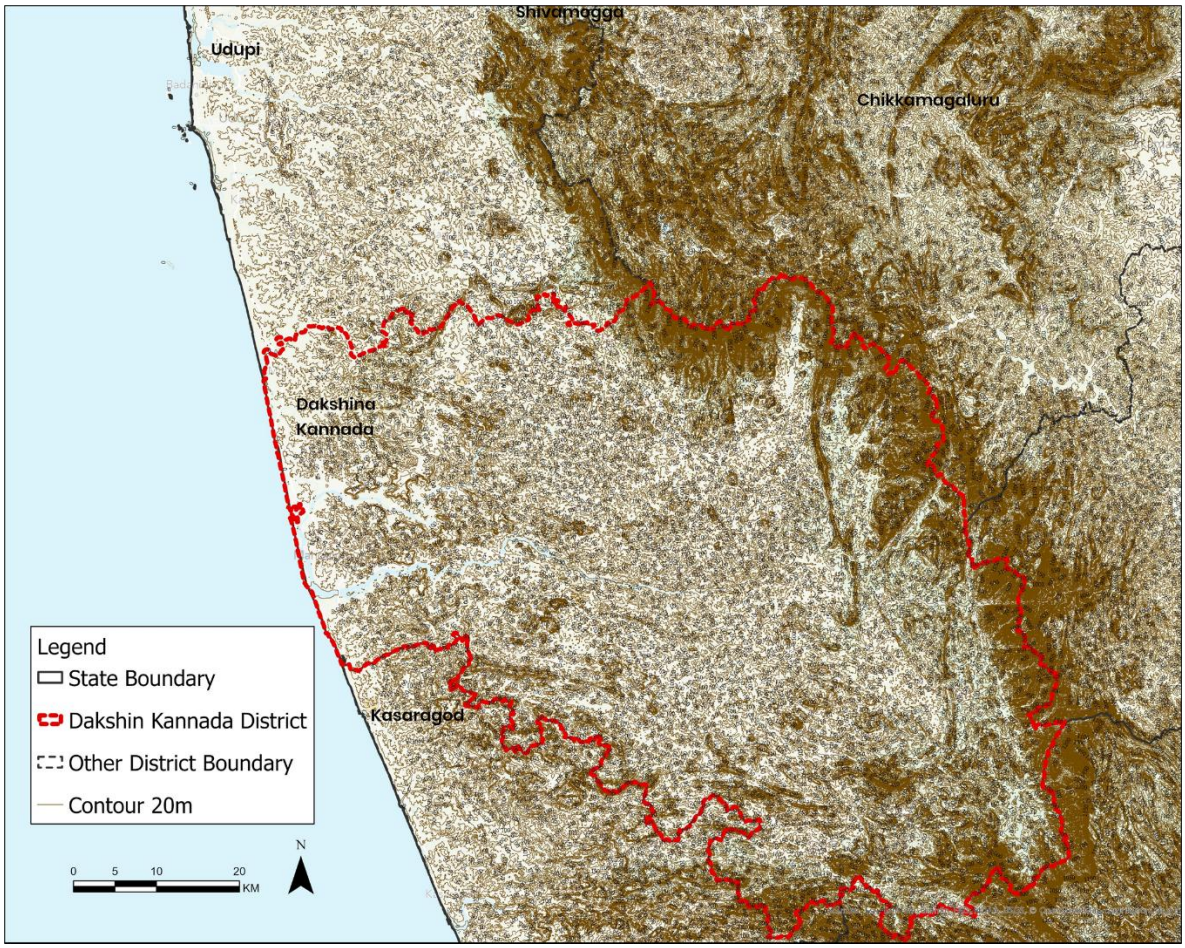
Source 45 Generate by Author using SoI Topo-sheets

3.2.3 Land Environment

Contours

Diverse topography ranging from coastal plains to undulating terrains of the western ghats. Western coastal edge: Relatively flat terrain with elevation up to 50m ASL featuring broad sandy beaches, Dense River networks & estuaries. The Mid-elevation Zone falls between 50-500m ASL indicating slightly undulating terrain and High elevation zone falls between 500-1000 ASL where the terrain enters the Western ghats.

Map 17 Contour

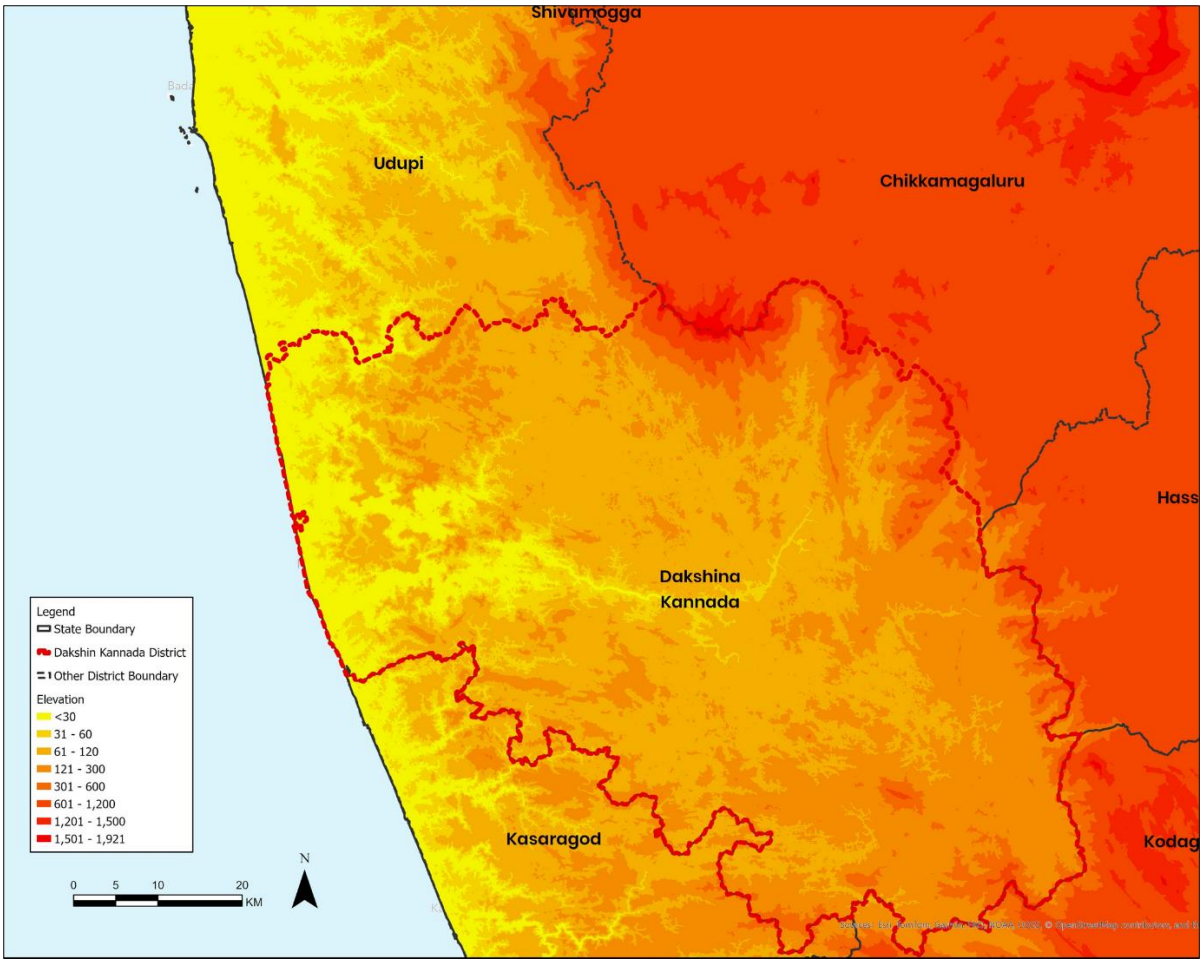


Source 46 Generated by Author

Elevation

The elevation of the district includes **Coastal lowlands, Mid elevation zone** with undulating terraces suitable for crops like areca nuts, Paddy, coconut, **High lands** mark the western ghats falling between 500-1894 ASL, featuring the 3rd highest peak of Karnataka which is the Kudremukh Peak.

Map 18 Elevation

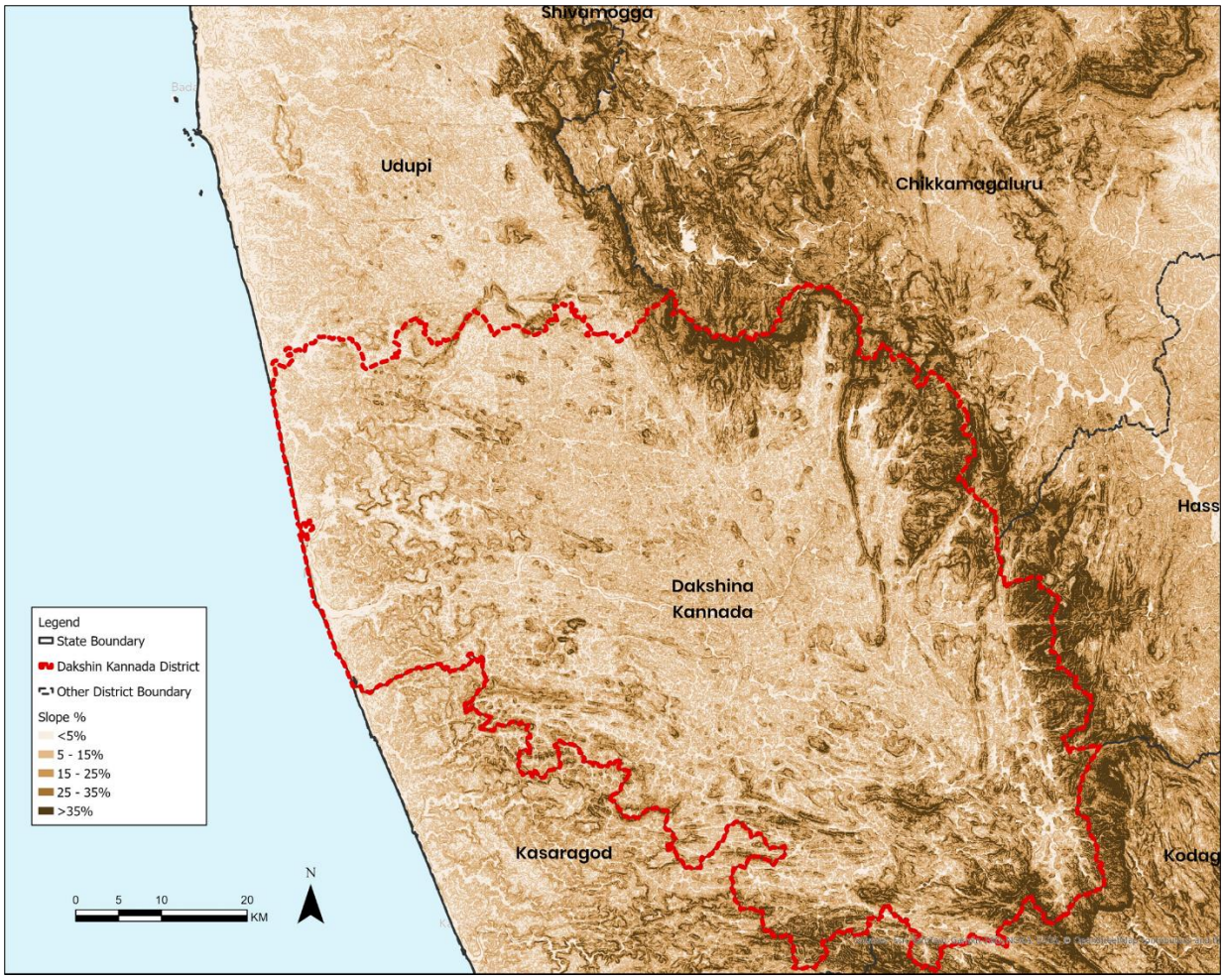


Source 47 Generated by Author

Slope

The lower elevations in the eastern part of the Dakshin Kannada district feature slopes of up to 25° which mark the coastal plains, Making them highly suitable for human settlement. The central part of the district has steeper slopes up to 35° marking the undulating terrain, and the western edge of the district has slope greater than 35° marking the steeper western ghats.

Map 19 Slope

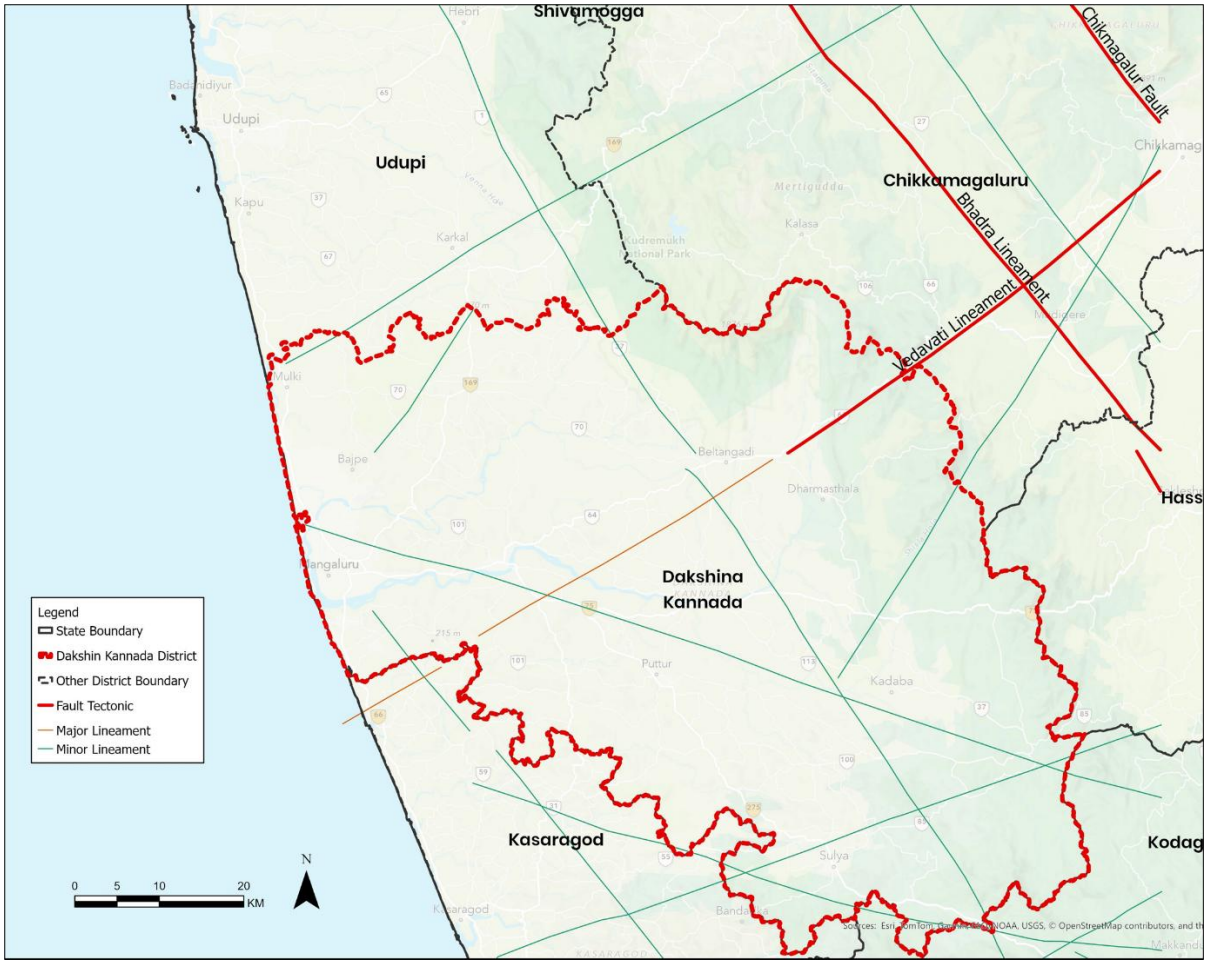


Source 48 Generated by the Author

Faults and Lineaments

The district has several Faults & Lineaments. A tectonic fault in the western ghats, 1 major fault & numerous minor faults, indicating geological instability and falls in the **seismic zone III**

Map 20 Faults & Lineaments



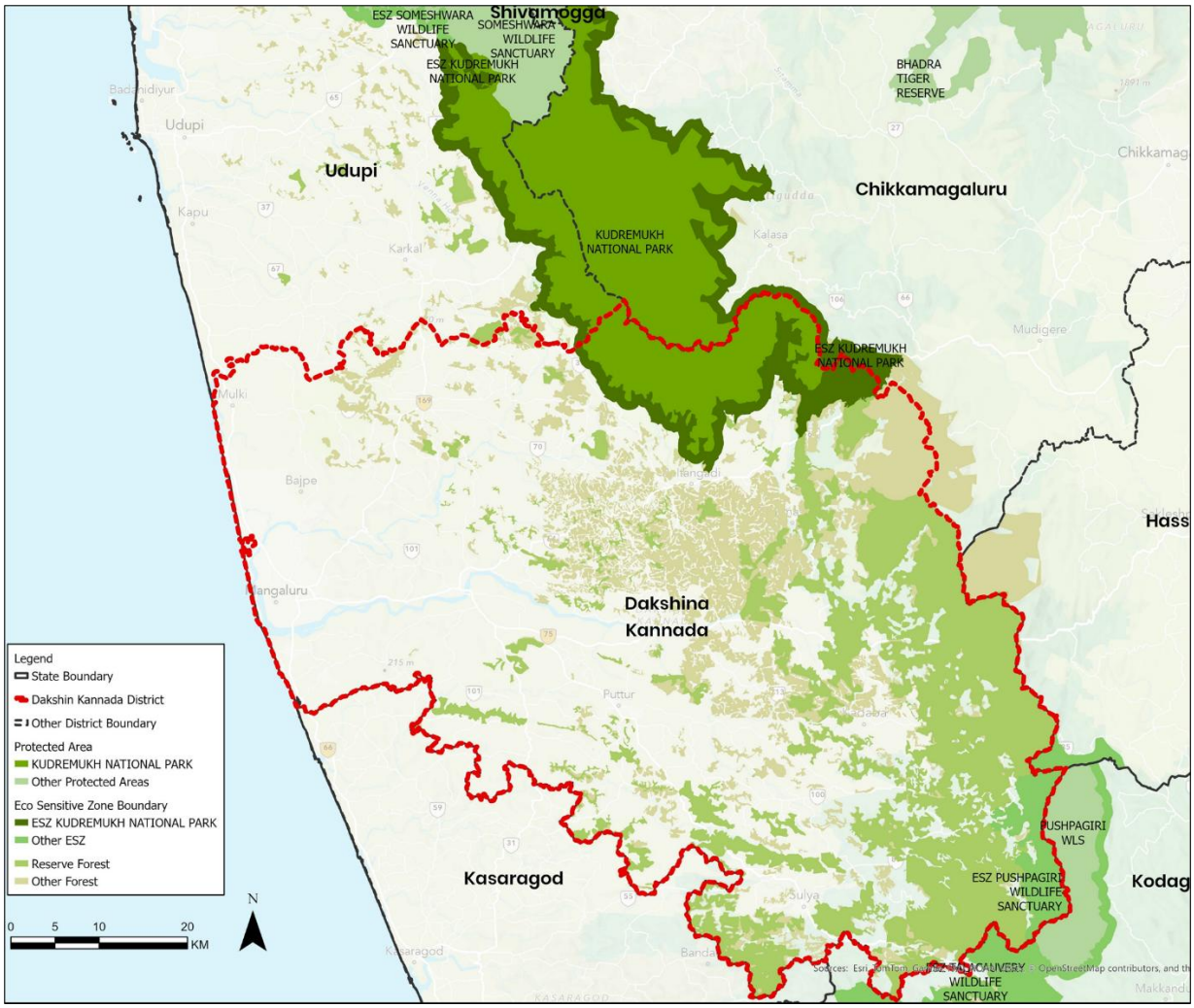
Source 49 Bhukosh

3.2.4 Biotic Environment

Forest

46% of the district is under forest cover, Reserve Forest constitutes the majority of the forest area, and a part of Kudremukh National Park a Biodiversity Hotspot continues into Udupi District.

Map 21 Forest Cover

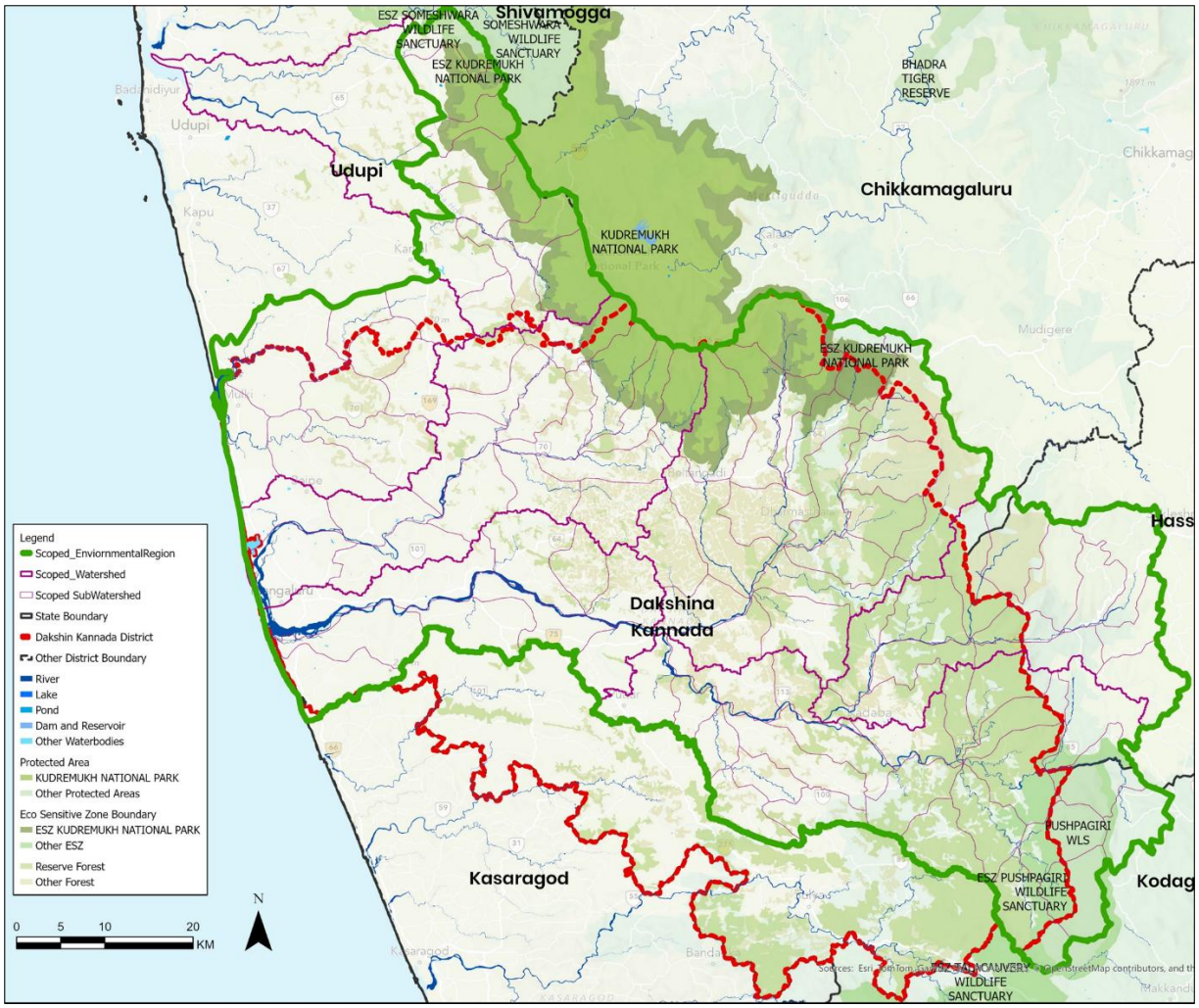


Source 50 SoI toposheet & KGIS

3.2.5 Scoped environmental region

The scoped environmental region comprises of the Sub watersheds of the Gurupura, Netravati and Shambhavi River, that takes care of the Land related aspects and part of Kudremukh National Park and its ESZ divided by the water divide at an elevation of 1850 m ASL.

Map 22 Scoped Environmental Region



Source 51 Generated by Author

3.2.6 Scoping of Man-made region

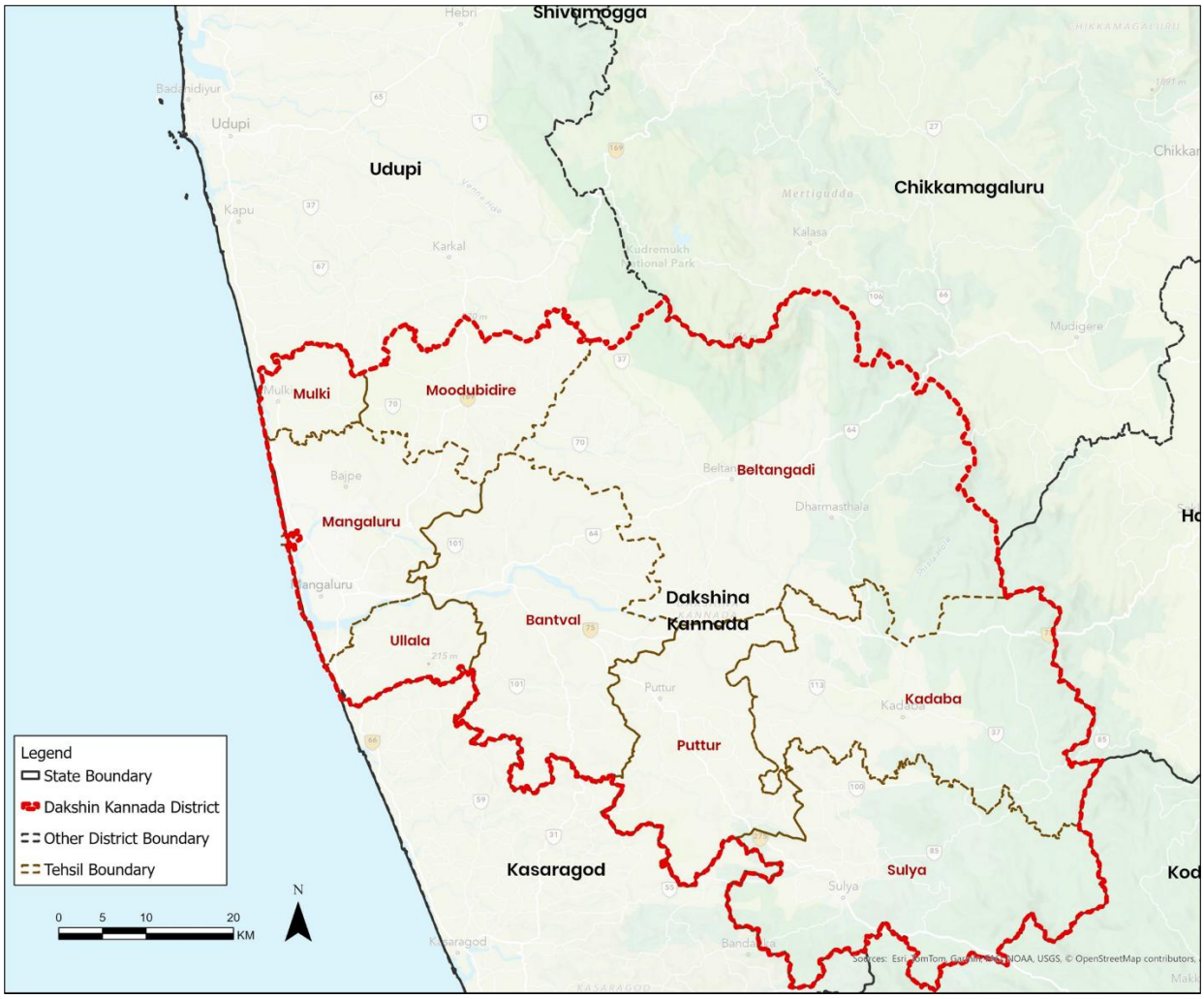
As part of scoping the man-made region, the aspects considered include **administrative boundaries, total & urban population, road networks, tourism network & industries.**

Administrative boundary

The Tehsil boundary & village boundary are considered as part of administrative areas. The district has 9 tehsils – Mulki, Mangaluru, Ullala, Mudabidri, Beltangady, Bantwal, Puttur, Kadaba, & Sulya.

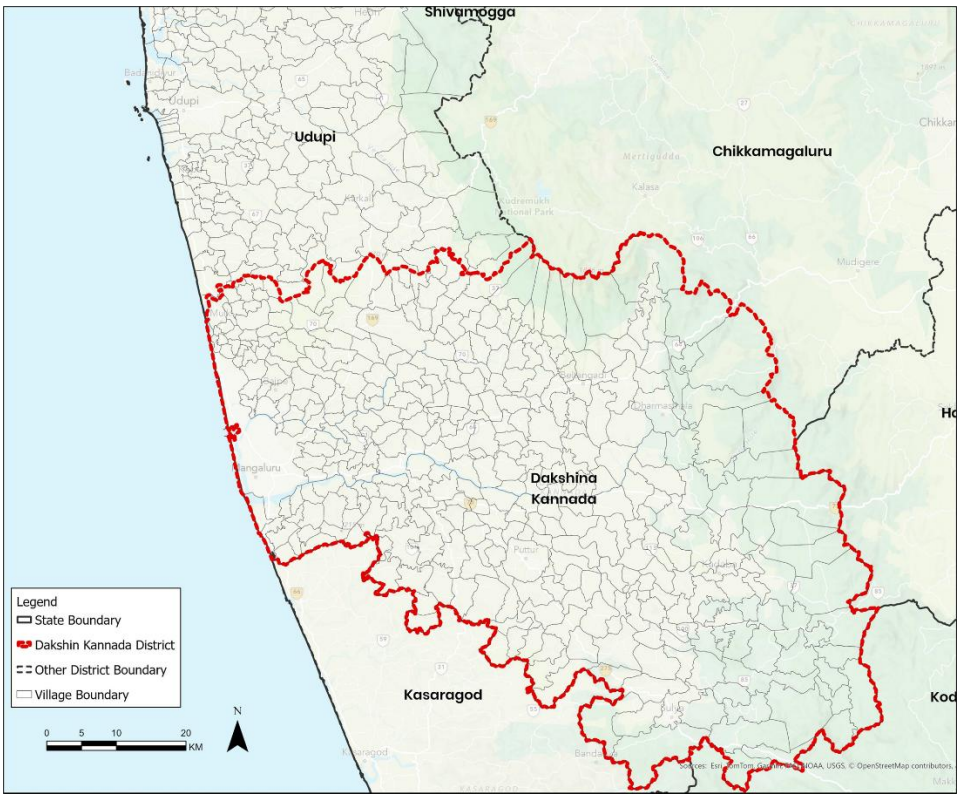
Additionally, the Mangaluru Planning Area & Municipal Corporation Boundary are considered. The planning area boundary that extends along the entire coast of the district.

Map 23 Tehsil Boundary of Dakshin Kannada District



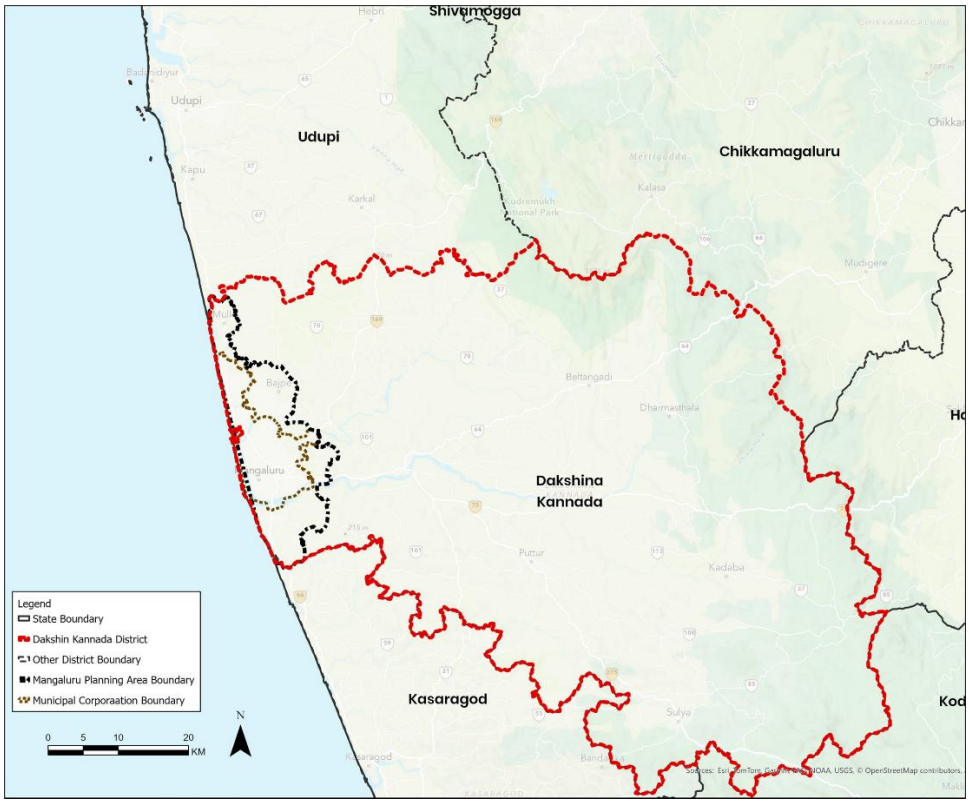
Source 52 KGIS

Map 24 Village boundary



Source 53 KGIS

Map 25 Mangaluru Planning Area & Municipal Corporation Boundary

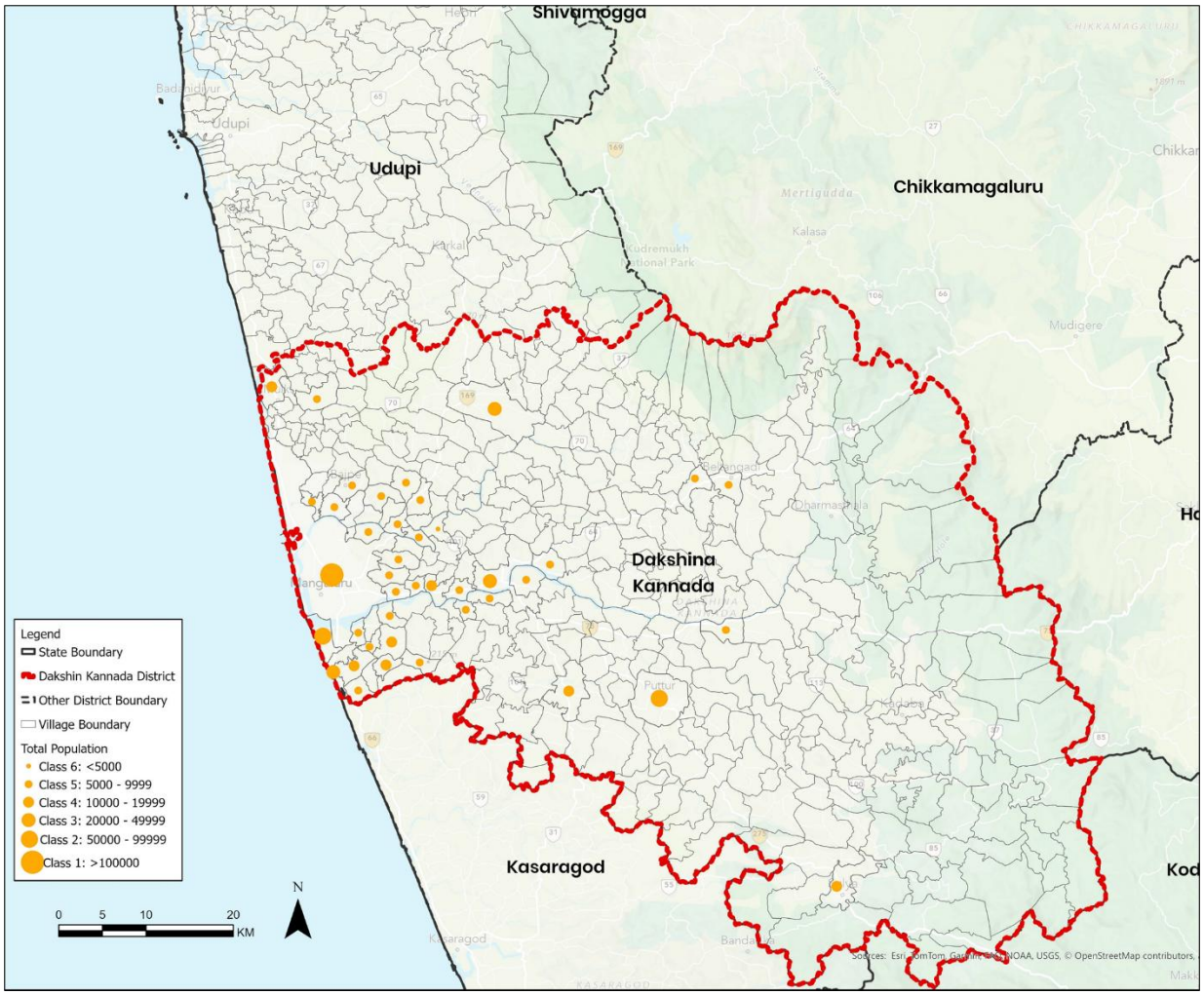


Source 54 Mangaluru Urban Development Authority & Mangaluru M. Corp

Demographic aspects

The **Total Population** of the district is 20,89,649, predominantly rural in nature, with only 29% of its population in urban areas, distributed among 8 tehsils.

Map 26 Urban Centres in Dakshin Kannada District

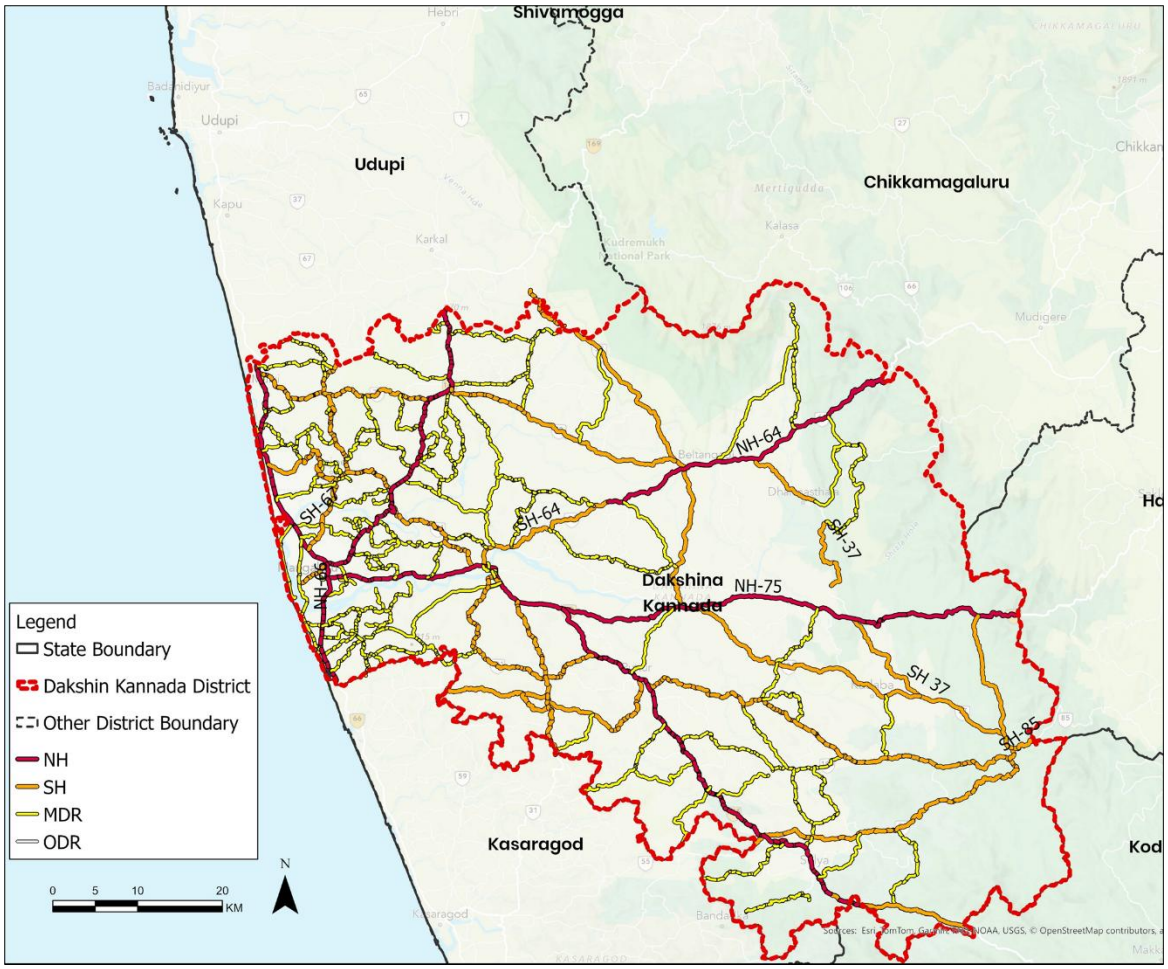


Source 55 Generated by Author based on Census of India 2011

Road Network

The district's road network plays a critical role in both the movement of goods and services. Major roads network considered are NH, SH, MDR, and ODR. NH 64 connects Dakshin Kannada to Chikkamangaluru District, NH 75 connects to Hassan district on the western edge, NH 66 runs along the coast and connect the District to Goa, SH 64 connects NH 75 & NH 64 within the district, NH 109 connects to Udupi in the North and NH 275 connects to Kodagu District via Madikeri.

Map 27 Road Network of Dakshin Kannada District

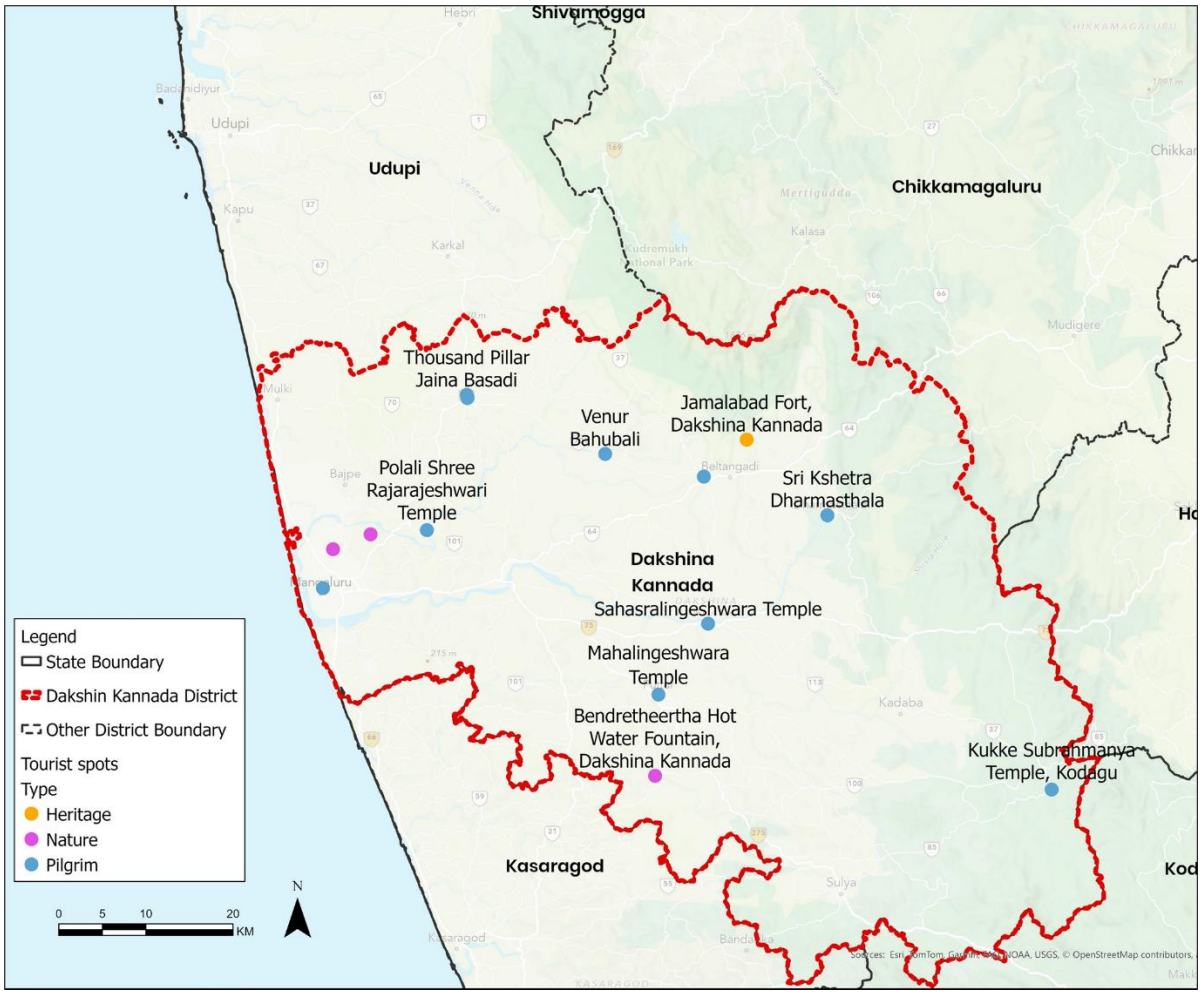


Source 56 KGIS

Tourism

The district is known for Pilgrim & Nature tourism, with Major Pilgrim sites such as Dharmasthala, Kukke Subramanya Temples located in the western ghats & various other pilgrim sites in the Puttur, Beltangady, Mudabidri tehsils. The Nature tourism is concentrated along the coast.

Map 28 Tourist locations in the district

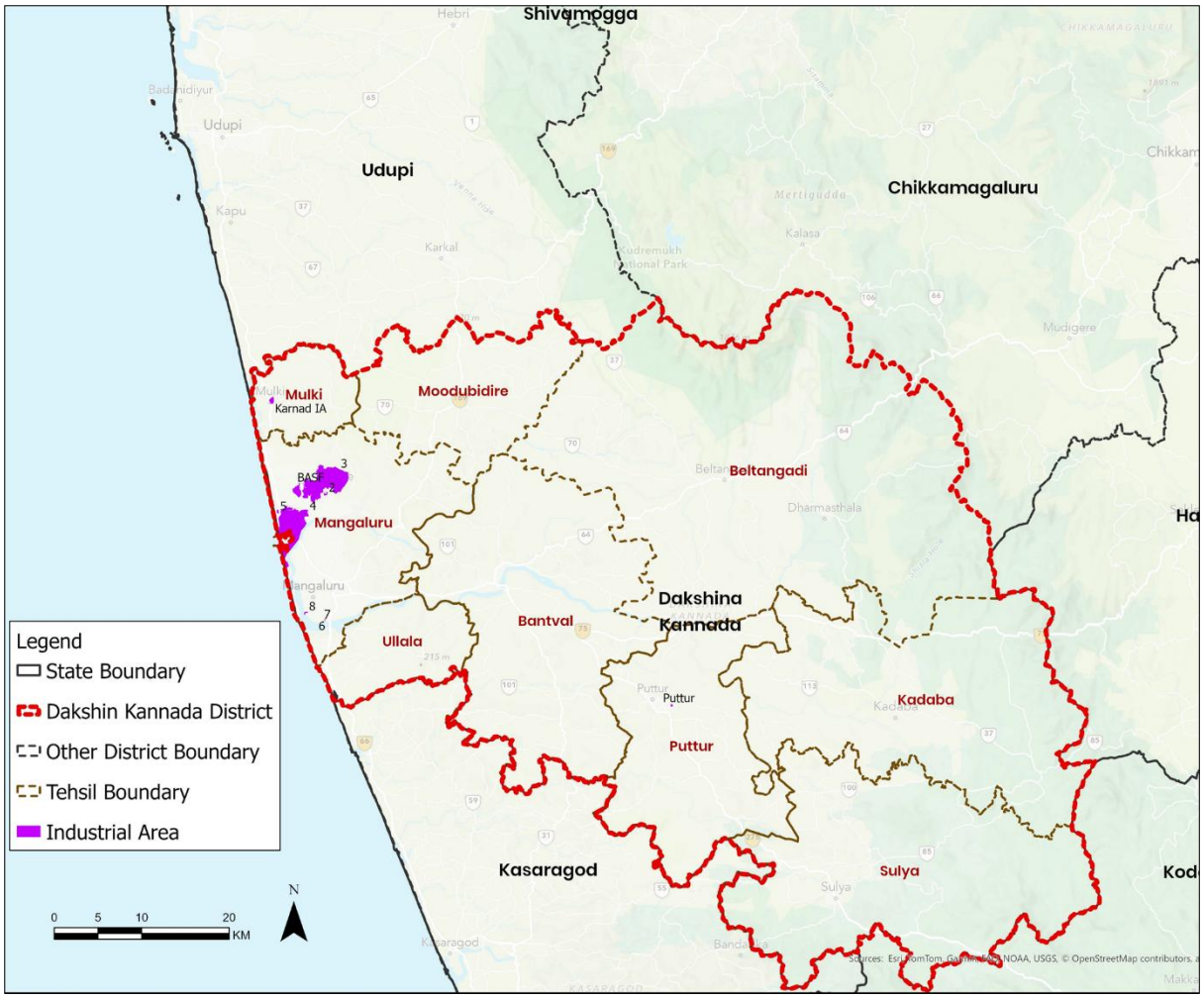


Source 57 KGIS

Industries

Industries are concentrated in the Mangalore, Mulki & Mudabidri Tehsils, includes major industries like Mangalore Refineries & Petrochemical Limited, BASF & Baikampady Industrial area which is identified as Critically polluted Industrial Area with CEPI Score above 70 by CPCB in 2018

Map 29 Industries



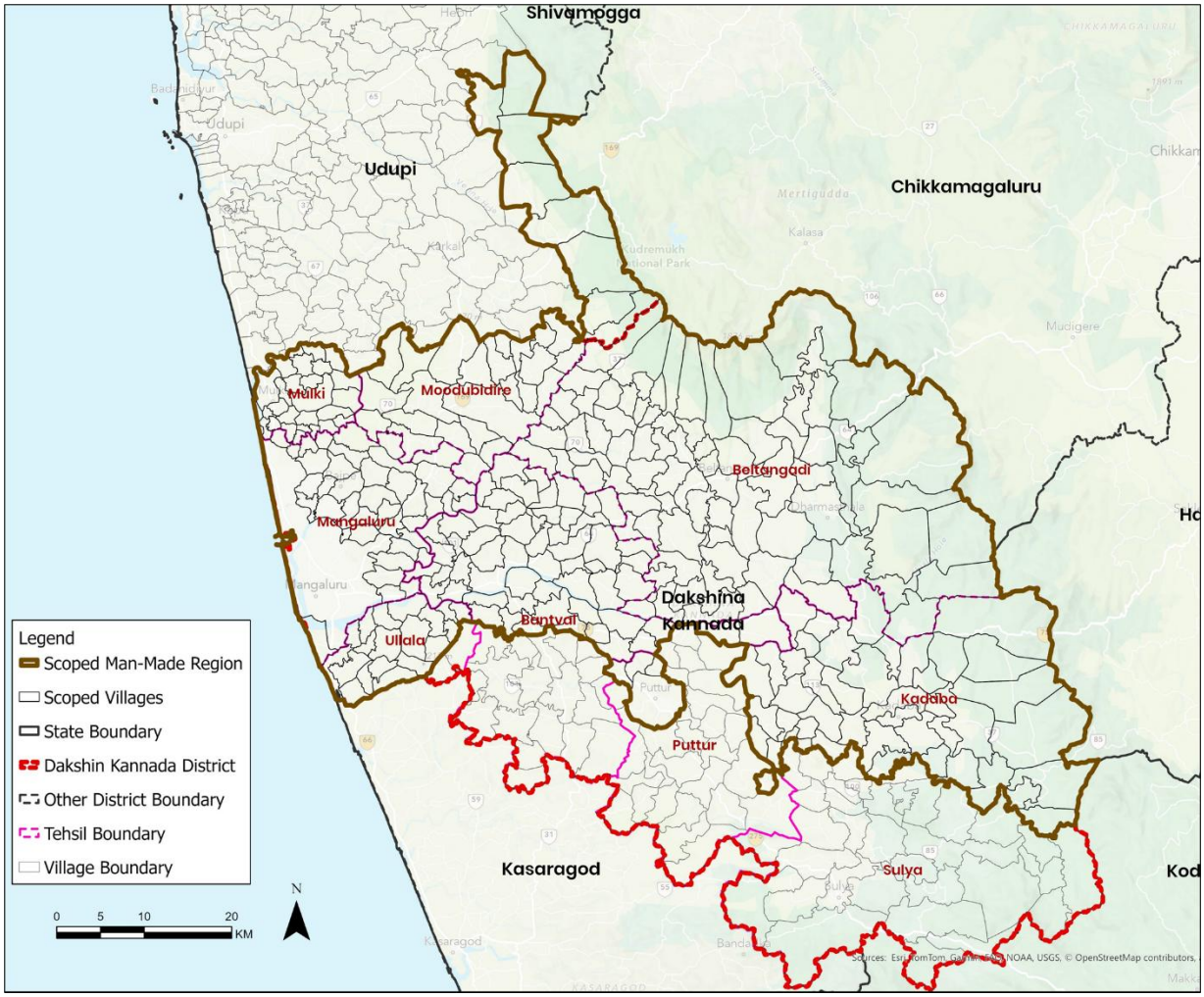
Source 58 KIADB

3.2.7 Scoped Man-made Region

Comprises the villages that encompass the Urban centres, tourism network, Industries.

Additionally, the villages along the ESZ of Kudremukh National Park have also been considered, which extends the man-made region into the Udupi District.

Map 30 Scoped Man-made region



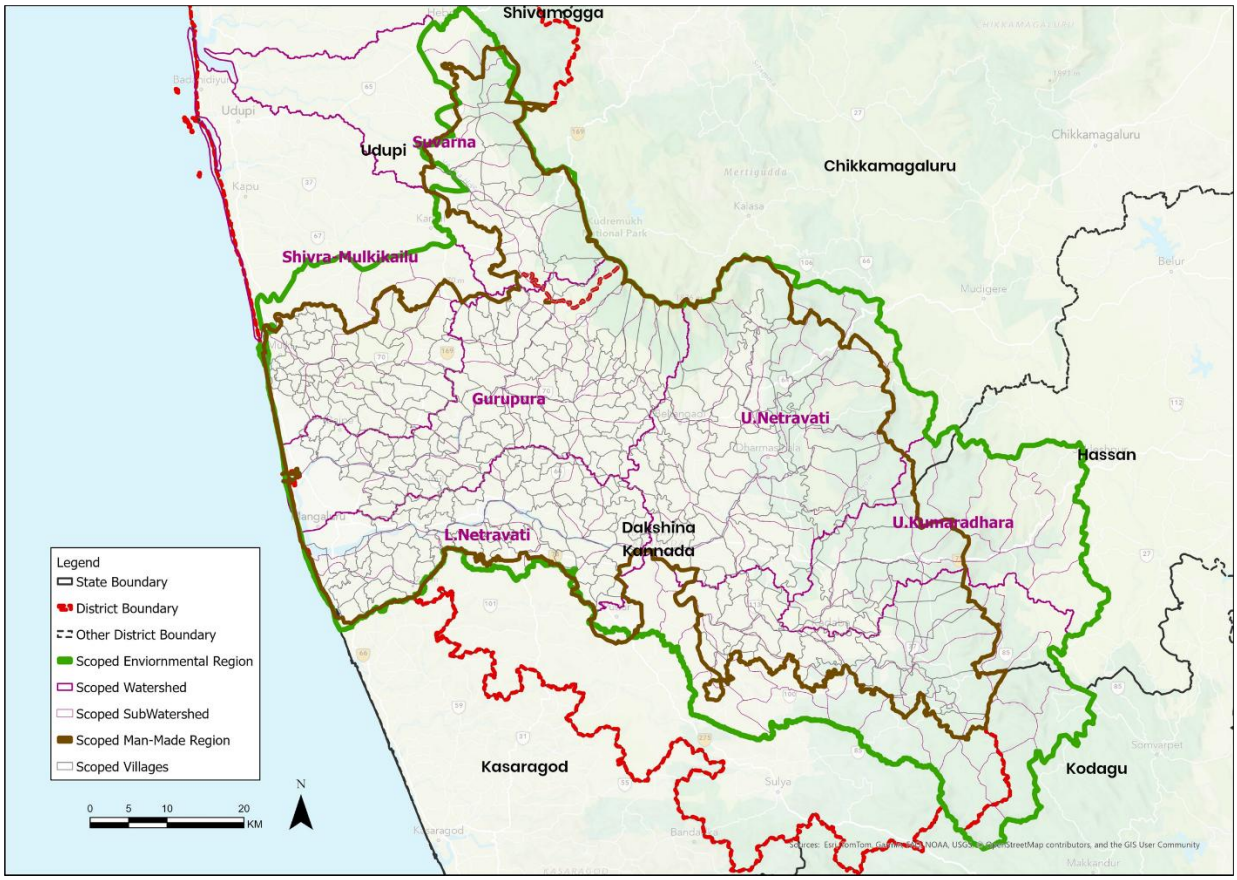
Source 59 Generated by Author

3.2.8 Scoped Region

Upon overlaying the delineated environmental and man-made regions, the selected sub-watersheds effectively encompass the delineated man-made areas.

This alignment ensures that the natural and man-made elements are cohesively represented in the planning framework.

Map 31 Overlay of Environmental & Man-made region



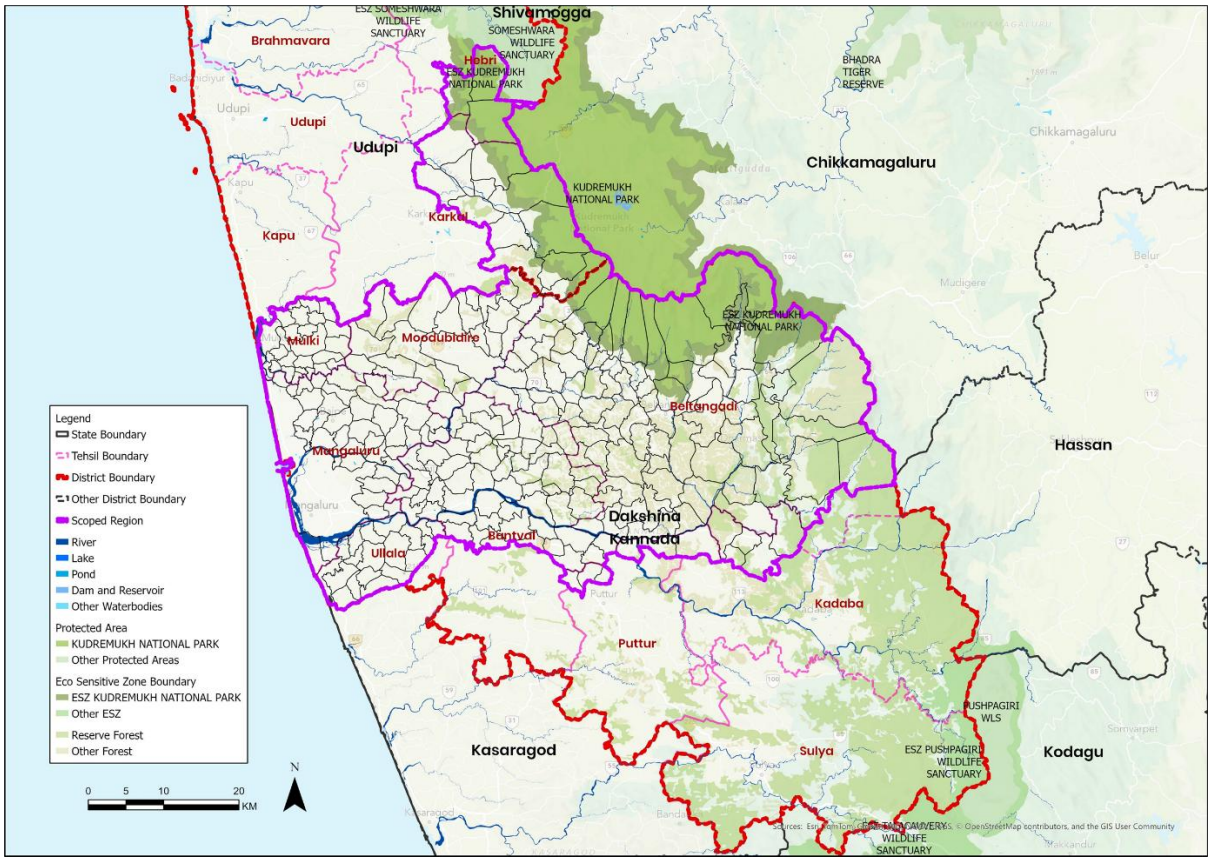
Source 60 Generated by Author

The final delineated study region is defined and includes the **232 Villages, & 38 Urban Centres** within **Mulki, Mangaluru, Mudabidri, Beltangady, Puttur, & Bantval Tehsils of Dakshin Kannada District & Karkala & Hebri Tehsils of Udupi District.**

This comprehensive delineation reflects a balanced approach, accommodating environmental considerations such as sub-watershed boundaries while incorporating critical man-made aspects like settlements, infrastructure, and industrial activities.

The area of the scoped region is **3,350.93 Sq.km** (335093.40 Ha).

Map 32 Scoped Region



Source 61 Generated by Author

3.3 Environmental Resources

This section includes a comprehensive baseline of the Biotic & Abiotic environmental aspects – Climate, Water, Land & Forest resources, and the relevant analytical tools as mentioned in the methodology is adopted for understanding these resources.

3.3.1 Climate

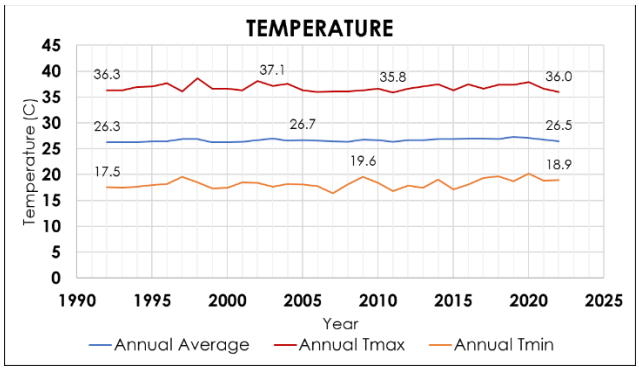
Temperature

Annual Average Temperature: Over the last 3 decades, it has fluctuated between **26.25 to 27.34 Deg C**

Maximum & Minimum Temperature: Maximum temperature ranges between **25.84 to 38.66 Deg C**, while minimum temperature ranges between 16.43 to 20.19 Deg C.

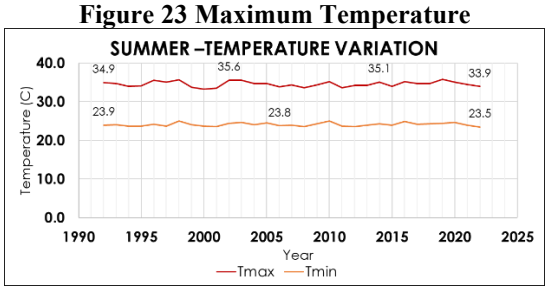
Seasonal Variations show **Summer Maximum temperature** peaking between 22.30 to 35.80 Deg C and **Winter Minimum temperature** drops between 21.25 to 17.83 Deg C

Figure 22 Temperature over the years - 1992 to 2022



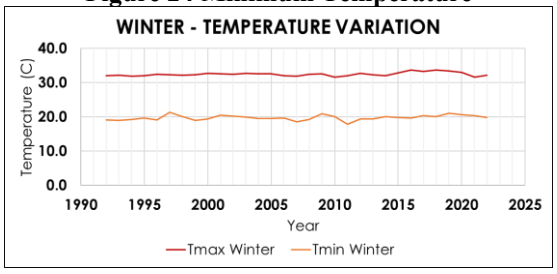
Source 62 IMD

Figure 23 Maximum Temperature



Source 63 IMD

Figure 24 Minimum Temperature



Source 64 IMD

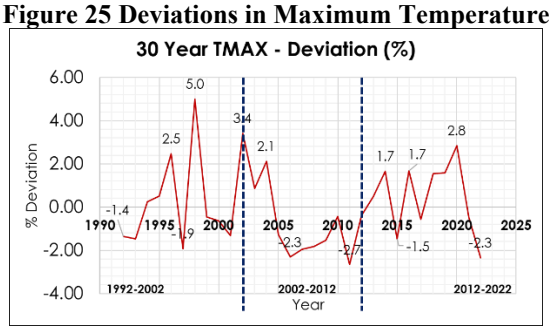
Temperature deviations

Maximum Temperature: Peaks in **1992-02** (+5%), and in **2012-22** (+2.8%) suggest warmer temperatures and the least deviation occurs in **2002-12 (-2.7%)**

Minimum Temperature: Lower '+' deviations can be observed in **1992-02 (+7.16)** & the highest '+' deviation occurs post **2015**, the occurrences of '–' deviations have reduced post **2012,** indicating increasing temperatures

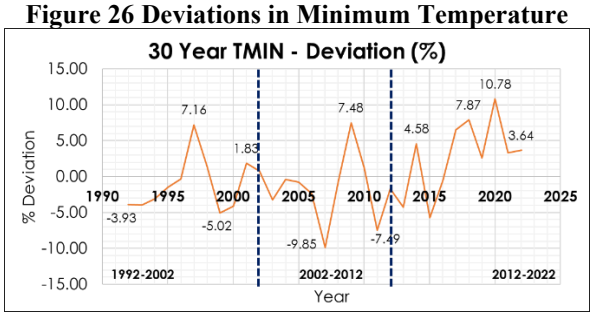
The increase in '+' deviations & reduced '-' deviations of both Minimum & Maximum temperature indicate **warmer temperatures** which may increase **evaporation, higher water losses & water demand.**

Figure 25 Deviations in Maximum Temperature



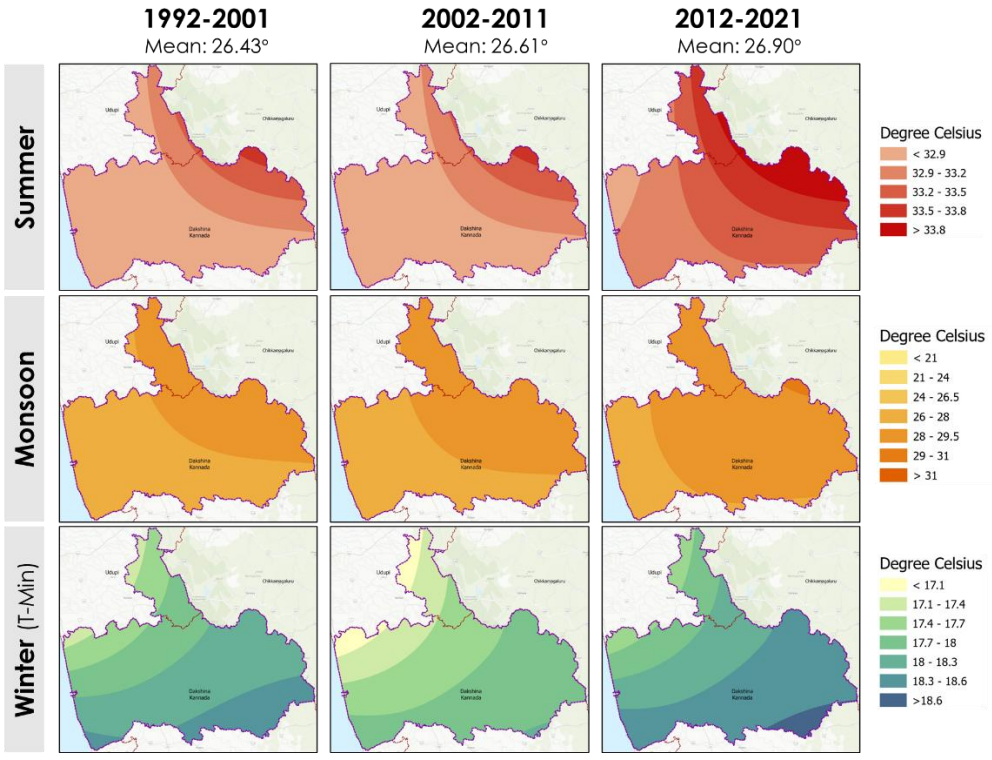
Source 65 IMD

Figure 26 Deviations in Minimum Temperature



Source 66 IMD

Figure 27 Decadal seasonal mean temperature – Isotherms 1992-2021



Source 67 Generated by Author using IMD Gridded data

Projected Temperature Changes in Karnataka as per SAPCC

Short-term (2030s) projections show an increase of 0.5°C to 1.5°C depending on the region, Long-term (2080s) projections show an increase of 2.0°C to 4.0°C under high-emission scenarios. This indicated more heatwaves and higher night temperatures, particularly in urban and inland regions.

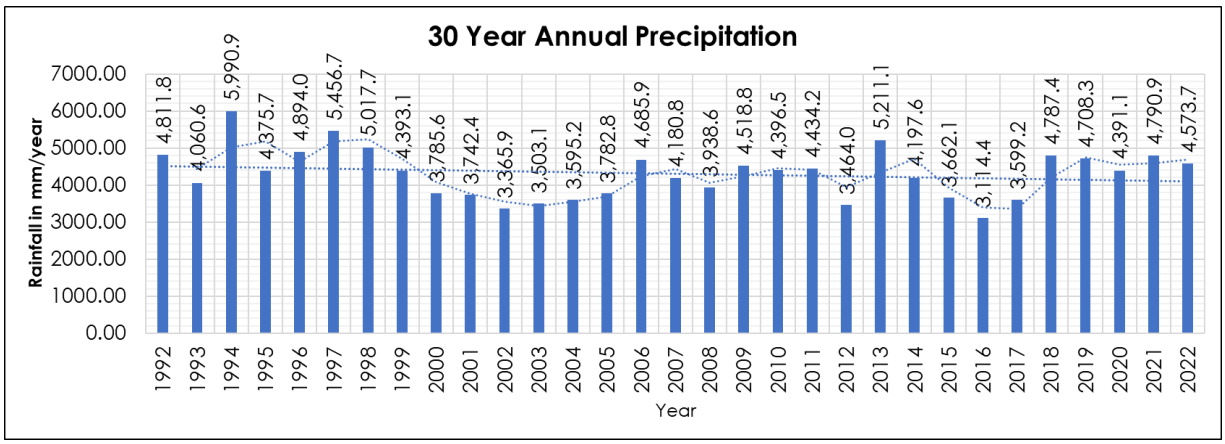
Temperature in Dakshina Kannada

Lower temperature rise is expected in Coastal regions compared to inland Karnataka due to the moderating influence of the Arabian Sea, Warmer nights and increased humidity are expected, leading to higher heat index values even if the temperature rise is lower and extreme heat events could increase in frequency, affecting agriculture and public health.

Rainfall

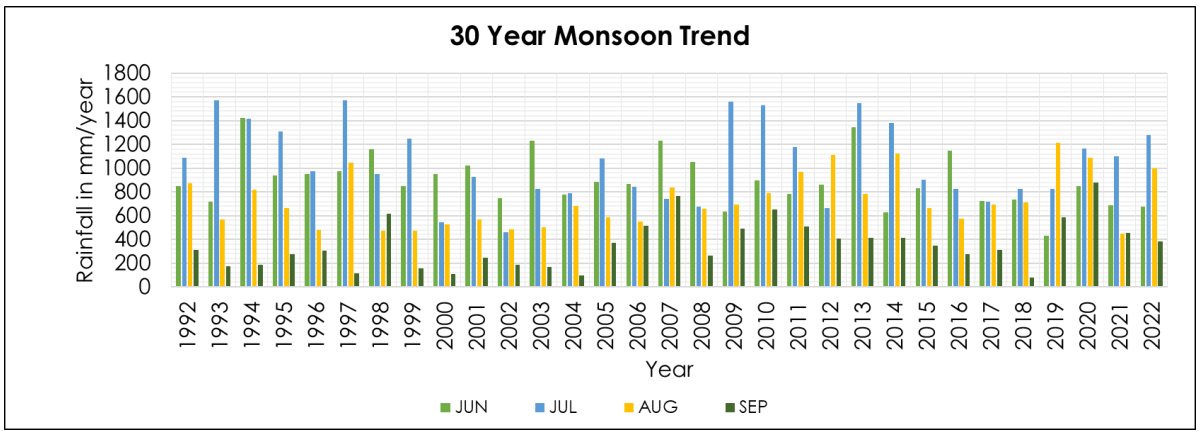
The monsoon season occurs between **June to September.** Annual precipitation ranges between **3114 to 5990 mm/year. Monsoon Trends** shows that the rainfall in **July remains dominant, followed by Aug, Jun & Sept.**

Figure 28 30 Year Annual Precipitation



Source 68 IMD Gridded data

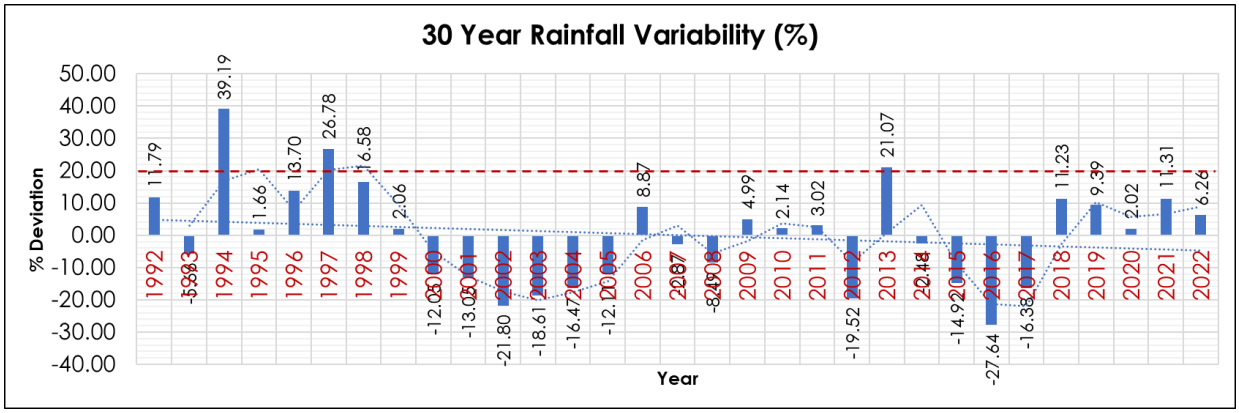
Figure 29 30 Year monsoon trend



Source 69 IMD

Rainfall Variability: '+20%' deviations are seen in the years **1994, 1997,2013 (3 years) while '-20%'** deviation is observed in **2002, 2016. (2 Years)**

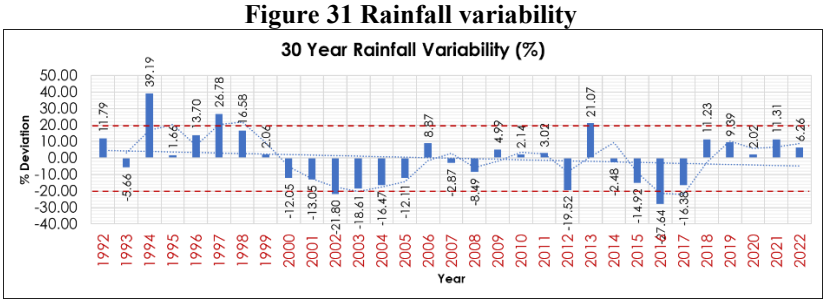
Figure 30 30 Year rainfall variability



Source 70 Based on IMD Data

Standardised Precipitation Index: The initial decade shows **extremely wet conditions,** while in the last two decades, **very wet to severely dry** conditions are frequent.

Figure 31 Rainfall variability



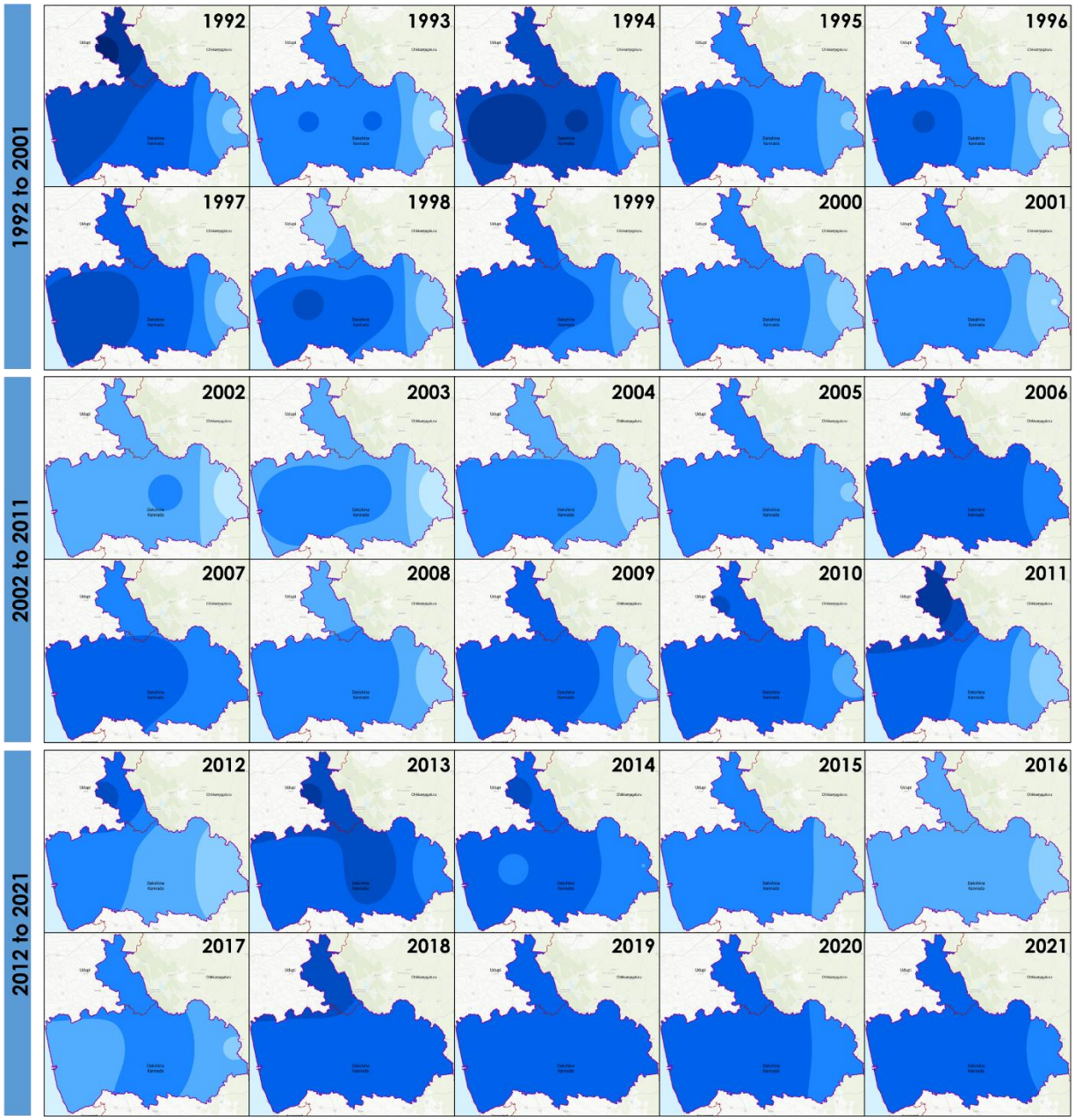
Source 71 Based on IMD data

Table 9 SPI

SPI	Category
2 & Above	Extremely wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near Normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 & Less	Extremely dry

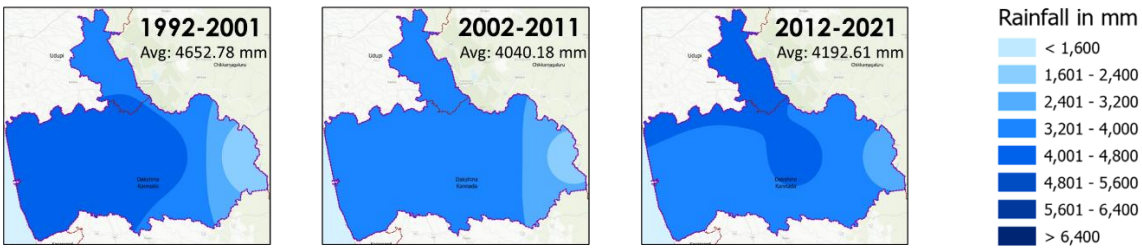
Source 72 National Institute of Hydrology, Roorkee

Figure 32 30 Year Isohyets 1992-2021



Source 73 Generated by Author using IMD Gridded data

Map 33 Decadal Isohyets 1992-2021



Source 74 Generated by author using IMD gridded data

General Rainfall Trends in Karnataka as per SAPCC

Rainfall has increased in most districts, with a general rise of up to **25%** in some areas. The Western Ghats districts, including Udupi, Dakshina Kannada, Kodagu, Uttara Kannada, and parts of Hassan and Shivamogga, have experienced an increase in rainfall ranging from **20% to 25%.** Monsoon (JJAS) rainfall is projected to increase by **15% to 25%** in the **NE and Western Ghats districts** under both **RCP 4.5 and RCP 8.5** scenarios.

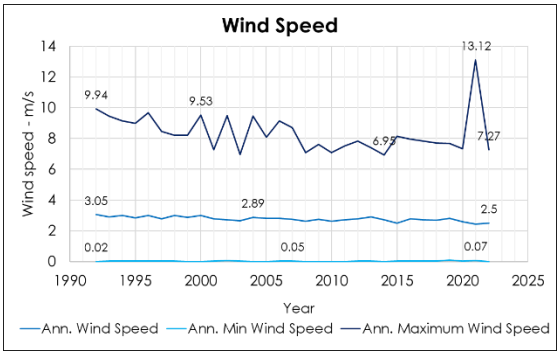
Rainfall Projections for Dakshina Kannada as per SAPCC

Short-term (2030s) projections indicate Monsoon rainfall increase by **15% to 20% Long-term (2080s)** projections show that rainfall is expected to increase by **20% to 25%**. **Rainy Days** are expected to increase by **1 to 3 days** annually under RCP 4.5 and **2 to 9** days annually under RCP 8.5. **Extreme Rainfall Events** show that **'Very High'** intensity rainfall events (days receiving more than 100mm) will increase by **1 to 2 events annually**, **'High'** intensity rainfall events (exceeding 50mm) will increase by **4 events annually** and **Drought** shows marginal decline by around 2 years. This indicates ssignificant rainfall increases (20-25%) expected in both Monsoon & Winters

Wind speed

Annual wind speed varies between 2.45 to 3.05 m/s. **Maximum wind speed** can be high reaching up to 6.95 to 13.12 m /s.

Figure 33 Wind speed

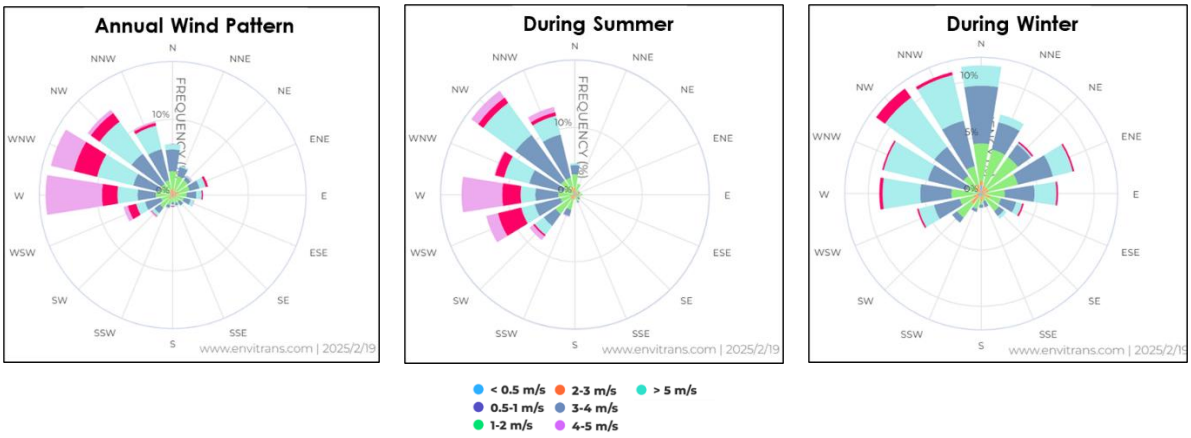


Source 75 IMD

Wind Direction

West and North-west winds dominate, especially during high-speed occurrences in **summer** **Low wind speeds** are more common and typically occur from the **East/Northeast**. **Winter** brings a shift towards **NNW and NW winds.**

Figure 34 Wind direction & speed



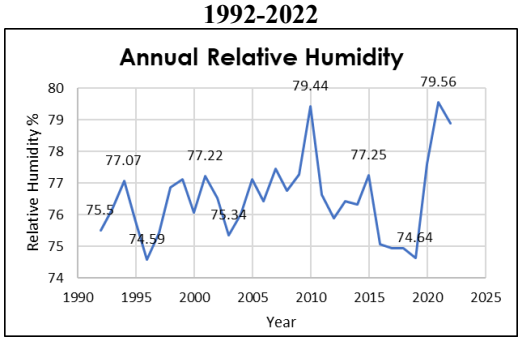
Source 76Envitrans

Relative humidity

Annual Relative Humidity: The region generally experiences high relative humidity throughout the year. **Average RH** fluctuates between 75% & 80% over the years.

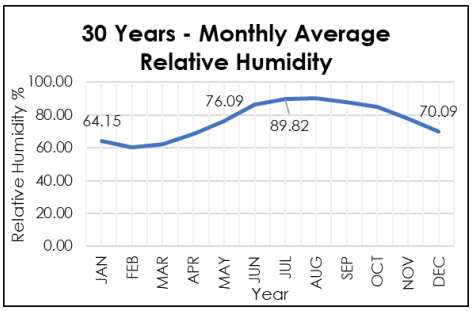
Monthly Relative Humidity: Seasonal RH is Lowest in January and March and highest from June to October. Peaks in the Monsoon months (June to September), often reaching 80% to 90%

Figure 35 Annual Relative Humidity 1992-2022



Source 77 IMD

Figure 36 Average monthly relative humidity 1992-22



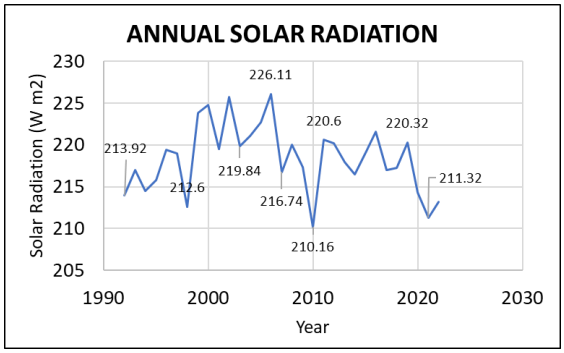
Source 78 IMD

Solar Radiation

The region generally experiences **moderate solar radiation** and the **average range of solar radiation** fluctuates between 210 to 226 W/m^2 over the years.

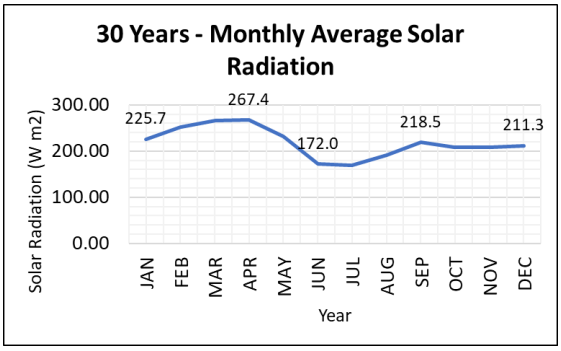
Monthly Relative Humidity: Seasonal RH is Highest in Jan-Mar and lowest from June to October. **Peaks** between Dry months (February to May), often reaching 265-267 W/m^2

Figure 37 Annual Solar Radiation 1992-2022



Source 79 IMD

Figure 38 Monthly average solar radiation 1992-2022

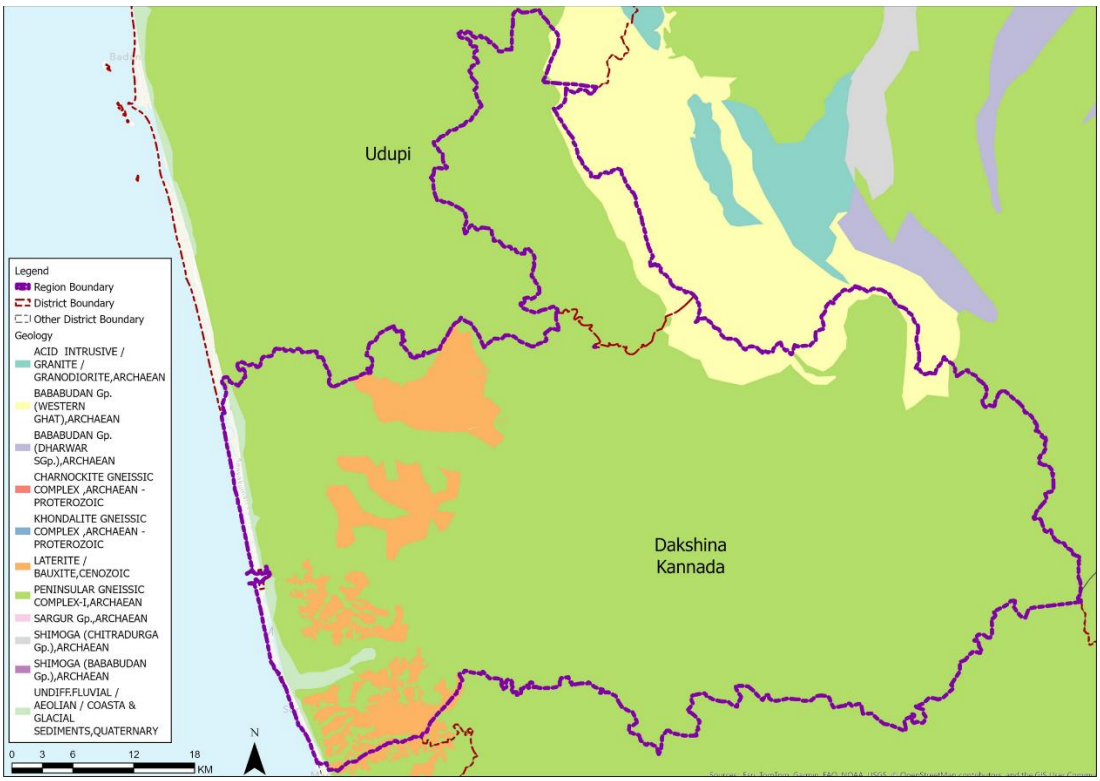


Source 80 IMD

3.3.2 Land Environment

Geology

Map 34 Geology map of the region



Source 81 Bhukosh

Table 10 Geology of the scoped region

Group	Sub-group & Age	Formation	Key Characteristics	Stability Implications
Peninsular Gneissic complex - I	Peninsular Gneissic complex, Archaean	Granitic and gneissic rocks	Hard, resistant to weathering	High stability, minimal erosion
-	Laterite/ Bauxite, Cenozoic	Ferruginous and aluminous rock, highly porous	High weathering susceptibility	Low stability, prone to erosion and mass wasting
Bababudan	Dharwar, Archaean	Quartzite, phyllite, and schist	Medium hardness, moderate fracturing	Moderate stability with some erosion risk
-	Unconsolidated Sediments, Quaternary	Alluvial, coastal, aeolian, and glacial deposits	Loose, unconsolidated, high porosity	Low stability, prone to erosion and flooding

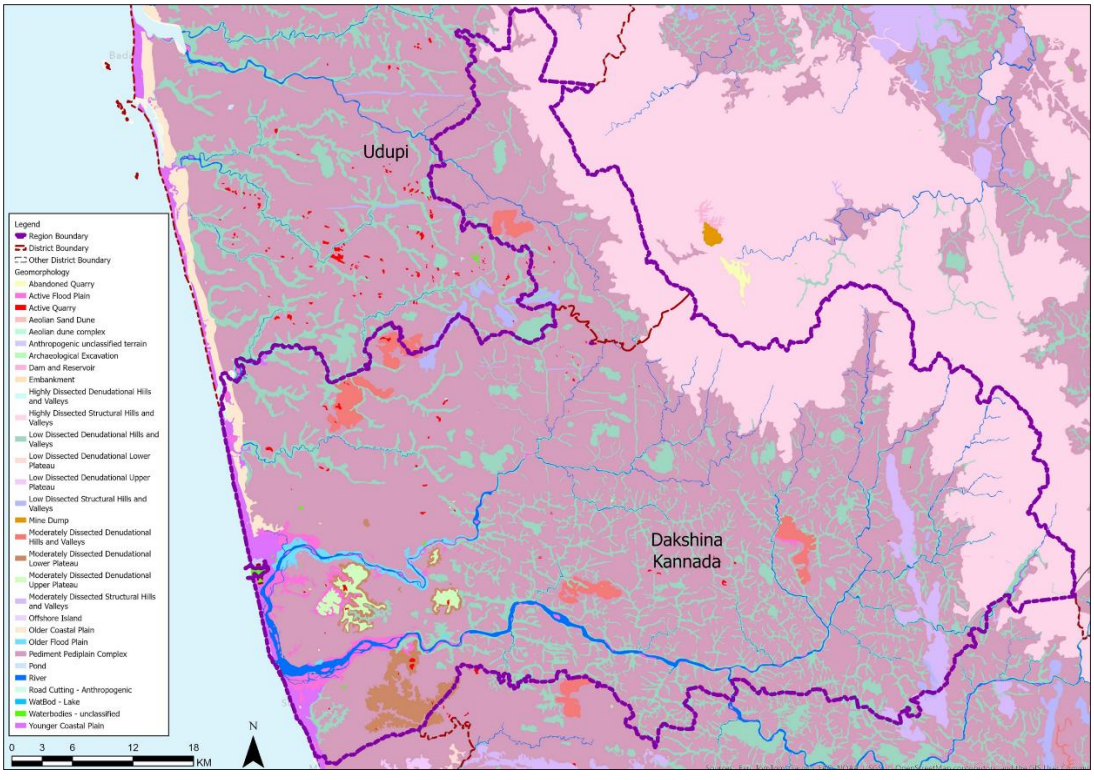
Source 82 Author

The geology of the district consists mainly of Archean-era, gneisses, and schists, with lateritic formations along the coast and fluvial & coastal sediments in areas along the coast.

Geomorphology

58.52% of the region is comprised of Pediment Pedi plain complex. The region is dominated by pediment Pedi plain complexes, highly dissected hills, and denudational valleys, with notable floodplains, coastal plains, and riverine areas, indicating diverse topography and varying erosion patterns.

Map 35 Geomorphology of the region



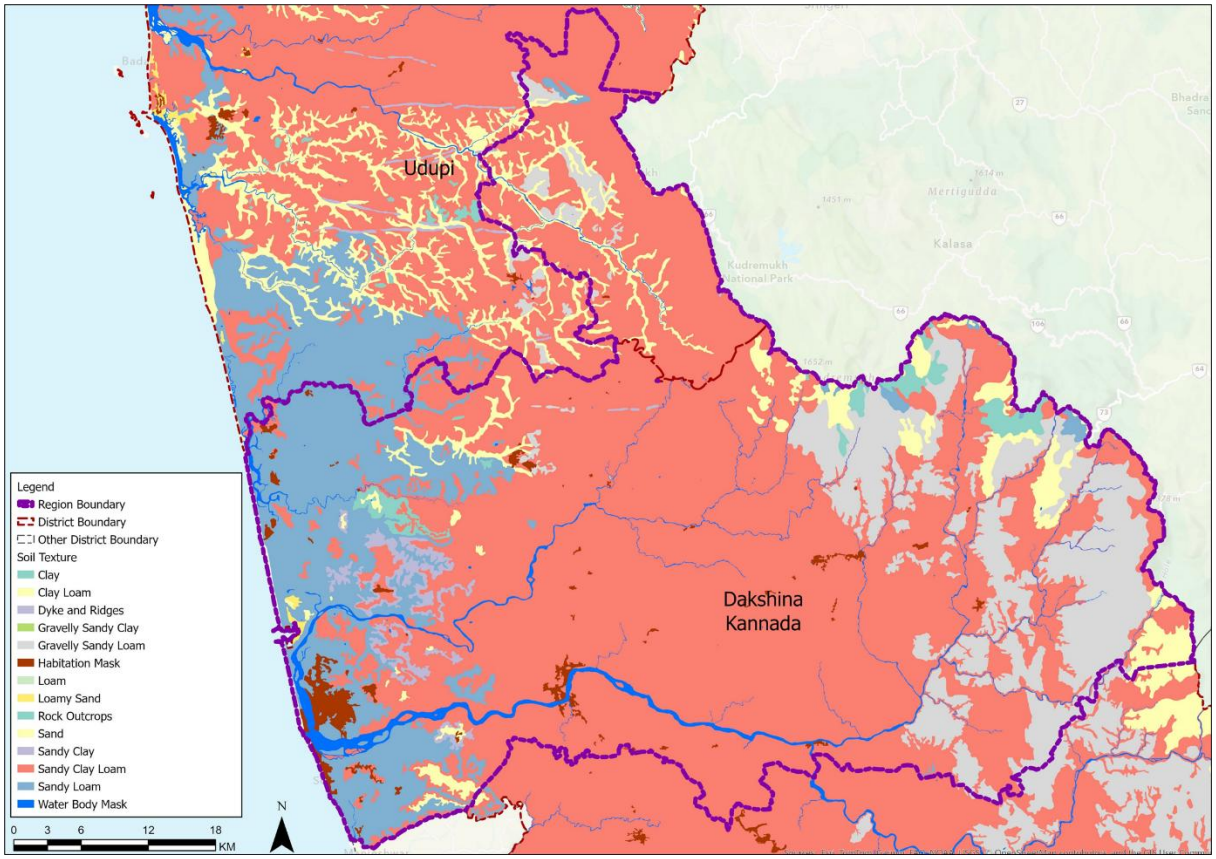
Source 83 Bhukosh

Soil

The soil texture is predominantly **clay, sandy clay, sandy clay loam**, and **gravelly sandy clay**, with patches of **loam and sandy loam**.

The dominance of **sandy clay loam** in the region indicates **well-drained yet moisture-retentive soil**, suitable for crops like **Arecanut, coconut, and paddy**, which require moderate water retention.

Map 36 Soil map of the region

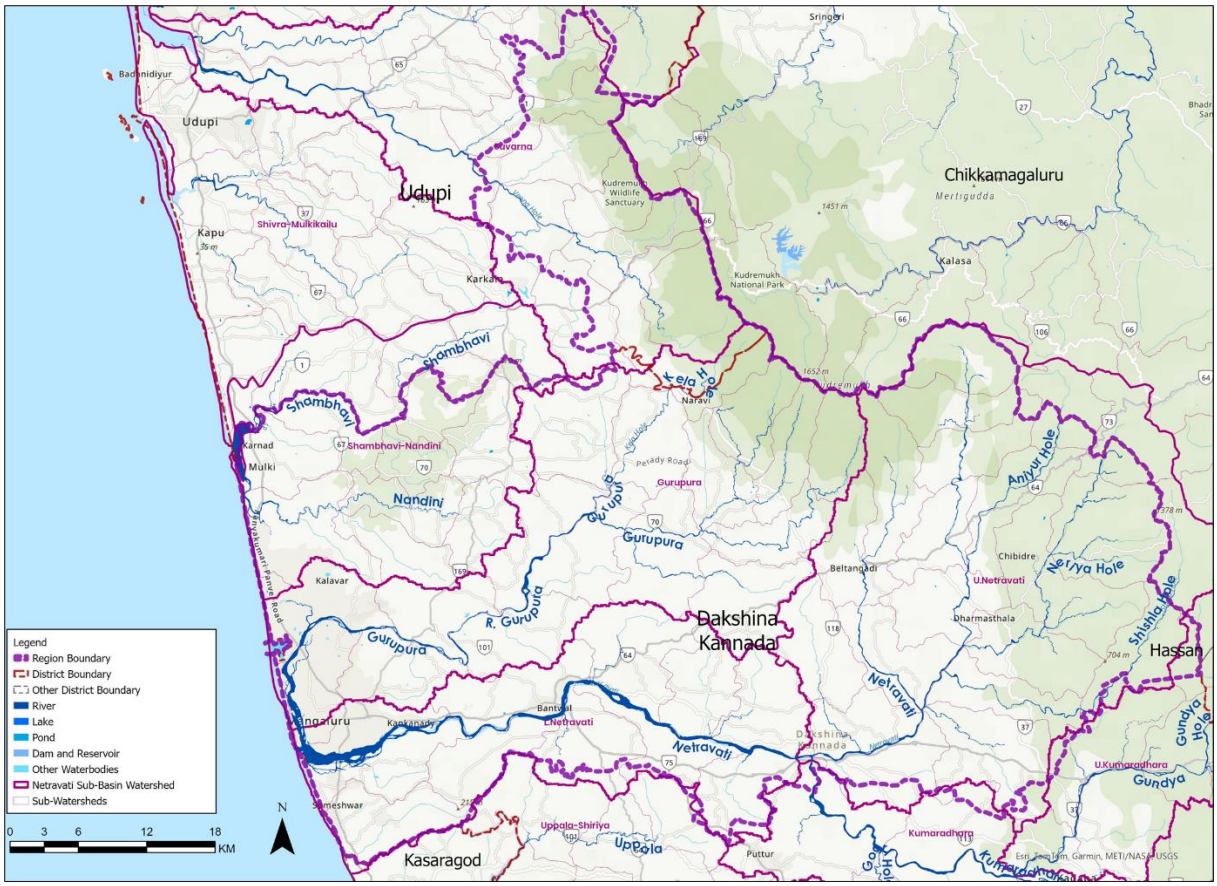


Source 84 Bhukosh

3.3.3 Water Environment

Surface Water

Map 37 Watersheds, sub-watersheds & Rivers



Source 85 Generated by Author

Watershed - The region lies in the watersheds of **Gurupura, Upper Netravati, Lower Netravati** of Dakshin Kannada District & partly on **Shivra-Mulkikailu, & Suvarna** Watersheds in Udupi District

River systems – Gurupura River originates from the western ghats in the Udupi district and flows through Dakshin Kannada district from the north western part into the Arabian sea.

The north-eastern edge of the district is drained by Shambhavi & Nandini Rivers that are a part of the Shivra & Mulkikailu watershed shared between the Udupi & Dakshin Kannada Districts.

South western parts of the district are drained by Uppala, Shiriya & Payaswini rivers that flows into the Arabian sea via Kasaragod district in Kerala.

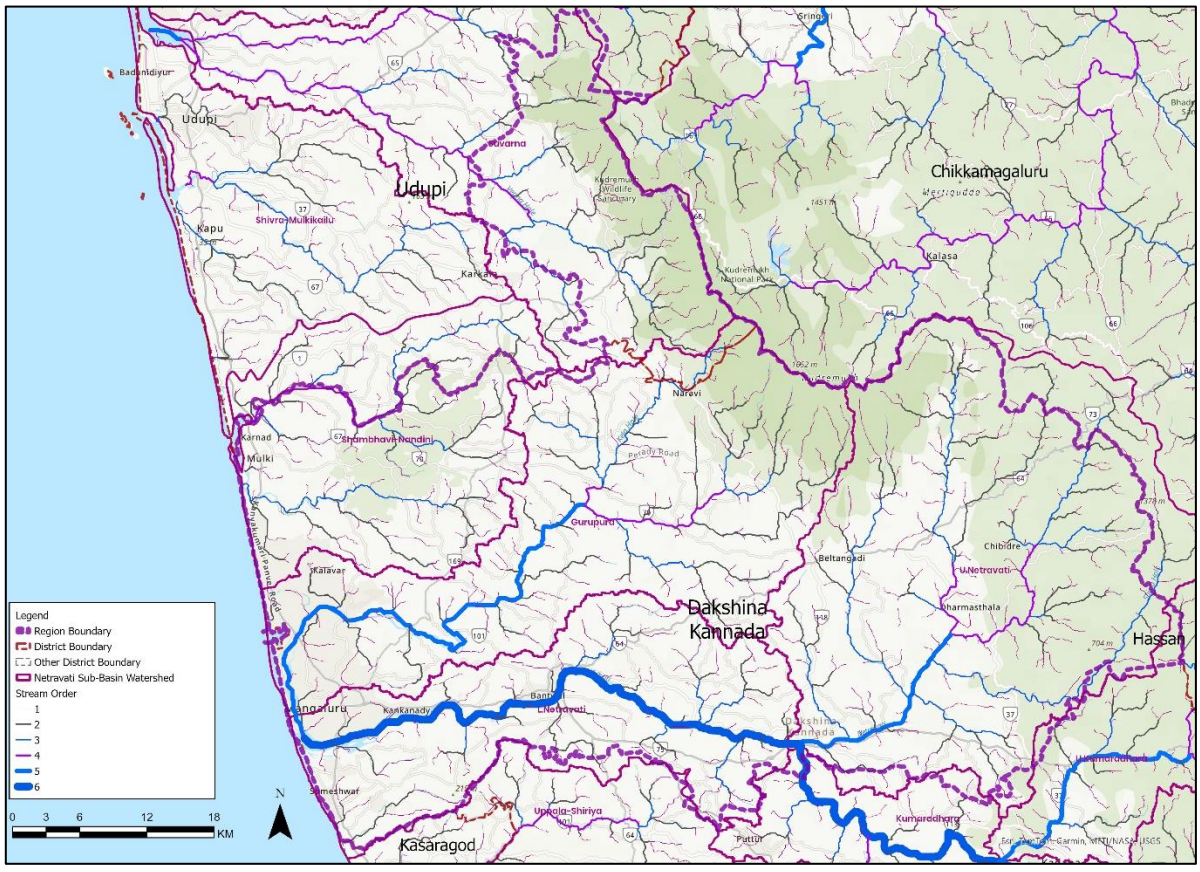
Table 11 River & Watershed details

River	Origin	Tributaries	Watershed	Catchment Area (Sq.km)	% Region Area
Netravati	Western Ghats, Dakshin Kannada District	Kumaradhara, Neriya Hole, Shishla Hole, Aniyur Hole, Gundya, Gundya Hole, Gogri Hole	Netravati	1802.79 (Upper & Lower Netravati)	**46.18%**
Gurupura	Kudremukh National Park ESZ, Uudpi District	Kela Hole	Netravati	930.36	**31.75%**
Shambhavi	Sanoor Village, Udupi District	-	Shivra-Mulkikailu	490.70	**11.34%**
Nandini	Kanakabettu, Dakshin Kannada District	-	Shivra-Mulkikailu		
Suvarna Watershed					**10.73**

Source 86 Author

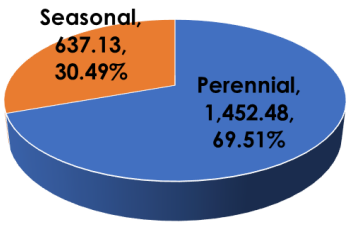
The region has 6 stream orders, with Netravati being the 6th order stream & Gurupura being the 5th Order stream.

Map 38 Stream Order



Source 87 Generated by Author

Figure 39 Stream length in km

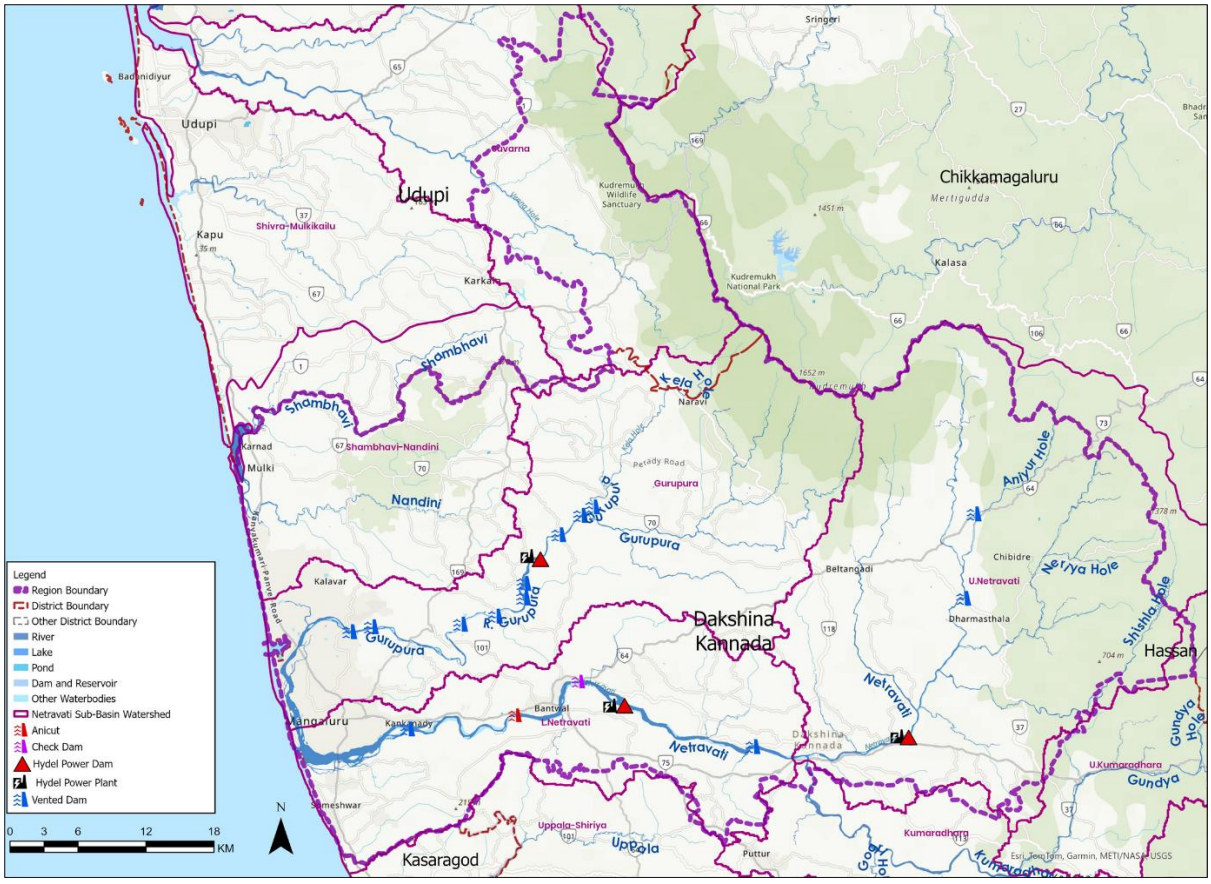


Source 88 Author

The region is dominated by perennial stream covering 69.5% of the total stream lengths of all orders.

Surface water infrastructure

Map 39 Infrastructure built on surface water



Source 89 Author

Several **Vented Dams, Hydel power infrastructure** and **Dam for water supply** are constructed on the Netravati & Gurupura River

Gurupura River: The river has **9 Vented dams** meant for the purpose of ground water recharge, and supplies water for drinking purpose in the rural areas along the river. It also has a small Hydel power project located on it.

Netravati River: The Tumbe Anicut/Dam is the main source of water for the Mangaluru City and other rural areas located along its banks

There are vented dams & check dams that support the rural areas for irrigation and drinking water purposes. The river also has two small hydel power projects located on it.

Surface Water Quality

Although no sample points and their quality data is readily available, through field observations & Research papers, presence of fish such as Garra mullya, Garra stenorhynchus & Hypselobarbus lithopidos (though to be extinct) indicate that the water quality is good with desirable limits of DO, BOD & COD.

Figure 40 Hypselobarbus lithopidos

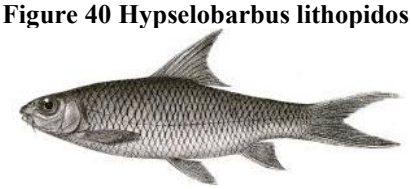


Figure 41 Garra mullya



Figure 42 Garra stenorhynchus



Source 90 Envis & other research papers

Basin Morphometry

Basin morphometry, is the quantitative study of landform shape and dimensions, which is critical in planning because it provides insights into a basin's characteristics such as slope, topography, drainage patterns, and runoff generation, and helps in resource management and infrastructure development.

Linear, Aerial, & Relief aspects of Basin Morphometry are considered in this analysis of sub & micro watersheds – some of these aspects will be considered in the prioritization of sub-watersheds.

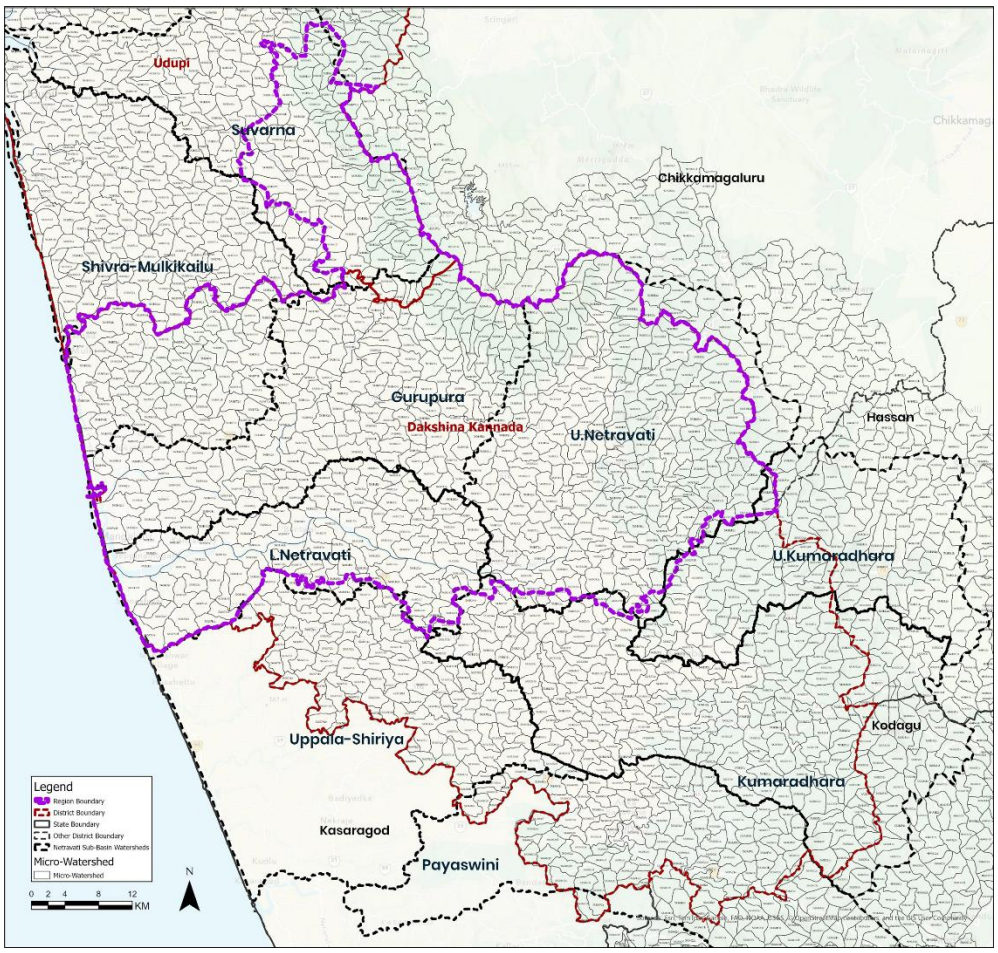
The definitions of all the morphometric parameters have already been discussed in the Literature study, **Section 2.1.1** of this thesis report.

Table 12 Overview of Basin Morphometric parametric

Aspect	Parameter	Definition	Formula	Significance	Character
Linear	Bifurcation ratio	The ratio of the number of the stream segments "**Nu**" of given order to the number of segments of the next higher order **N (u+1)** (Schumn, 1956).	R_b = **(Nu/Nu + 1);** Nu = no. of streams of a particular order 'u', Nu + 1 = Number of streams of next higher order 'u + 1'	An indicator of structural control & flood proneness. Will help in watershed prioritization	**High bifurcation** ratio -> higher peak discharge & flood risk
	Length of overland flow	Average distance water travels before reaching a stream	L_g=1/2*D Dd = Drainage Density	Indicator of run-off and infiltration potential, Reflects the susceptibility of the basin to erosion and sedimentation	**Shorter length** of overland flow indicates **higher run-off** and **lower infiltration**
Aerial	Circularity ration	The ratio between the area of the basin to the area of a circle having the same perimeter. Value of R_c varies from '0' (minimum circularity) to '1' (Maximum circularity).	R_c = 4πA/P2 A = area of basin (km²), P = perimeter of basin (km)	Indicates the flow characteristics of a basin	**Higher R_c** -> more circular is the basin -> high peak flow in shorter duration, **lower R_c** -> more elongated is the basin -> low peak flow with longer duration
	Stream Frequency	Stream frequency (F_s) is the total number of stream segments irrespective of the order in per unit area (Horton 1945).	F_s= N/A N =total number of streams of a given basin, A =total area of basin (km²)	An indicator of drainage network development & Permeability	**High stream frequency** -> dissected terrain with rapid runoff, increased erosion, and a higher risk of floods. **Low stream frequency ->** better infiltration and groundwater recharge potential.
	Drainage Density	The total stream length to the total area of watershed.	Dd = L/A L = length of streams (km), A = Basin area (km2).	Helps understand drainage efficieny	High drainage density -> more surface runoff, less infiltration Low drainage density -> The basin is permeable
	Texture ratio	The ratio between total numbers of stream segments to the perimeter of the basin.	R_t = No of stream of all orders/ perimeter of basin	Indicated the finess of drainage network, affects drainage efficiency, erosion and sedementation	**R_t < 2 ->** very coarse, **2–4** coarse, **4–6** moderate, **6–8** fine, **> 8** very fine drainage texture (Smith 1950). Lesser the ratio -> Lesser the erosion and run-off
	Infiltration Number	The product of drainage density and stream frequency, reflects the infiltration potential of a watershed.	I_n = Dd * F_s Dd – Drainage density F_s – Stream Frequency	Helps assess the infiltration capacity	Lower infiltration number -> higher infiltration and lower run-of
Relief	Basin Relief	Difference between the maximum and the minimum elevations within the basin	H = R – r R = highest relief, r = lowest relief	Helps understand the elevation difference within the basin	Higher the relief -> more run-off and erosion
	Relief Ratio	Relief ratio is a measure of the relative steepness or ruggedness of a landscape.	Rr = (H/L max) H = Basin relief, L = length of basin	Helps understand the steepness of the basin	Higher the relief ratio -> more run-off and erosion
	Ruggedness number	Indicated the terrain roughness of the watershed	R_i = Dd * H/1000 Dd = drainage density, H = relative relief	Helps assess the infiltration & erosion	Higher the R_i -> more run-off and erosion

Source 91 Compiled by Author

Map 40 Micro-watersheds of the Region



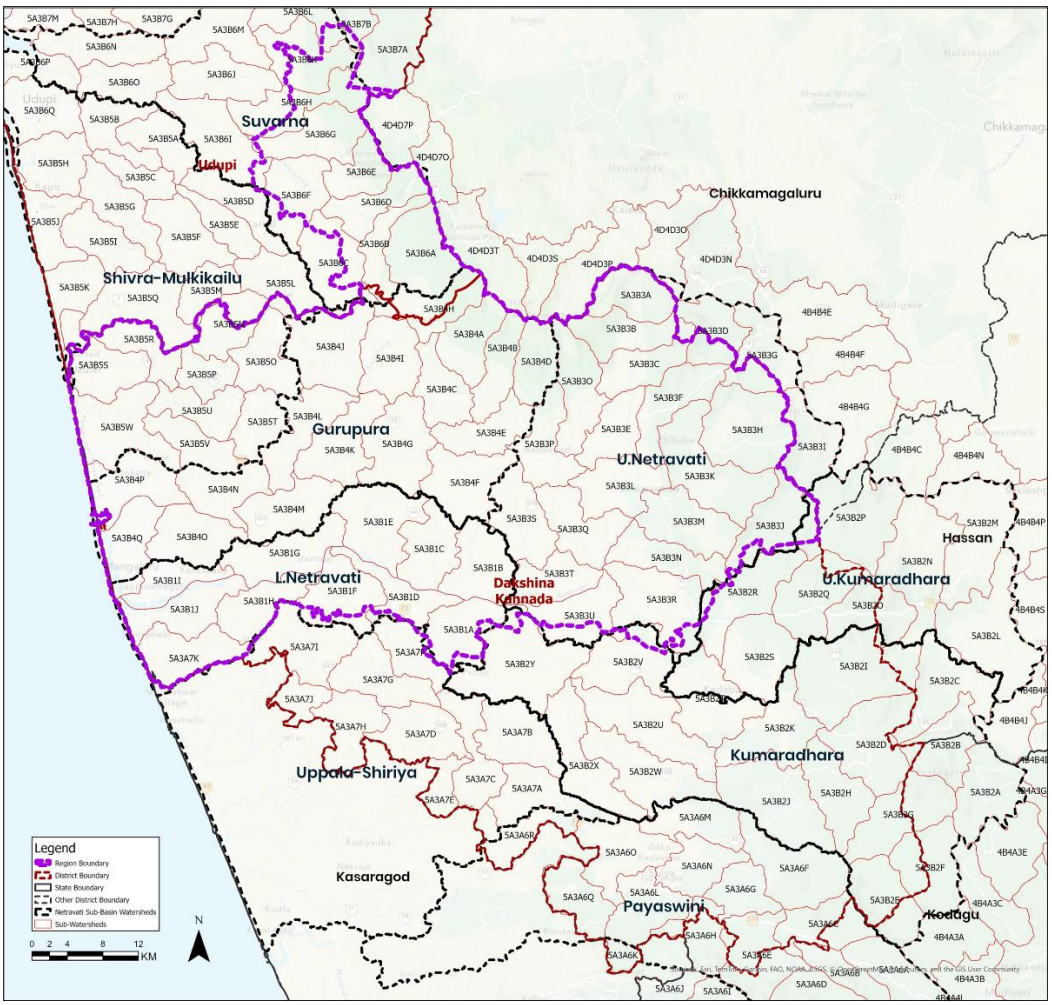
Source 92 Generated by Author

Table 13 Details of Sub-basins

Parameter	Sub-Basins					
	Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Number of sub-watershed	17	11	21	25	8	4
Length of stream (Km)	563.11	361.88	691.74	1130.27	218.51	115.37
Sub-Basin Length (Km)	52.6	43.56	41.5	58.18	28	23.2
Sub Basin Area (km^2)	879.3	562.8	1126.74	1797.91	361.18	186.96
Sub-Basin Perimeter (Km)	243.21	197.71	2015.55	496.77		
Stream Order						
1	197	108	237	379	78	42
2	49	29	54	85	23	7
3	11	9	22	31	11	2
4	5	62	4	10	3	0
5	7	2	10	6	0	0
6	0	10	0	4	0	0
Total	**269**	**220**	**327**	**515**	**115**	**51**

Source 93 Compiled by Author

Map 41 Watersheds & Sub-Watersheds of the region



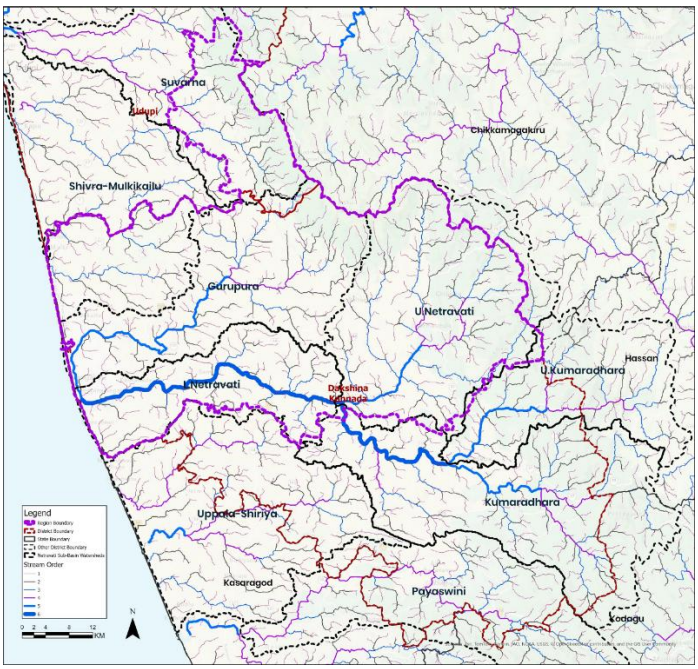
Source 94 Generated by Author

Gurupura River has **17 sub-watersheds** and a **total stream length of 563.11 km**, which is substantial compared to other sub-basins in the region. The sub-basin length (52.6 km) and area (879.3 km²) indicate its significance in the regional hydrology.

Stream Order Analysis and Water Flow Characteristics

Most streams are of 1st order, indicating a dendritic drainage pattern with numerous small tributaries. The Gurupura watershed has only a few higher-order streams -> infiltration potential is moderate to low. Since it has many low-order streams, urbanization and encroachments could significantly impact drainage patterns, leading to higher surface runoff, flooding, and erosion. Compared to Netravati, which has more developed stream orders (up to 6th order), Gurupura might have lower water availability during dry seasons.

Map 42 Stream Order



Source 95 Generated by Author

Linear Aspects

Aerial aspects considered are **Bifurcation ratio & length of overland flow.** The relation of these aspects with **flood susceptibility** is captured in the tables & Maps below.

Table 14 Bifurcation ratio & flood susceptibility

Bifurcation Ratio (R_b)	Flood susceptibility
<1	Low flood peaks but prolonged floods
1-5	Balanced run-off, moderate flood susceptibility
>5	High flood susceptibility

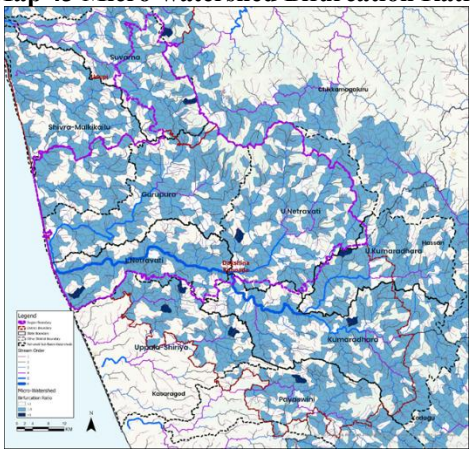
Source 96 Author

Table 15 Length of Overland Flow

Length of Overland Flow (L_g) (km)	Erosion Potential	Sediment transport	Flood & Run-off
<0.8	High	High	Flash floods likely
0.8-1	Medium	Medium	Moderate flood duration
>1	Low	Low transport, high deposition	Slow flood response, extended flood duration

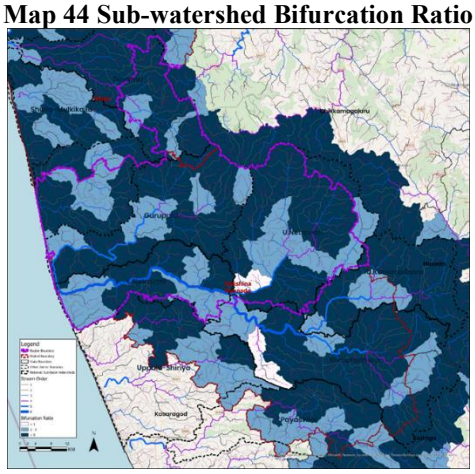
Source 97 Author

Map 43 Micro-watershed Bifurcation Ratio



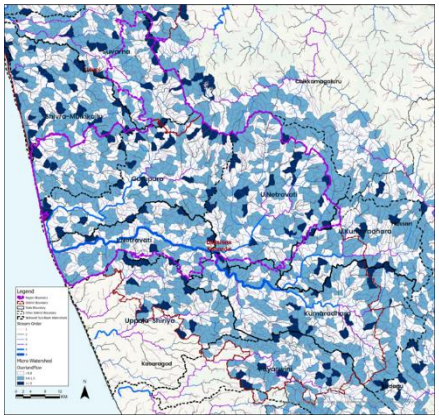
Source 98 Generated by Author

Map 44 Sub-watershed Bifurcation Ratio



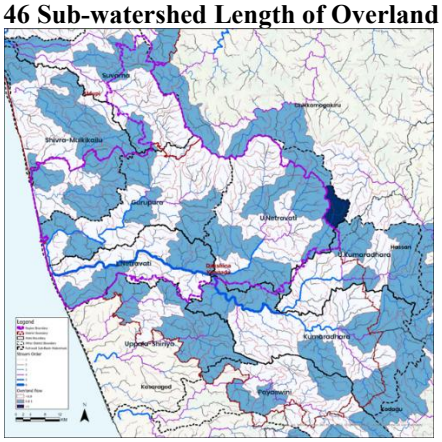
Source 99 Generated by Author

Map 45 Micro-watershed - Length of Overland flow



Source 100 Generated by Author

Map 46 Sub-watershed Length of Overland flow



Source 101 Generated by Author

Inference

Bifurcation Ratio (Rb) and Its Flood Risk Implications

The Gurupura river has **R_b = 6.52,** Falls in the moderate to high range (4.7 - 9.4). This indicates a balanced runoff with a moderate flood susceptibility. Urban areas along Gurupura might have adopt flood mitigation measures, such as retention ponds and flood zoning.

Length of Overland Flow (Lo) and Its Role in Sediment Transport

For Gurupura river, Lo = 0.78 km. This falls in the 0.8-1 km range, meaning moderate flood duration with medium sediment transport and indicates a balanced infiltration and runoff scenario.

Table 16 Linear aspects of Watersheds co-related with the Table 16 & 17

Aspect	Parameter	Sub-Basins					
		Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Linear	Bifurcation Ratio (R_b)	6.52	4.62	6.23	6.65	5.17	6.75
	Length of Overland Flow (L_g) (km)	0.78	0.78	0.2	0.79	0.82	0.82

Source 102 Author

Aerial Aspects

Aerial aspects considered are **Circularity ratio, Stream Frequency, Drainage density, Texture ratio & Infiltration Number.** The relation of these aspects with **Infiltration, Run-off and flood susceptibility** is captured in the tables & Maps below.

Table 17 Circularity ratio & its relation to flood potential & erosion susceptibility

Circularity Ratio (R_c)	Basin Shape	Flood potential	Erosion susceptibility
<0.3	Highly elongated	Low (Slow runoff, less flood risk)	Very high (More surface exposure to erosion)
0.3-0.4	Moderately elongated	Low to moderate	High
0.4-0.5	Moderately circular	Moderate	Moderate
>0.5	Nearly circular	High (Rapid run-off, Flash floods likely)	Low (Shorter flow paths, less erosion)

Source 103 Compiled by author

Table 18 Stream frequency & its relation to permeability

Stream Frequency (F_s) (Streams/km²)	Permeability
<0.15	High
0.15-0.3	Moderate
>0.3	Low

Source 104 Compiled by Author

Table 19 Drainage density & its relation with infiltration, run-off & flood risk

Drainage Density (Dd) (km)	Infiltration	Run-off	Flood risk
<0.5	High	Very low	Low
0.5-0.6	Moderate	Moderate	Medium
>0.6	Low	High	High

Source 105 Compiled by Author

Table 20 Texture ratio & its relation with Infiltration & run-off

Texture Ratio (R_t)	Texture	Infiltration & Run-off
<0.2	Very coarse	High infiltration, low runoff, stable landforms
0.2-0.4	Coarse	Moderate infiltration, balanced runoff
>0.4	Moderately coarse	Reduced infiltration, high runoff

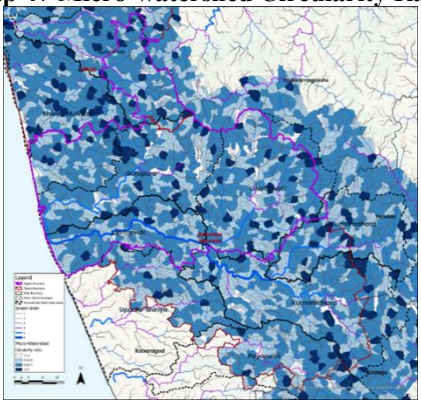
Source 106 Compiled by Author

Table 21 Infiltration number & its relation to Run-off

Infiltration Number (I_n)	Infiltration	Run-off
<0.1	High	Low
0.1-0.2	Moderate	Moderate
>0.2	Low	High

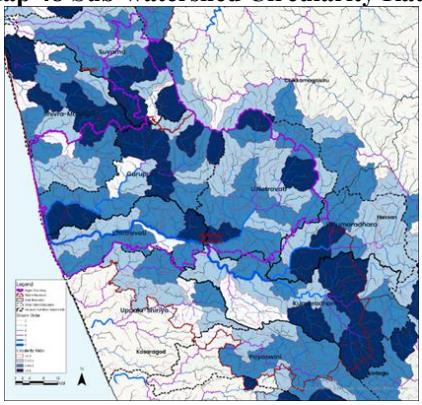
Source 107 Compiled by Author

Map 47 Micro-watershed Circularity Ratio



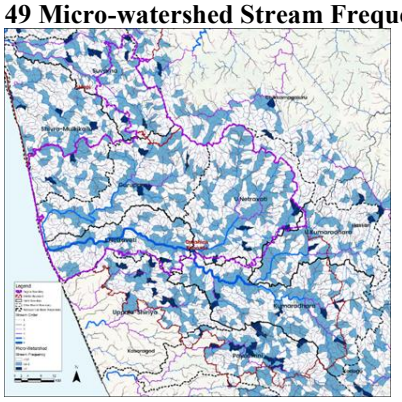
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Map 48 Sub-watershed Circularity Ratio



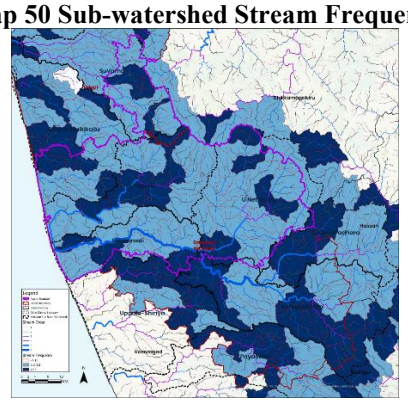
Source 109 Generated by Author

Map 49 Micro-watershed Stream Frequency



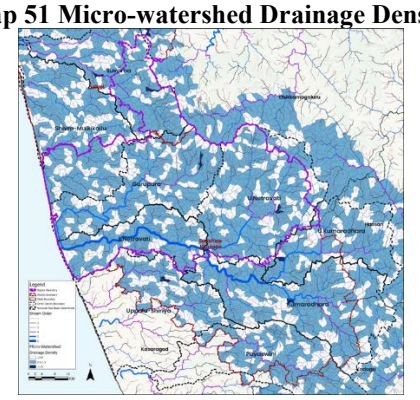
Source 110 Generated by Author

Map 50 Sub-watershed Stream Frequency



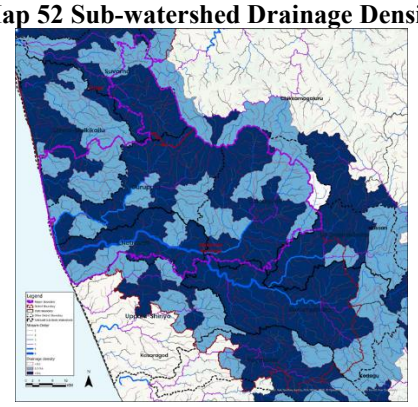
Source 111 Generated by Author

Map 51 Micro-watershed Drainage Density



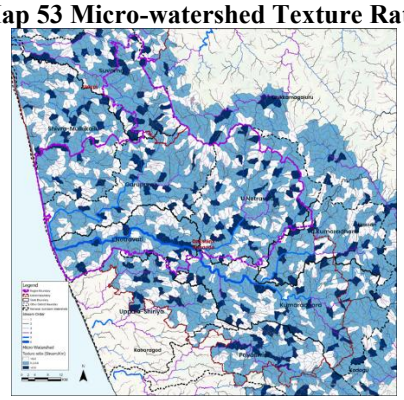
Source 112 Generated by Author

Map 52 Sub-watershed Drainage Density



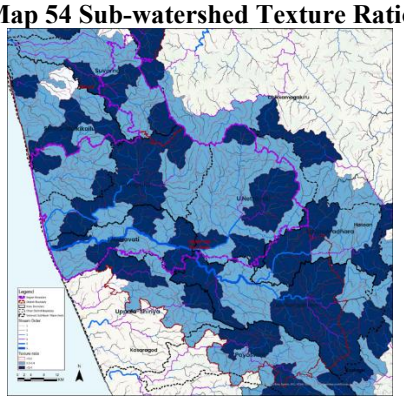
Source 113 Generated by Author

Map 53 Micro-watershed Texture Ratio



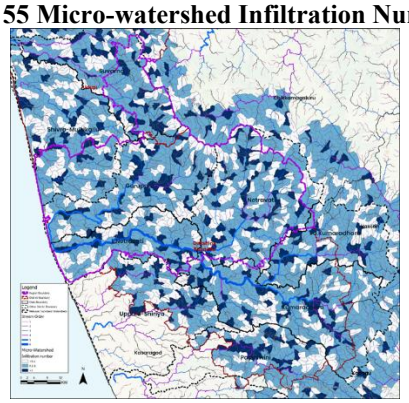
Source 114 Generated by Author

Map 54 Sub-watershed Texture Ratio



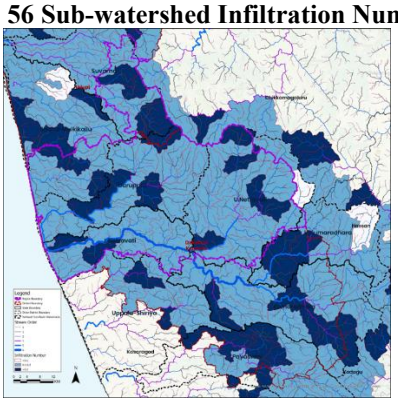
Source 115 Generated by Author

Map 55 Micro-watershed Infiltration Number



Source 116 Generated by Author

Map 56 Sub-watershed Infiltration Number



Source 117 Generated by Author

Table 22 Aerial aspects of Watersheds co-related with the Table 19 & 23

Aspect	Parameter	Sub-Basins					
		Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Aerial	Circularity Ratio (R_c)	0.47	0.41	0.44	0.45	0.48	0.38
	Stream Frequency (F_s) (Streams/km²)	0.3	0.28	0.28	0.29	0.31	0.28
	Drainage Density (Dd) (km)	0.64	0.64	0.61	0.62	0.6	0.6
	Texture Ratio (R_t)	0.41	0.36	0.39	0.46	0.4	0.32
	Infiltration Number (I_n)	0.19	0.18	0.17	0.18	0.19	0.17

Source 118 Author

Inference

The Gurupura river has **Moderate circularity ratio** suggesting that flood risk exists but is not extreme. The **Moderate drainage density and infiltration number** indicate Groundwater recharge potential that can benefit from incorporating recharge wells and urban wetlands. The **Moderately coarse texture ratio** indicates risk of runoff-induced erosion

Relief Aspects

Relief aspects considered are **Basin Relief, Relief Ratio & Ruggedness number**. The relation of these aspects with **infiltration & run-off** is captured in the tables & Maps below.

Table 23 Range on which the relief aspects are assessed

Total Basin Relief (H) (Meter)	Relief Ratio (R_r)	Ruggedness number (R_f)
<150	<50	<0.2
150-300	50-100	0.2-0.4
300-450	100-150	0.4-0.6
450-600	150-200	0.6-0.8
>600	>200	>0.8

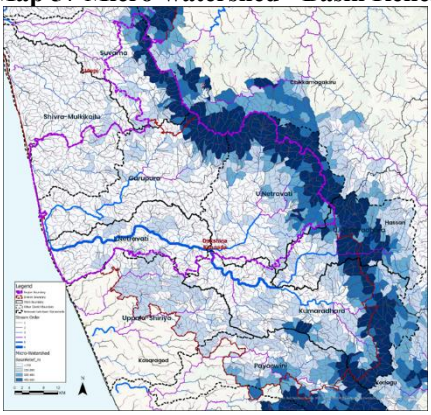
Source 119 Compiled by Author

Table 24 Co-relation of the relief aspects with terrain, infiltration & Run-off

Terrain	Infiltration & Run-off
Nearly flat terrain, minimal slope variation	Very low runoff, high infiltration, low erosion
Gentle slopes, slightly rolling terrain	Moderate infiltration, low runoff, stable landforms
Rolling hills, well-drained terrain	Balanced infiltration-runoff, moderate erosion potential
Steep slopes, increased surface runoff	Reduced infiltration, high erosion risk
Rugged terrain, sharp elevation differences	Very high runoff, severe erosion, landslide risk

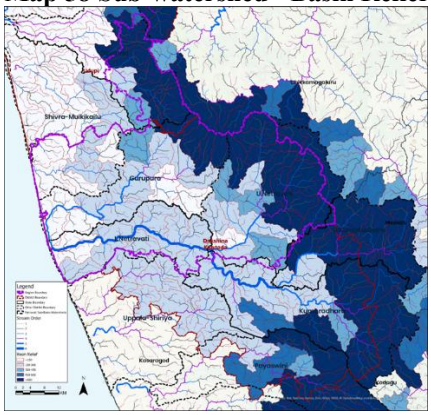
Source 120 Compiled by Author

Map 57 Micro-watershed - Basin Relief



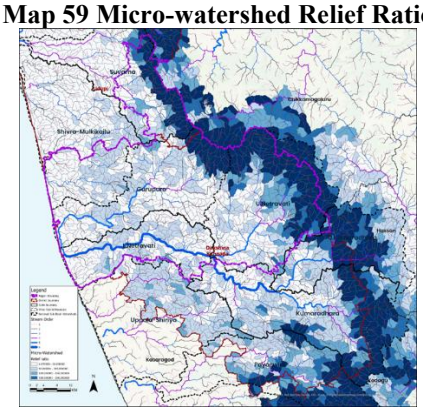
Source 121 Generated by Author

Map 58 Sub-watershed - Basin Relief



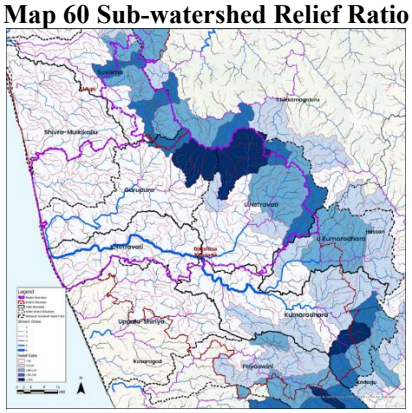
Source 122 Generated by Author

Map 59 Micro-watershed Relief Ratio



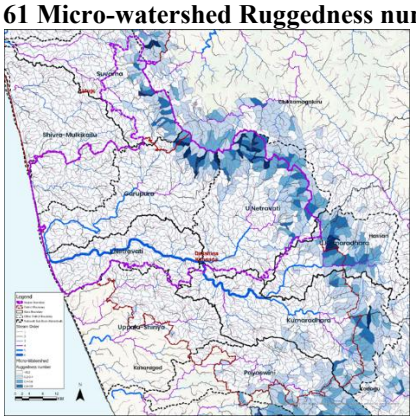
Source 123 Generated by Author

Map 60 Sub-watershed Relief Ratio



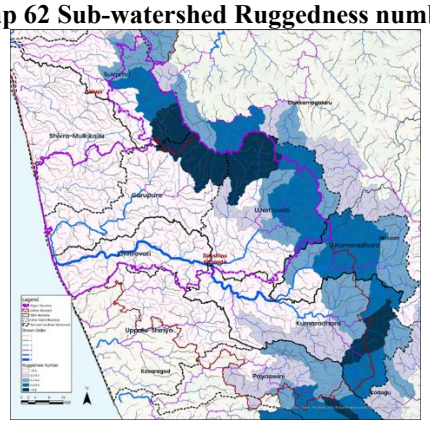
Source 124 Generated by Author

Map 61 Micro-watershed Ruggedness number



Source 125 Generated by Author

Map 62 Sub-watershed Ruggedness number



Source 126 Generated by Author

Inference

1. Basin Relief (H)

For Gurupura, Basin relief is 509.23m, falls in the 300-450m range, indicating a moderate relief with rolling hills and well-drained terrain, Balanced infiltration-runoff conditions with moderate erosion potential and Moderate Basin Relief → Requires slope stabilization and erosion control.

2. Relief Ratio (Rr)

For Gurupura river, Relief ratio is 85.36, Falls in the 50-100 range, indicating moderate to high runoff with moderate erosion potential. Flash flood risk is not extreme but exists. Moderate Relief Ratio suggest that flash floods are possible

3. Ruggedness Number (Rn)

For Gurupura river, ruggedness number is 0.34, Falls in the 0.2 - 0.4 range, meaning moderate erosion risks. This indicates moderate landslide potential in steep areas.

Table 25 Relief aspects of watersheds co-related with table 25-26

Aspect	Parameter	Sub-Basins					
		Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Relief - Watershed	Total Basin Relief (Meter)	1885	275	1163	1674	176	260
Relief (Average of Sub-watersheds)	Basin Relief (H) (Meter)	509.23	194.81	806.57	762.24	157.25	151.25
	Relief Ratio (R_r)	85.36	26.53	112.09	89.15	23.58	22.28
	Ruggedness number (R_n)	0.34	0.12	0.49	0.47	0.09	0.092

Source 127 Compiled by Author

Flow

Flow within the sub-watersheds is crucial as it helps in understanding the environmental health, resource management and flood risk mitigation impacting water quality & ecosystem stability

Drainage density indicates runoff potential and infiltration capacity, while **perennial stream length** reflects sustained water availability, making them key factors in determining seasonal flow variations.

Table 26 Seasonal flow decision matrix

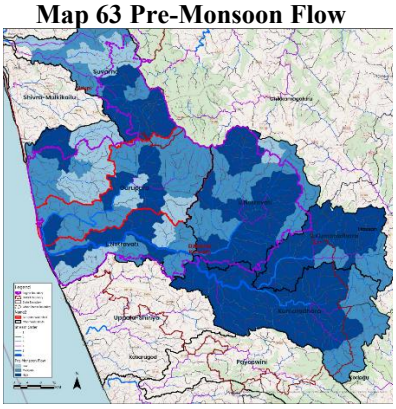
Pre & Post monsoon			
Stream Length (km)	Drainage density km/km²		
	< 0.5	0.5 - 0.6	> 0.6
0 - 11.47	Low	Low	Moderate
11.48 - 22.94	Moderate	Moderate	High
22.95 - 34.42	Moderate	High	High

Monsoon			
Stream Length (km)	Drainage Density km/km²		
	< 0.5	0.5 - 0.6	> 0.6
0 - 11.47	Moderate	High	High
11.48 - 22.94	High	High	High
22.95 - 34.42	High	High	High

Source 128 Author

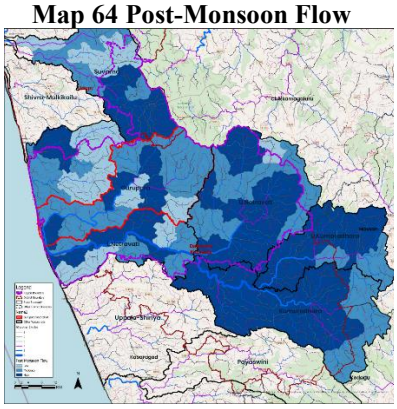
Based on the seasonal flow decision matrix, the Seasonal flow of the watersheds is generated.

Map 63 Pre-Monsoon Flow



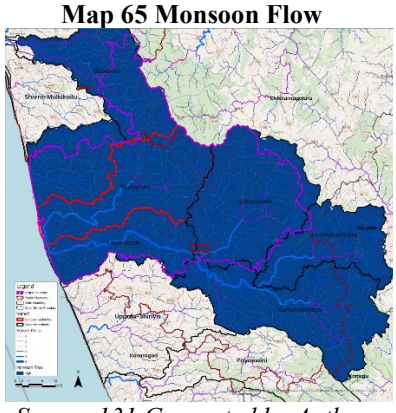
Source 129 Generated by Author

Map 64 Post-Monsoon Flow



Source 130 Generated by Author

Map 65 Monsoon Flow



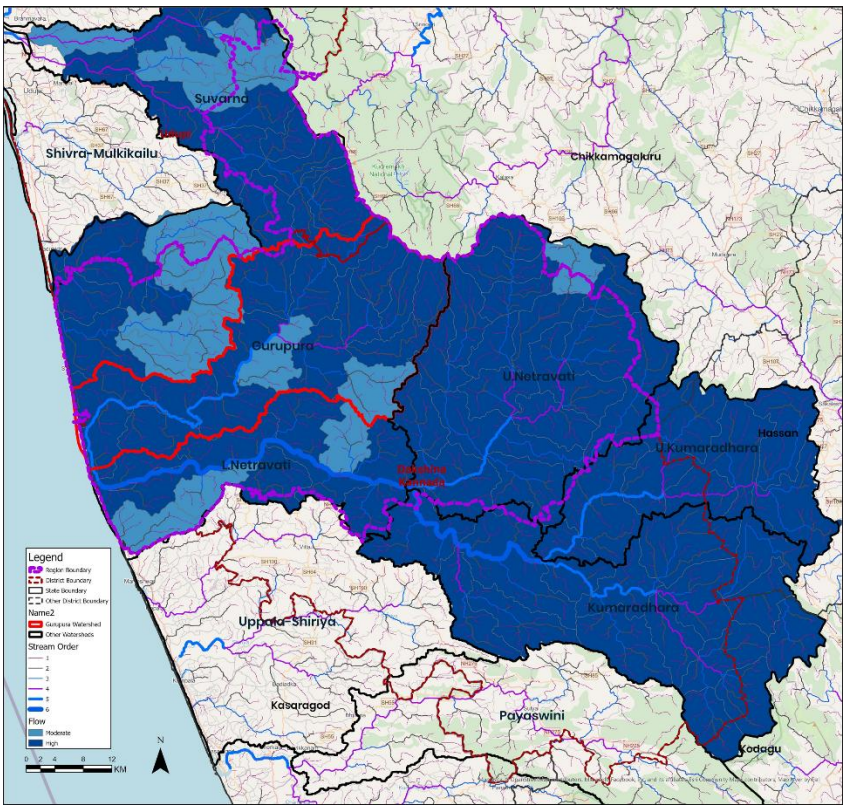
Source 131 Generated by Author

Table 27 Cumulative flow decision matrix based on seasonal flow

Pre-Monsoon Flow	Monsoon Flow	Post-Monsoon Flow	Cumulative Flow
Low	Low	Low	Low
Low	Low	Moderate	Moderate
Low	Low	High	Moderate
Low	Moderate	Low	Moderate
Low	Moderate	Moderate	Moderate
Low	Moderate	High	High
Low	High	Low	Moderate
Low	High	Moderate	High
Low	High	High	High
Moderate	Low	Low	Moderate
Moderate	Low	Moderate	Moderate
Moderate	Low	High	High
Moderate	Moderate	Low	Moderate
Moderate	Moderate	Moderate	High
Moderate	Moderate	High	High
Moderate	High	Low	High
Moderate	High	Moderate	High
Moderate	High	High	High
High	Low	Low	High
High	Low	Moderate	High
High	Low	High	High
High	Moderate	Low	High
High	Moderate	Moderate	High
High	Moderate	High	High
High	High	Low	High
High	High	Moderate	High
High	High	High	High

Source 132 Compiled by Author

Map 66 Cumulative flow of sub-watersheds



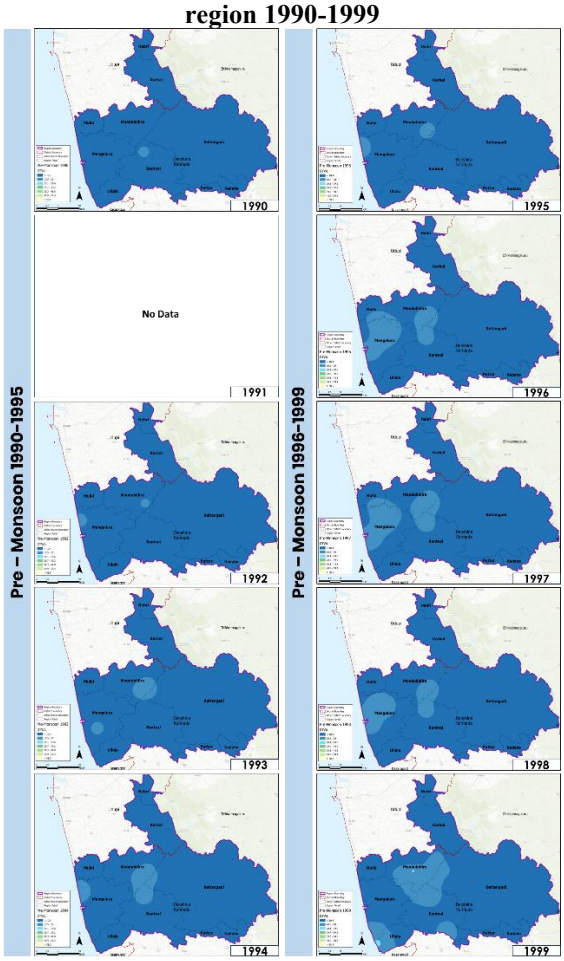
Source 133 Generated by Author

Inference: Gurupura Watershed has high flow watersheds.

Ground water

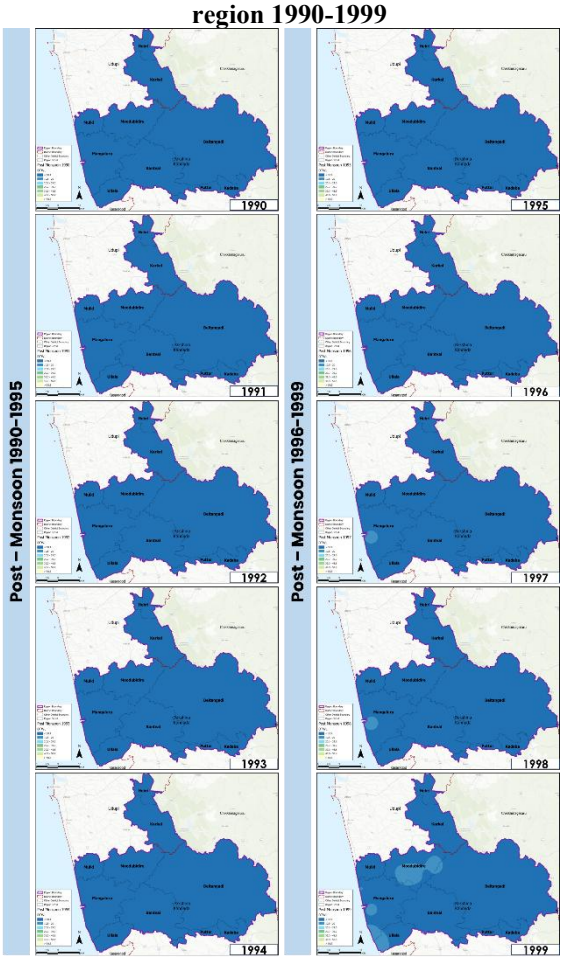
The ground water levels during pre-monsoon, post-monsoon & monsoon with fluctuations is studied to understand the impact of natural & human activities and develop strategies for sustainable water management. 30-year data, from the period of 1990 to 2020 is considered for the same.

Map 67 Pre-Monsoon Depth to water level in the region 1990-1999



Source 134 Generated by Author, using District ground water board data

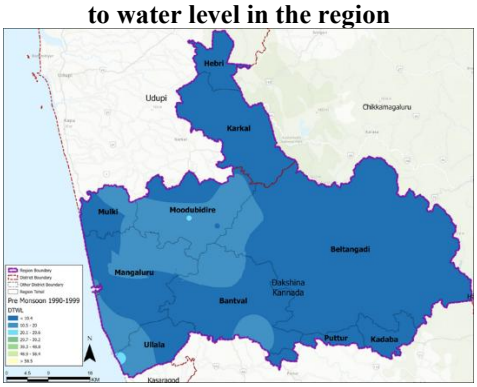
Map 68 Post-Monsoon Depth to water level in the region 1990-1999



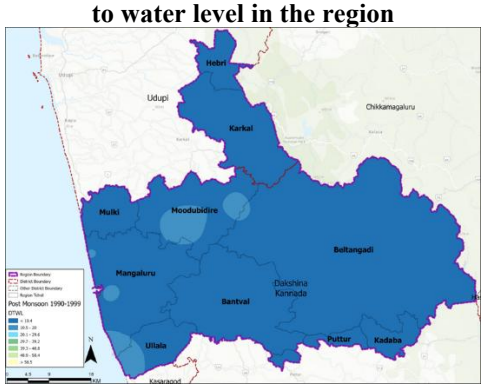
Source 135 Generated by Author, using District ground water board data



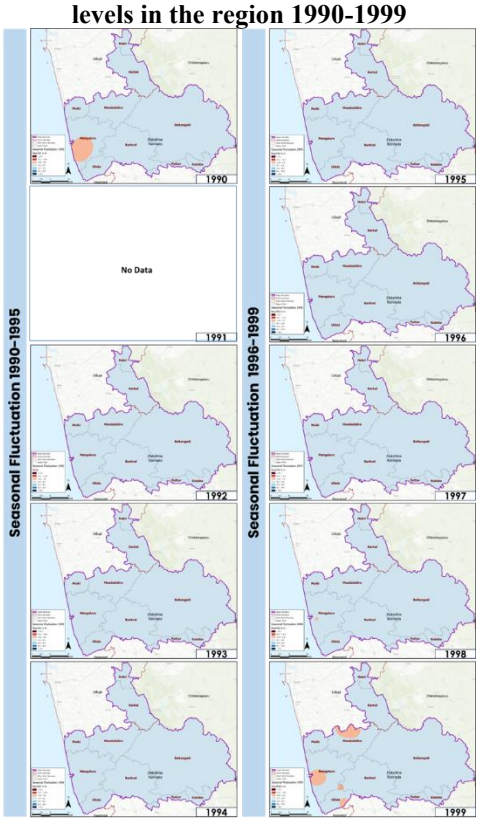
Map 69 Decadal (1990-1999) Pre-Monsoon Depth to water level in the region

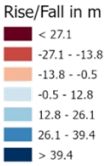


Map 70 Decadal (1990-1999) Post-Monsoon Depth to water level in the region

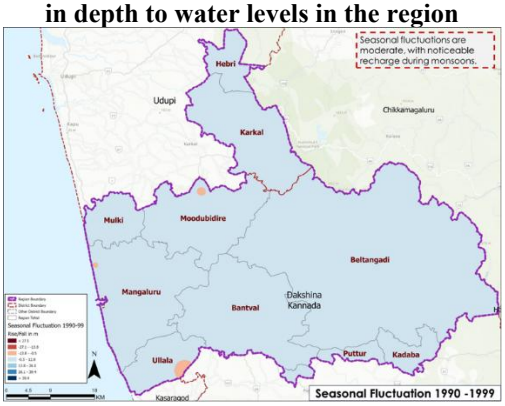


Map 71 Seasonal Fluctuation in depth to water levels in the region 1990-1999

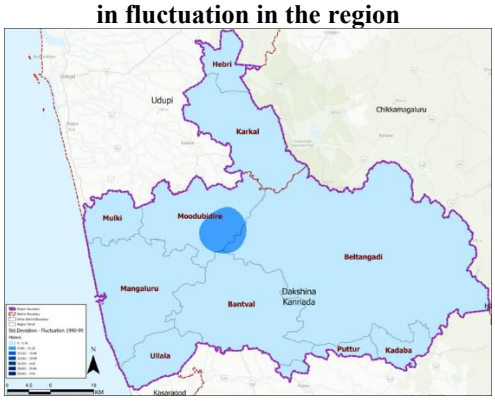




Map 72 Decadal (1990-1999) Seasonal Fluctuation in depth to water levels in the region



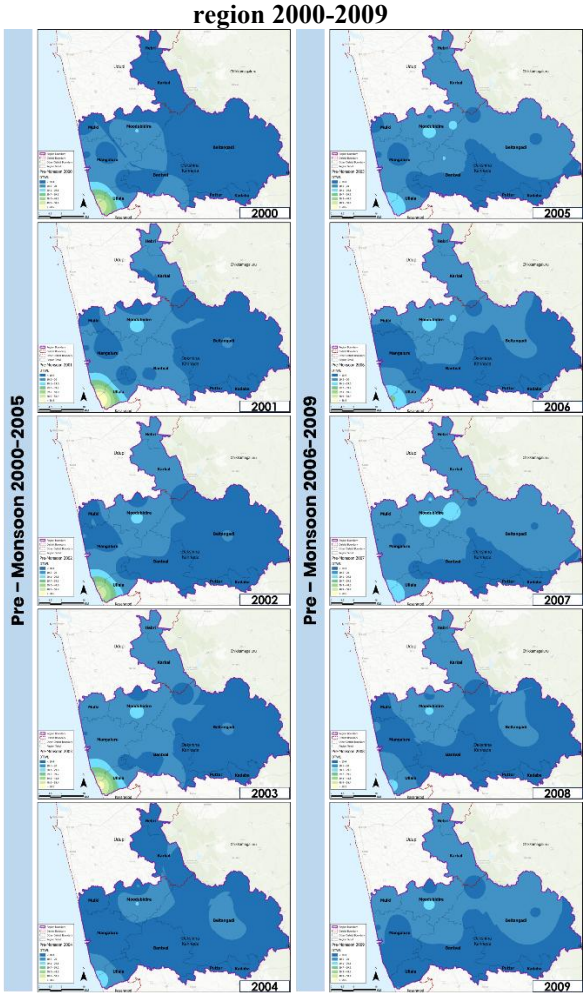
Map 73 Decadal (1990-1999) Standard deviation in fluctuation in the region



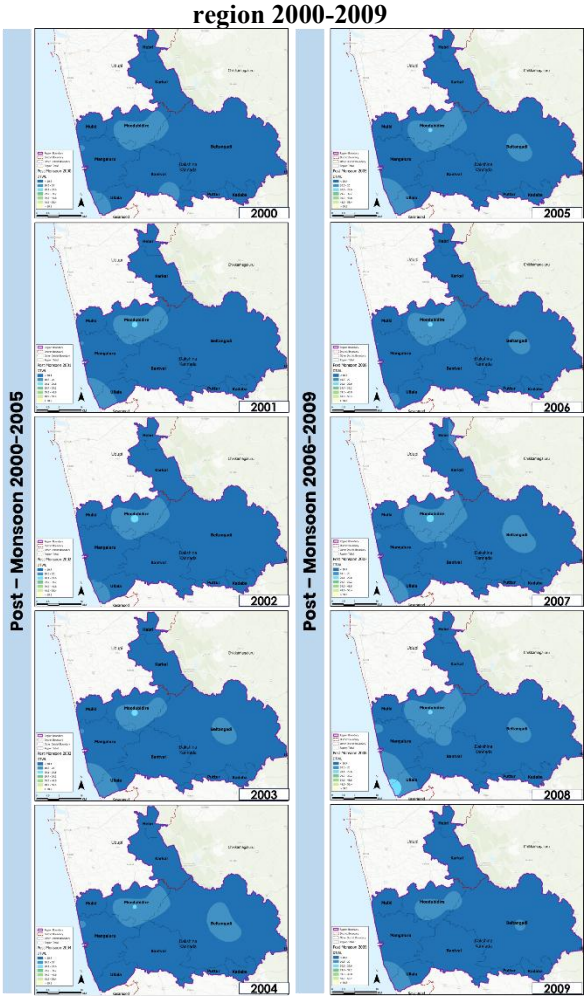
Source 136 Generated by Author, using District ground water board data

Inference: From 1990–1999: DTWL remains stable between 0. to 10.4m, in the urban areas the depth goes up to 20.1m.

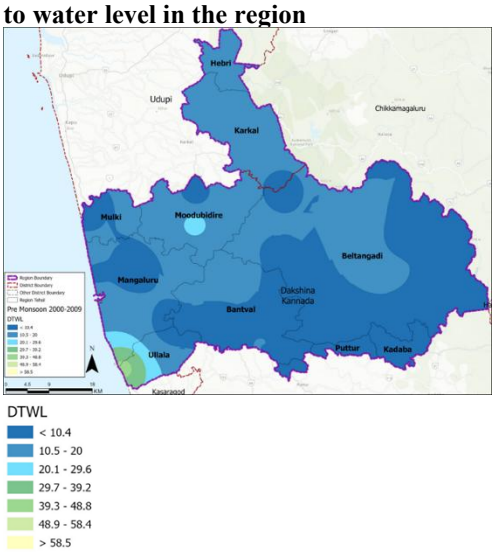
Map 74 Pre-Monsoon Depth to water level in the region 2000-2009



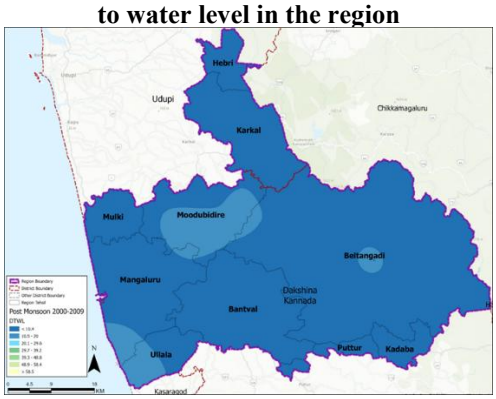
Map 75 Post-Monsoon Depth to water level in the region 2000-2009



Map 76 Decadal (2000-2009) Pre-Monsoon Depth to water level in the region

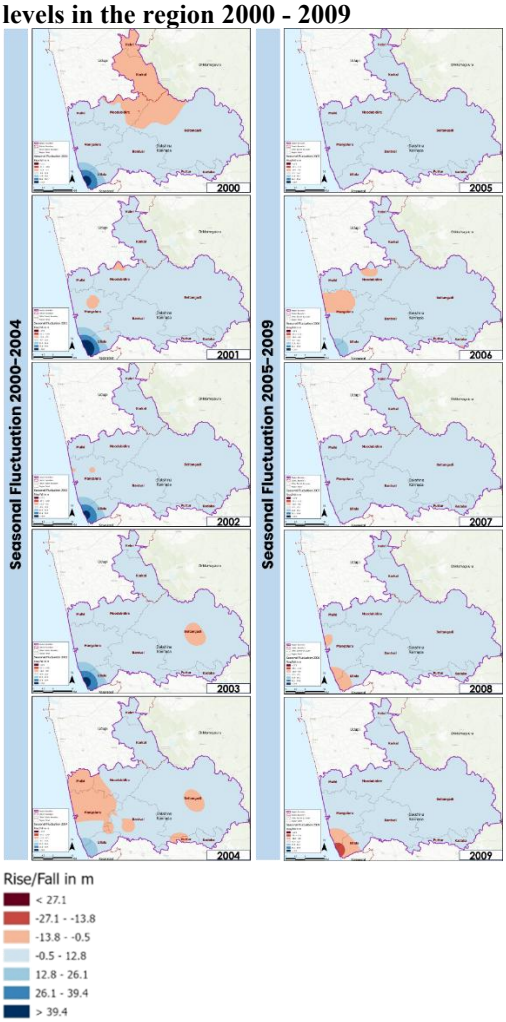


Map 77 Decadal (2000-2009) Post-Monsoon Depth to water level in the region

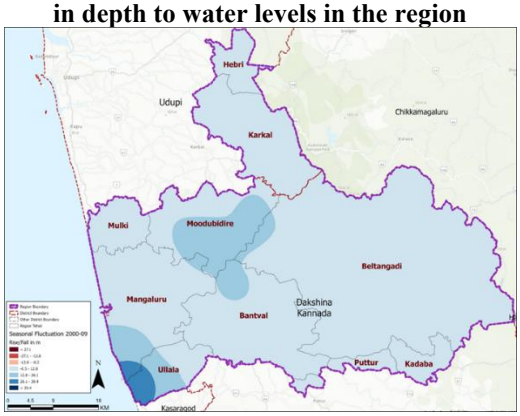


Source 137 Generated by Author, using District ground water board data

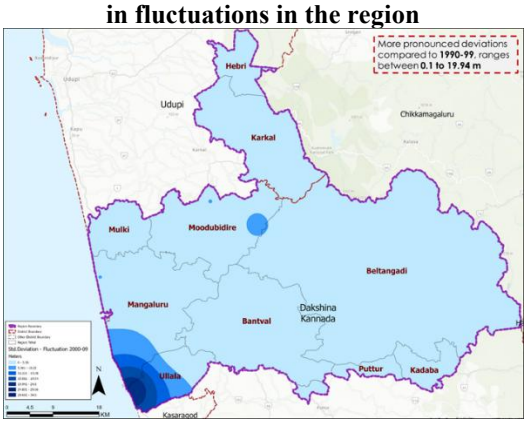
Map 78 Seasonal Fluctuation in depth to water levels in the region 2000 - 2009



Map 79 Decadal (2000-2009) Seasonal Fluctuation in depth to water levels in the region



Map 80 Decadal (2000-2009) Standard Deviation in fluctuations in the region

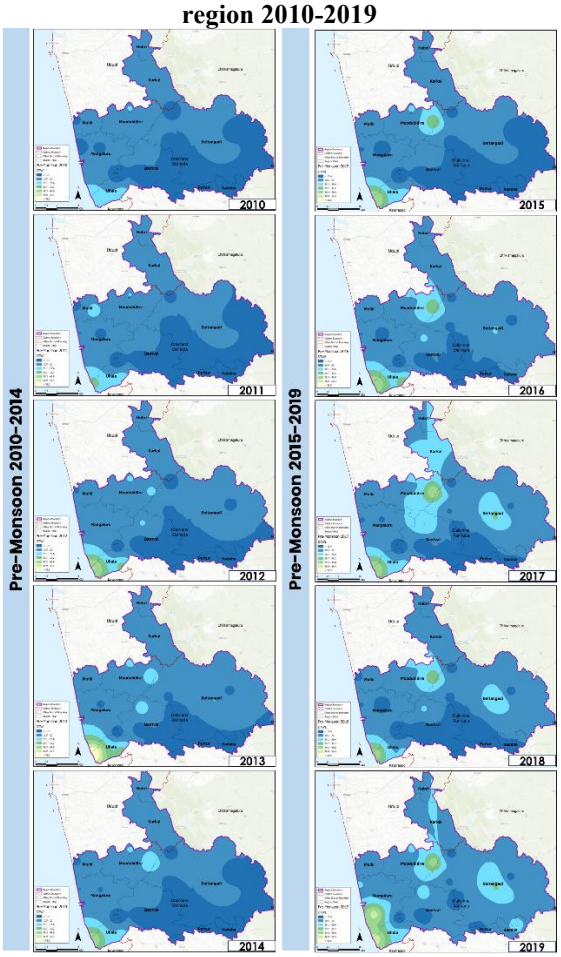


Source 138 Generated by Author, using District ground water board data

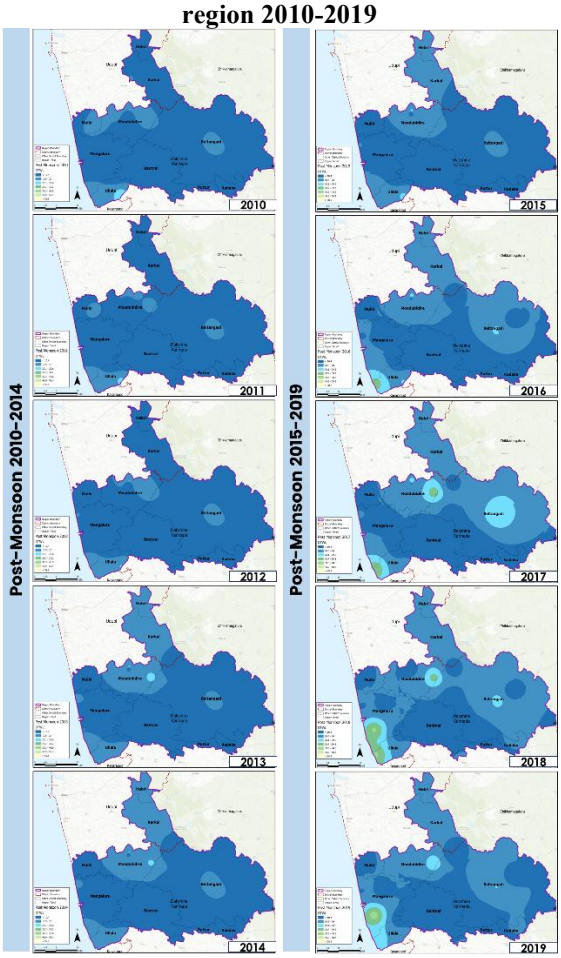
Inference:

From 2000 to 2009, Increased urbanization had led to more pronounced pre-monsoon declines, especially in urban areas. Fluctuation is more pronounced compared to the first decade, particularly along the coast in the South western part of the region, suggesting more erratic recharge and depletion cycles.

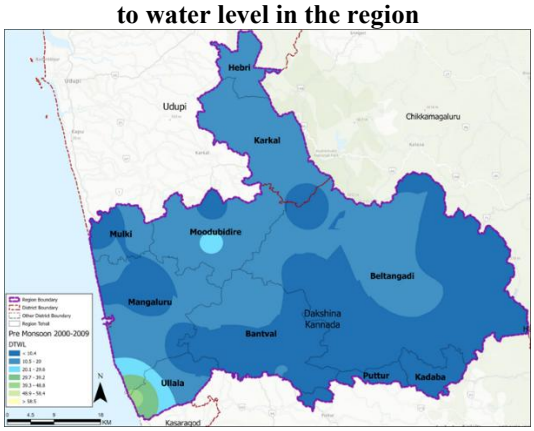
Map 81 Pre-Monsoon Depth to water level in the region 2010-2019



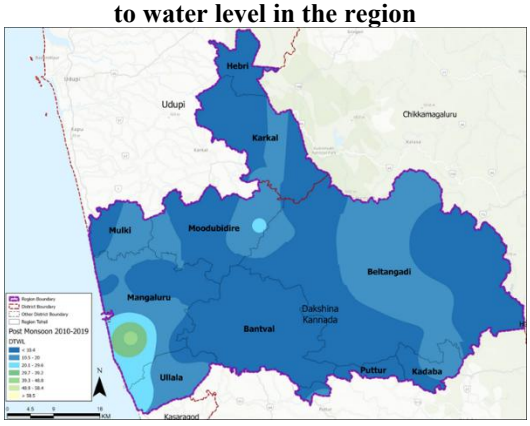
Map 82 Post-Monsoon Depth to water level in the region 2010-2019



Map 83 Decadal (2010-2019) Pre-Monsoon Depth to water level in the region

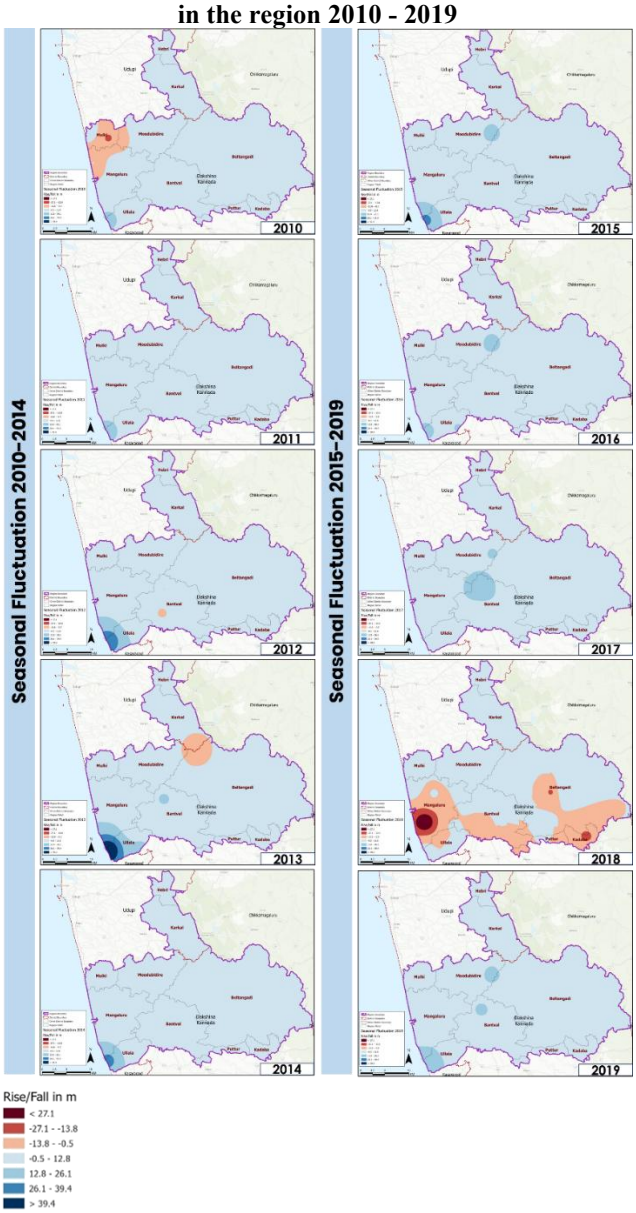


Map 84 Decadal (2010-2019) Post-Monsoon Depth to water level in the region

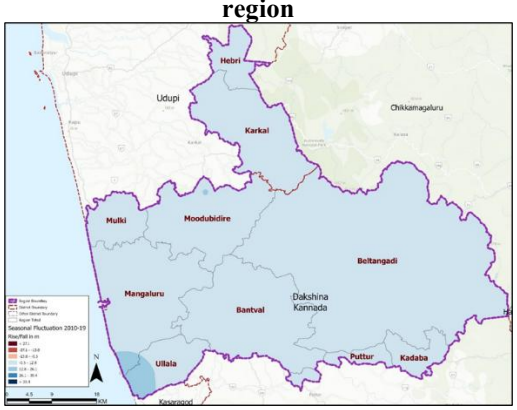


Source 139 Generated by Author, using District ground water board data

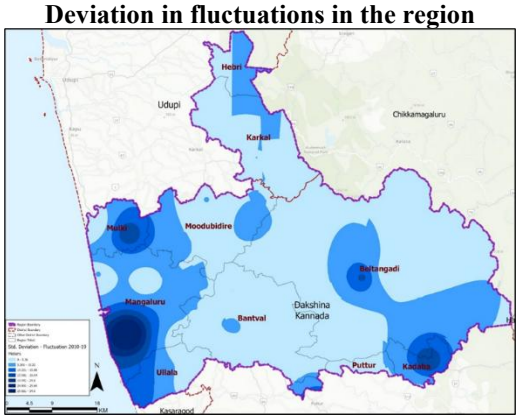
Map 85 Seasonal Fluctuation in depth to water levels in the region 2010 - 2019



Map 86 Decadal (2010-2019) Seasonal Fluctuation in depth to water levels in the region



Map 87 Decadal (2010-2019) Standard Deviation in fluctuations in the region

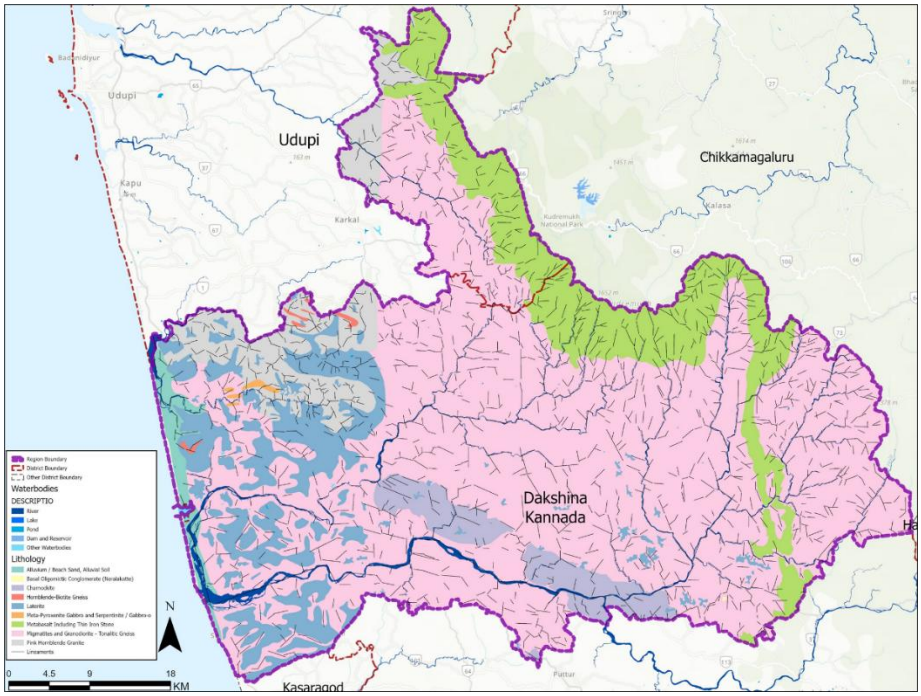


Source 140 Generated by Author, using District ground water board data

Inference:

1. **From 2010–2019:** DTWL has increased, and goes beyond **48.65m** & fluctuation becomes more severe indicating unsustainable groundwater use and reduced recharge efficiency.
2. **Pre-monsoon DTWL** shows a decline across the decades, particularly around the urban areas of Mangaluru, Ullala and Bantval indicating increased extraction.
3. **Post-monsoon DTWL** indicates partial recharge but with a declining trend over the decades, suggesting insufficient replenishment relative to extraction.
4. **Coastal regions** face added stress due to **saline intrusion** caused by **over-extraction of groundwater.**

- **Map 88 Rock formation & Lineaments in the region**



- *Source 141 Bhukosh*

Along with aquifer types, understanding the rock formation and lineaments are helpful in identifying the rock types and recharge potential in the region. The tables below capture the characteristics of the area based on rock type & also draws its recharge potential.

Table 28 High recharge potential zones

Rock Type	Recharge Potential	Characteristics
Alluvial Deposits (Sand, Riverine Sediments)	Very High	High porosity & permeability, direct infiltration. Supports shallow unconfined aquifers.
Laterite	Moderate to High	Porous, acts as a sponge storing rainwater, allowing slow infiltration to deeper aquifers.
Fractured & Weathered Gneiss, Granite	Moderate	Secondary porosity (cracks & fractures) enables water movement. Recharge improves in jointed areas.

Source 142 Compiled by author

Table 29 Moderate recharge potential zones

Rock Type	Recharge Potential	Characteristics
Hornblende-Biotite Gneiss	Moderate	Stores water in fractures. Recharge depends on weathering depth.
Phyllites & Schists	Moderate	Secondary permeability controls recharge. Slow but steady percolation.

Source 143 Compiled by author

Map 89 Low recharge potential zones

Rock Type	Recharge Potential	Characteristics
Charnockite & Massive Granite	Low	Extremely low porosity, limits direct infiltration. Recharge occurs only in fractured zones.
Basalt & Conglomerates	Low-Moderate	Recharge possible in vesicular basalt but limited in dense formations.

Source 144 Compiled by author

Inference

Coastal & Riverine Areas (Alluvium & Sand) indicate the best recharge zones but vulnerable to saline water intrusion. Managed aquifer recharge (MAR) is essential. **Lateritic rock** is Suitable for rainwater harvesting & percolation ponds to enhance recharge. **Fractured Crystalline** Rocks also indicated that recharge can be improved by infiltration wells along lineaments. **Massive Hard Rocks (Charnockite & Granite**) have limited natural recharge; artificial recharge structures needed in fracture zones.

3.3.4 Biotic Environment

Forest

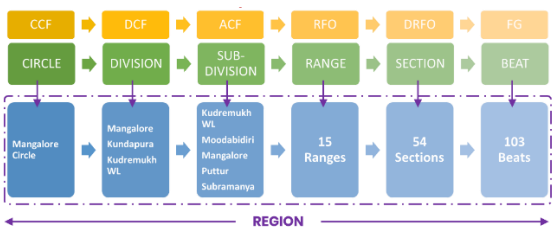
46% of the district is under forest cover, Reserve Forest constitutes the majority of the forest area, and a part of **Kudremukh National Park** a Biodiversity Hotspot continues into Udupi District.

Forest administrative boundary

The forest in the region falls under the Mangalore Forest circle, which is the highest administrative hierarchy. The circle is further divided into division, sub-division, Range, Section & beat which is the smallest administrative division in forests.

Governance order is as follows, Circle – Headed by Chief Conservator of Forest (CCF), Division - Deputy Conservator of Forest (DCF), Sub-Division - Assistant Conservator of Forest (ACF), Range - Range Forest Officer, Section - Deputy Range Forest Officer, Beat - Forest Guard

Figure 43 Forest Administration & Hierarchy



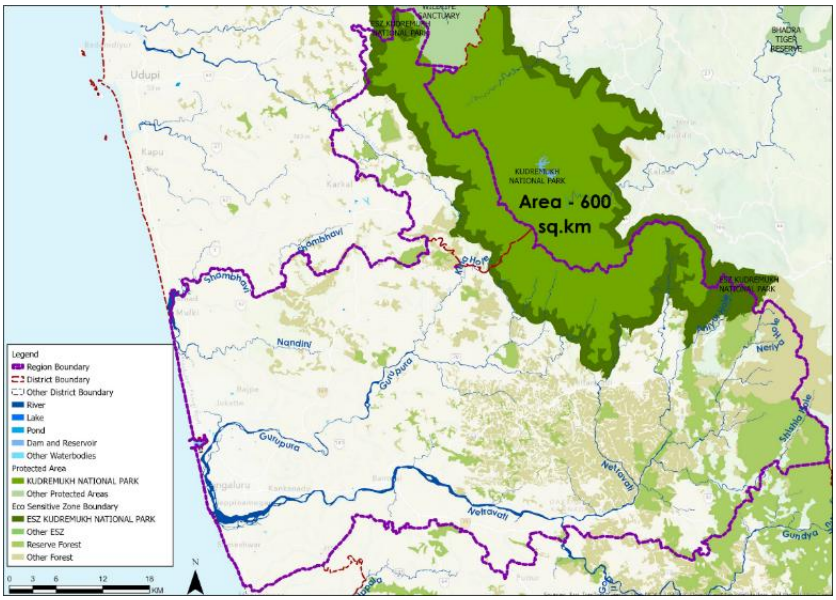
Source 145 Compiled by Author

Map 90 Forest Area

Forest type	Area (Sq.km)	% area of Region
Protected area	345.30	10.30
ESZ Boundary (1km wide)	177.46	5.29
Reserve forest	466.09	13.90
Other forest	467.39	13.94

Source 146 Compiled by Author

Map 91 Forest Area in the region



Source 147 SoI toposheet & KGIS

Kudremukh National Park is a part of the region and is identified as ESZ1 under the Western Ghats Ecology Expert Panel (WGEEP)

Geographic and Geomorphological Characteristics

Situated in the Chikkamangaluru, Udupi & Dakshin Kannada Districts. It is a part of the Western Ghats, a UNESCO World Heritage Site, Biodiversity Hotspot, one of the world's most critical ecological regions. This encompasses rugged terrain, rolling hills, and lush valleys, with interspersed waterfalls, streams, and dense forests. The Kudremukh peak, standing at **1,894 meters** (6,214 feet), is the third highest peak in Karnataka. Some of the common species found in Kudremukh Nation Park is listed in the table below.

Figure 44 Endangered species in the region



Source 148 Compiled by Author

Flora & Fauna

Table 30 List of Flora found in the region

Flora				
Scientific Name	**Common Name**	**IUCN Status**	**WPA Schedule**	**CITES Appendix**
Trees				
Santalum album	Indian Sandalwood	Vulnerable	VI	II
Dalbergia latifolia	Indian Rosewood	Vulnerable	VI	II
Pterocarpus santalinus	Red Sandalwood	**Endangered**	VI	II
Hopea parviflora	-	**Endangered**	-	-
Dipterocarpus indicus	Doom Tree	**Endangered**	VI	II
Mangifera indica	Mango	Least Concern	-	-
Terminalia arjuna	Arjun Tree	Least Concern	-	-
Xylia xylocarpa	Ironwood	-	-	-
Vateria indica	White Dammar	Vulnerable	-	-
Ficus benghalensis	Banyan Tree	Least Concern		
Ficus religiosa	Peepal Tree	Least Concern		
Cassia fistula	Golden Shower Tree	Least Concern		
Eucalyptus grandis	Eucalyptus	Least Concern		
Aegle marmelos	Bael	-	-	-
Artocarpus lakoocha	Monkey Jack	-	-	-
Garcinia indica	Kokum	-	-	-
Garcinia xanthochymus	False Mangosteen	-	-	-
Sapindus emarginata	Soapnut	-	-	-
Emblica officinalis	Amla/Indian Gooseberry	-	-	-
Artocarpus heterophyllus	Jackfruit	-	-	-
Limonia acidissima	Wood Apple	-	-	-
Ziziphus mauritiana	Indian Jujube	-	-	-
Mangifera indica	Mango	Least Concern	-	-
Shrubs				
Nilgirianthus ciliatus	-	Vulnerable	-	-
Clerodendrum inerme	Wild Jasmine	-	-	-
Adhatoda vasica	Malabar Nut	-	-	-
Carissa congesta	Karanda	-	-	-
Ixora brachiata	Jungle Flame	-	-	-
Climbers				
Abrus precatorius	Gulaganji	-	-	-
Calamus thwaitesii	Rattan	Least Concern	-	II
Entada pursaetha	-	Least Concern	-	-
Coscinium fenestratum	Tree Turmeric	Vulnerable	-	II
Cayratia pedata	Wild Grape	-	-	-
Entada pursaetha	African Dream Herb	-	-	-
Medicinal Plants				
Rauvolfia serpentina	Sarpagandha	**Endangered**	VI	II
Saraca asoca	Ashoka Tree	Vulnerable	-	-
Tinospora cordifolia	Guduchi	Least Concern	-	-
Vitex negundo	Nirgundi	Least Concern	-	-
Cinnamomum verum	True Cinnamon	-	-	-
Hemidesmus indicus	Indian Sarsaparilla	-	-	-
Aquatic and Mangroves				
Rhizophora mucronata	-	Least Concern	-	II
Acrostichum aureum	Golden Fern	Least Concern	-	-
Acanthus ilicifolius	Sea Holly	Least Concern	-	-
Avicennia marina	Grey Mangrove	Least Concern	-	-
Nymphaea pubescens	Water Lily	-	-	-
Porteresia coarctata	Wild Rice	-	-	-
Grass				
Bambusa arundinacea	Indian Thorny Bamboo	Least Concern	-	-
Dendrocalamus strictus	Solid Bamboo	Least Concern	-	-
Ochlandra travancorica	Travancore Reed	-	-	-
Cymbopogon martinii	Rosha Grass	-	-	-
Cymbopogon nardus	Citronella Grass	-	-	-

Source 149 Compiled by Author

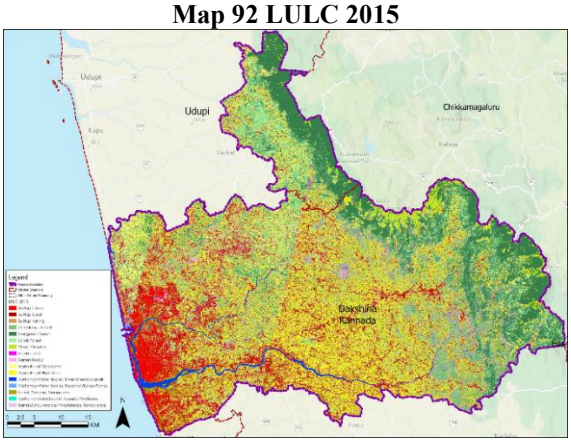
Table 31 List of Fauna found in the region & their status

Mammals				
Scientific Name	**Common Name**	**IUCN Status**	**WPA Schedule**	**CITES Appendix**
Panthera tigris	Bengal Tiger	Endangered	I	I
Panthera pardus	Indian Leopard	Vulnerable	I	I
Melursus ursinus	Sloth Bear	Vulnerable	I	I
Bos gaurus	Indian Gaur	Vulnerable	I	I
Axis axis	Spotted Deer	Least Concern	III	-
Muntiacus muntjak	Barking Deer	Least Concern	III	-
Cervus unicolor	Sambar Deer	Vulnerable	III	-
Ratufa indica	Malabar Giant Squirrel	Near Threatened	II	II
Trachypithecus johnii	Nilgiri Langur	Vulnerable	I	I
Macaca silenus	Lion-tailed Macaque	Endangered	I	I
Cuon alpinus	Indian Wild Dog	Endangered	I	I
Sus scrofa	Wild Boar	Least Concern	III	-
Lutrogale perspicillata	Smooth-coated Otter	Vulnerable	II	II
Elephas maximus	Asian Elephant	Endangered	I	I
Prionailurus bengalensis	Leopard Cat	Least Concern	I	II
Viverricula indica	Small Indian Civet	Least Concern	II	III
Funambulus palmarum	Indian Palm Squirrel	-	-	-
Herpestes edwardsii	Indian Grey Mongoose	-	-	-
Avian Fauna				
Buceros bicornis	Great Hornbill	Vulnerable	I	I
Ocyceros griseus	Malabar Grey Hornbill	Near Threatened	IV	-
Psittacula eupatria	Alexandrine Parakeet	Near Threatened	IV	II
Pitta brachyura	Indian Pitta	Least Concern	IV	-
Dendrocitta vagabunda	Rufous Treepie	Least Concern	IV	-
Ceyx erithaca	Oriental Dwarf Kingfisher	Least Concern	-	-
Gracula religiosa	Hill Myna	Least Concern	IV	II
Pavo cristatus	Indian Peafowl	Least Concern	I	-
Terpsiphone paradisi	Indian Paradise Flycatcher	Least Concern	-	-
Pycnonotus cafer	Red-vented Bulbul	-	-	-
Psittacula krameri	Rose-ringed Parakeet	-	-	-
Reptiles				
Ophiophagus hannah	King Cobra	Vulnerable	II	II
Python molurus	Indian Rock Python	Near Threatened	I	II
Varanus bengalensis	Bengal Monitor Lizard	Least Concern	I	I
Trimeresurus gramineus	Bamboo Pit Viper	Least Concern	-	-
Chrysopelea ornata	Ornate Flying Snake	Least Concern	-	-
Lycodon aulicus	Indian Wolf Snake	-	-	-
Coastal & Marine				
Chelonia mydas	Green Sea Turtle	Endangered	I	I
Dermochelys coriacea	Leatherback Turtle	Vulnerable	I	I
Aquatic Fauna				
Tor putitora	Mahseer	Endangered	I	-
Clarias dussumieri	Malabar Walking Catfish	Vulnerable	II	-
Etroplus suratensis	Pearl Spot Fish	Least Concern	IV	-
Barilius bakeri	Baker's Minnow	Least Concern	-	-
Invertebrates (Butterflies & Moths)				
Troides minos	Southern Birdwing	Least Concern	-	Appendix II
Papilio buddha	Malabar Banded Peacock	Least Concern	-	-
Graphium agamemnon	Tailed Jay	Least Concern	-	-
Junonia lemonias	Lemon Pansy	-	-	-
Apis dorsata	Giant Honey Bee	-	-	-
Amphibians				
Indirana gundia	Gundia Frog	Endangered	IV	-
Nyctibatrachus humayuni	Bombay Night Frog	Vulnerable	IV	-
Micrixalus saxicola	Wrinkled Frog	Near Threatened	IV	-
Euphlyctis cyanophlyctis	Indian Skittering Frog	Least Concern	-	-
Uperodon globulosus	Balloon Frog	Least Concern	-	-

Source 150 Compiled by Author

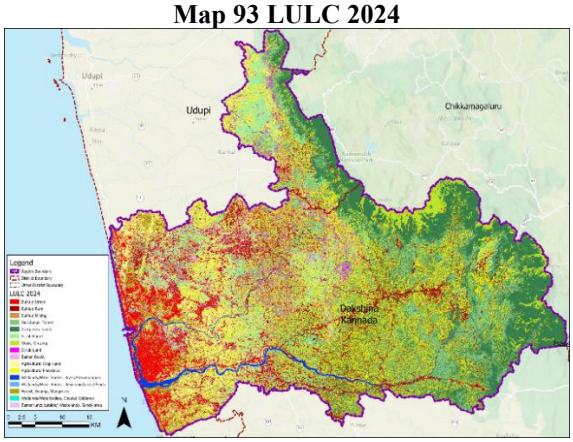
Forest Change Detection

Map 92 LULC 2015



Source 151 Generated by Author using Landsat 8 Imagery

Map 93 LULC 2024



Source 152 Source 186 Generated by Author using Landsat 8 Imagery

Table 32 Forest change

Sl no	Landuse Category	Area 2015	% Area	Area 2025	% Area	Area Change	% Area Change
4	Deciduous Forest	379.15	28.59	394.92	25.88	15.78	4.16
5	Evergreen Forest	520.66	39.26	618.30	40.52	97.64	18.75
6	Scrub Forest	306.56	23.12	367.69	24.09	61.13	19.94
7	Grass, Grazing	119.74	9.03	145.14	9.51	25.40	21.21
Total		1326.10		1526.04		199.94	15.08

Source 153 Author

Figure 45 Forest Area 2015

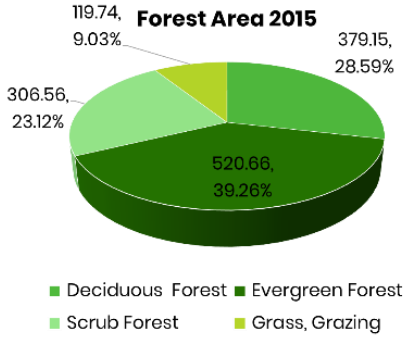
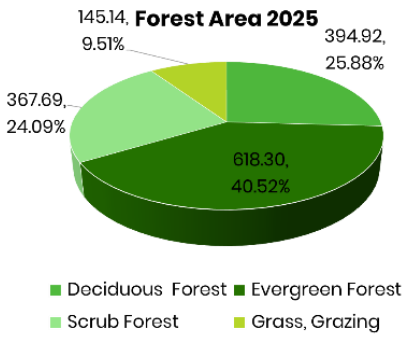


Figure 46 Forest Area 2024



Source 154 Author

3.3.5 Normalised Difference Vegetation Index (NDVI)

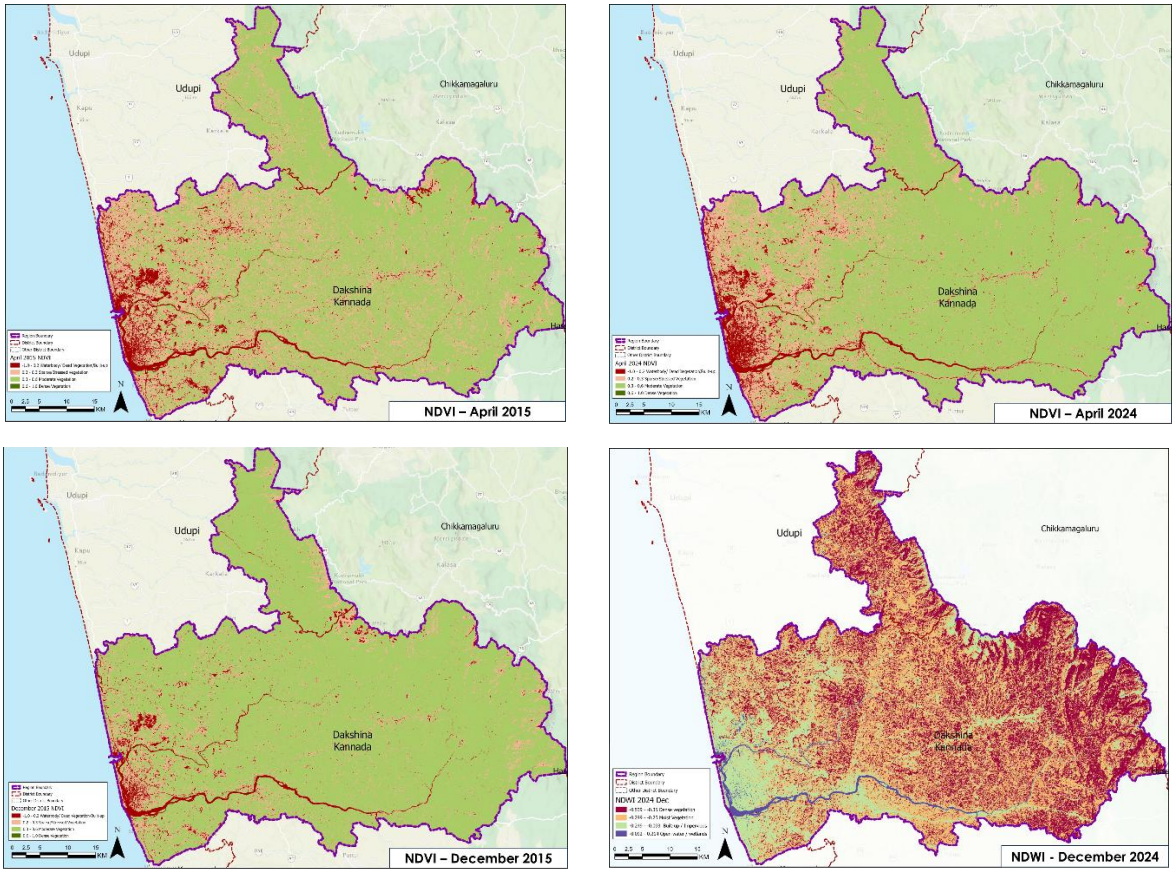
NDVI analysis of 2015 and 2024 has been used to assess the vegetation health across the region to understand the ecological integrity along the river corridors. The pre-monsoon and post-monsoon NDVI assessment shows a decline in "Moderate vegetation" and an increase in "Sparse/stressed vegetation" indicating possible land degradation.

Table 33 NDVI Analysis

NDVI Value	Characteristic	Apr-15	% Area of Region	Dec-15	% Area of Region	Apr-24	% Area of Region	Dec-24	% Area of Region	% Change April 2015 - 2024	% Change Dec 2015 - 2024
-1.0 to 0.2	Built-up	223.73	7.08	135.20	4.28	200.38	6.34	218.45	6.91	-0.74	2.64
0.2 to 0.3	Sparse/ stressed vegetation	845.49	26.76	389.60	12.33	596.5	18.88	644.93	20.41	-7.88	8.08
0.3 to 0.6	Moderate vegetation	2090.03	66.16	2634.45	83.39	2362.29	74.77	2295.90	72.67	8.62	-10.72
0.6 to 1.0	Dense Vegetation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source 155 Author

Map 94 NDVI - Pre-Monsoon & Post-Monsoon for 2015 & 2024



Source 156 Author

3.3.6 Normalized Difference Water Index (NDWI)

NDWI assessment of pre-monsoon and post-monsoon 2015 and 2024, helps detect the change in surface water presence across the region by identifying changes in waterbodies, shrinkage in rivers, loss of wetlands. The NDWI analysis shows no significant change in the presence of surface waterbodies, but the low NDWI value indicates that the rivers in the region are shallow surface water bodies.

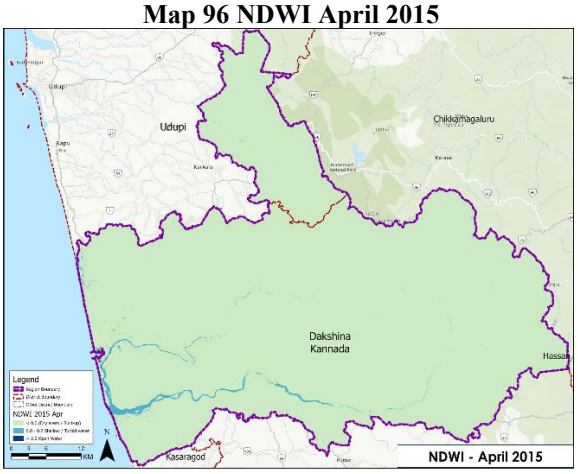
Although the region is dominated by perennial streams and high flow watersheds, the low NDWI values indicate Shallow rivers, which means there would be low storage capacity and retention time is less.

Map 95 NDWI Analysis

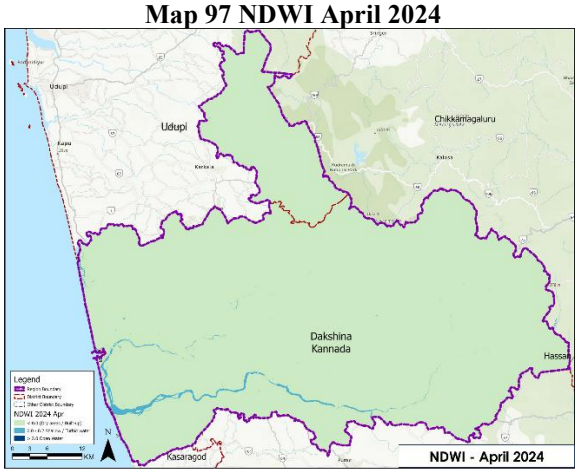
NDWI Value	Characteristic	Apr-15	% Area of Region	Dec-15	% Area of Region	Apr-24	% Area of Region	Dec-24	% Area of Region	% Change April 2015 - 2024	% Change Dec 2015 - 2024
< 0.0	Dry area/built-up/Dense Vegetation	3,137.01	98.99	3,135.75	98.95	3,136.81	98.98	3,134.92	98.92	-0.01	-0.03
0.0 - 0.2	Shallow/Turbid Water	32.10	1.01	33.36	1.05	32.30	1.02	34.19	1.08	0.01	0.03
> 0.2	Open Water	0	0.00	0	0.00	0	0.00	0	0.00	0.00	0.00

Source 157 Author

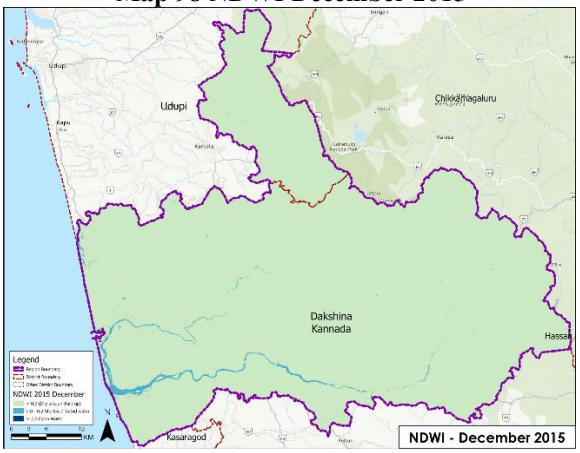
Map 96 NDWI April 2015



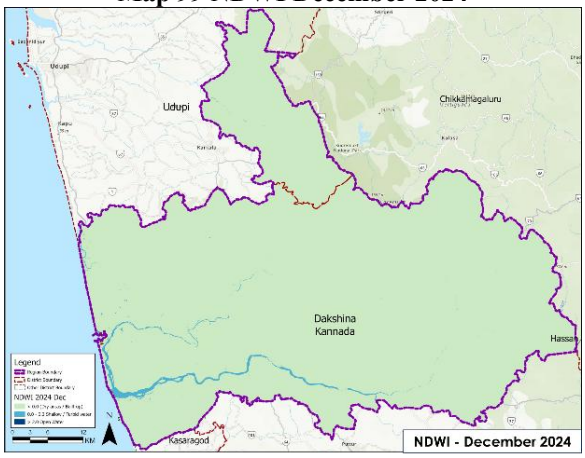
Map 97 NDWI April 2024



Map 98 NDWI December 2015



Map 99 NDWI December 2024



Source 158 Author

3.4 Settlement Analysis

3.4.1 Demographic & Socio-economic profile

The total population of Dakshin Kannada district is **20,89,649** as per Census of India 2011, which is **3.9%** of the state's population. The population of the scoped region is **16,33,129** which is about **78.04%** of the districts' population.

The growth trends in region reveal an increasing population with decreasing growth rates from 1981 to 2011, which suggests that development has stabilized, infrastructure has reached its capacity, and changes in economic conditions may have influenced migration patterns.

Within the region, Mangaluru is the most populous tehsil. Mangaluru' s population growth reflects its status as a burgeoning industrial hub, supported by its strong connectivity to National Highways connecting it to other coastal and inland areas.

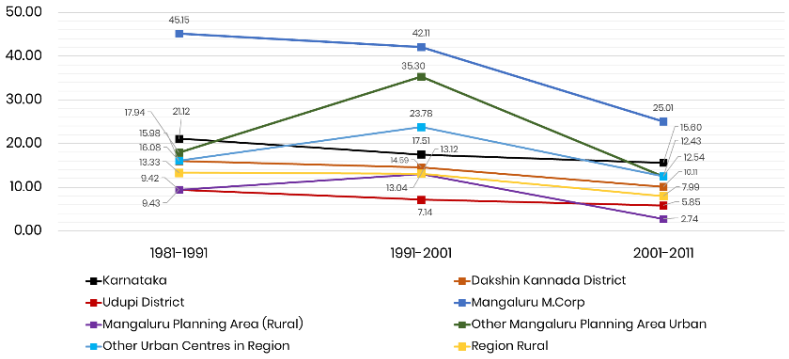
Total Area of the Region is **3,350.93 Sq.km**. Total Number of Village in the region is **232,** and has **38** Urban Centres. The population of the scoped region (Incl. LPA, M. Corp & other urban centres): **16,33,129**

Table 34 Population over the years

Area	Population			
	1981	1991	2001	2011
Karnataka	3,71,35,714	4,49,77,000	5,28,50,562	6,10,95,297
Dakshin Kannada District	14,28,028	16,56,165	18,97,730	20,89,649
Udupi District	9,48,696	10,38,099	11,12,243	11,77,361
Mangaluru M.Corp	193699	281161	399565	499487
Mangaluru Planning Area (Rural)	33,655	36,828	41,631	42,772
Other Mangaluru Planning Area Urban	112274	132413	179161	201430
Other Urban Centres	125069	145183	179706	202237
Rural (Region)	494739	560681	634215	684908

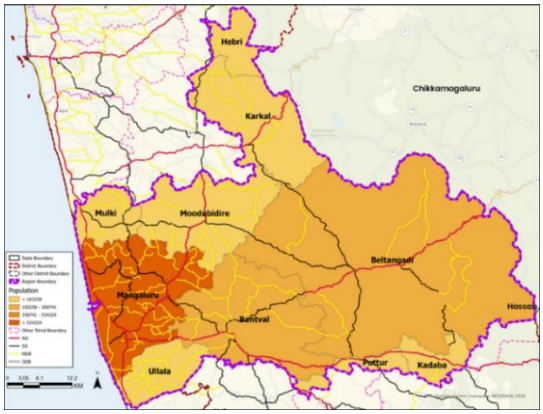
Source 159 Census of India

Figure 47 Growth rate over the years

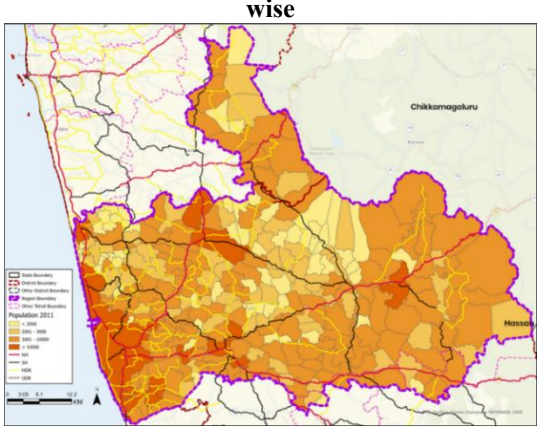


Source 160 Census of India

Map 100 Total population of the region – Tehsil wise



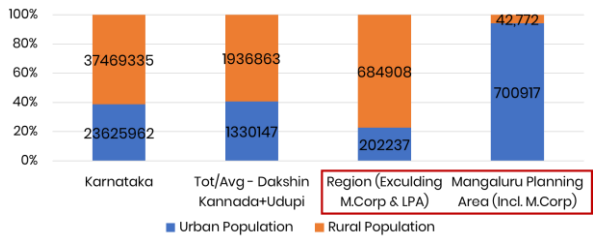
Map 101 Total population of the region – Village wise



Source 161 Generated by Author

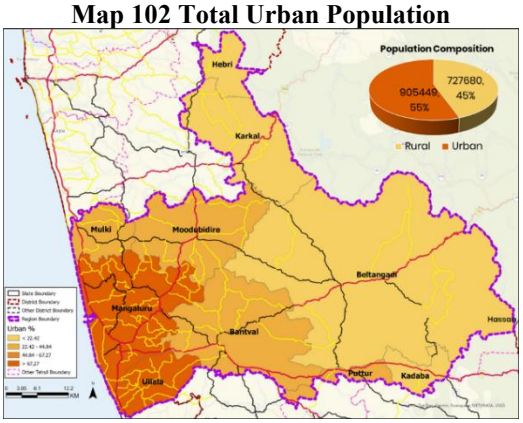
55.44% of the study region is Urban. The % of rural **(44.56)** is lower thana the state average of **61.3%.**

Figure 48 Population composition

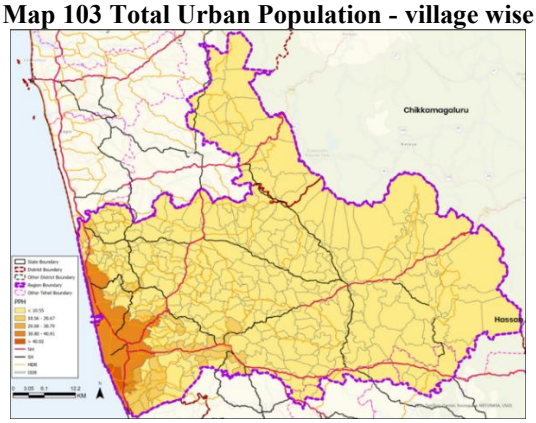


Source 162 Compiled by author

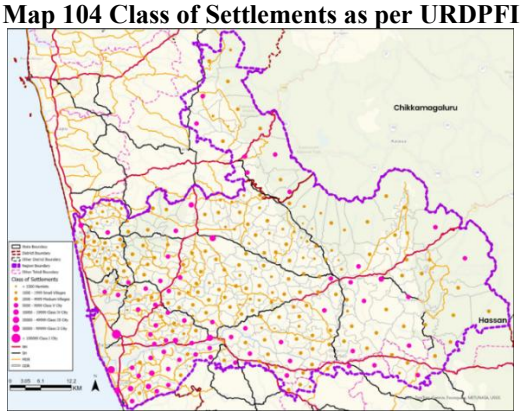
Map 102 Total Urban Population



Map 103 Total Urban Population - village wise



Map 104 Class of Settlements as per URDPFI



Source 163 Generated by author

Sex Ratio

Average sex. ratio of the region is **1024,** higher than the state, lower than districts. This indicates more female population who could potentially contribute to the region's economy.

Age Sex pyramid

The age sex pyramid revels a balanced sex ratio & typical age structure, indicating a stable & transitioning population. The broader bands in the middle age-group indicates large working-age population. The shrinking base suggests a decline in fertility rate & indicates a shift towards aging population. This would mean lesser young population entering workforce in the future.

Figure 49 Sex ratio

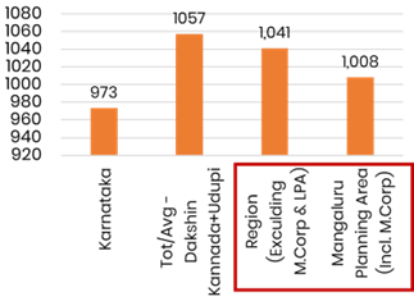
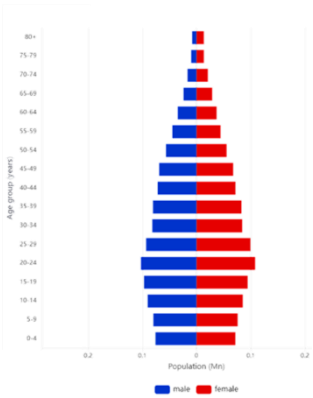
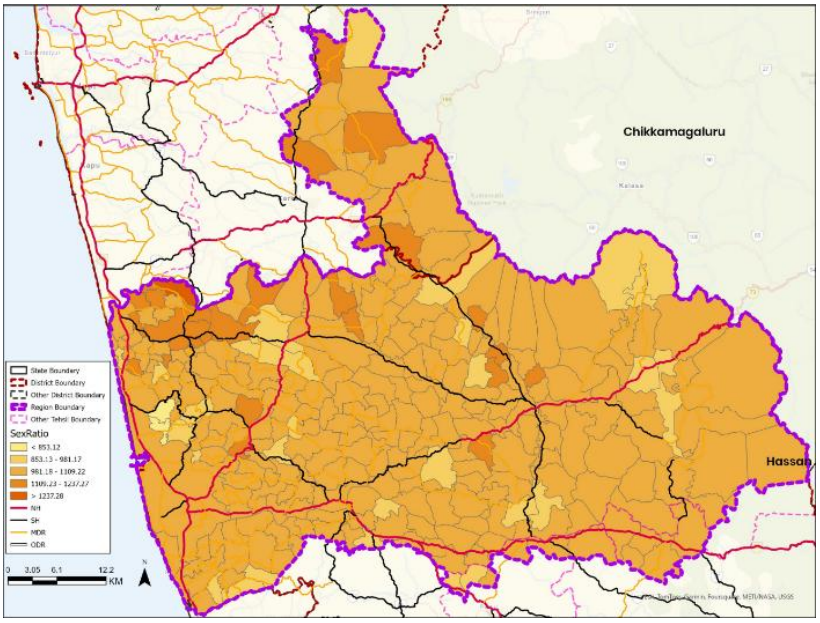


Figure 50 Age sex pyramid of Dakshin Kannada District



Source 164 Compiled by author

Map 105 Sex ratio in the region

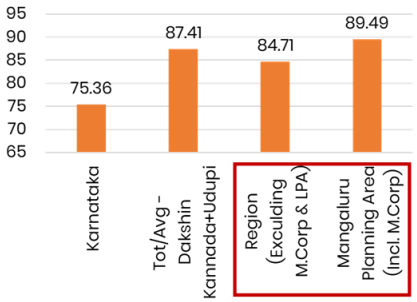


Source 165 Generated by author

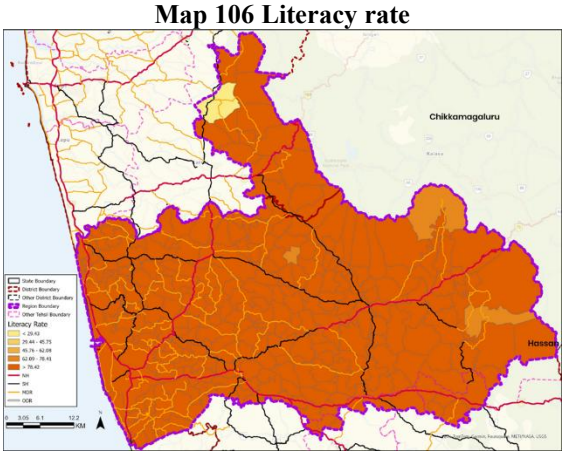
Literacy Rate

Average. Literacy rate in the region is **87.1%**, which is higher than state, lower than districts

Figure 51 Literacy rate



Map 106 Literacy rate

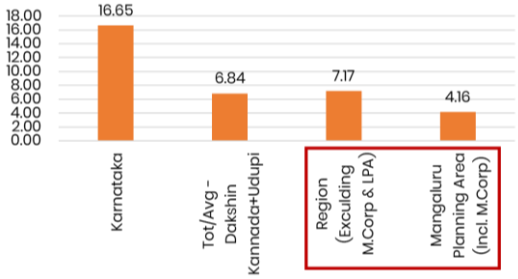


Source 166 Compiled by author

SC & ST Population

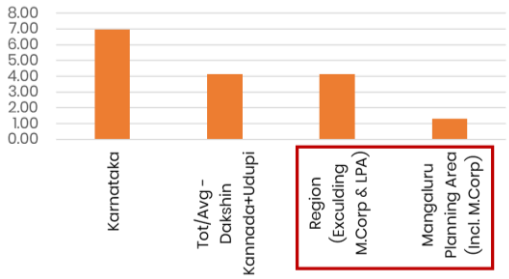
The average. SC Population in the region is **5.67%** Lower than state and districts average and the average ST Population in the region is **2.72%**, lower than state and districts.

Figure 52 SC Population



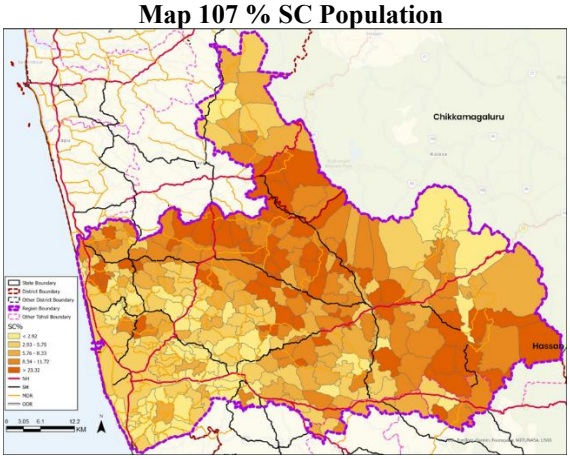
Source 167 Compiled by author

Figure 53 ST Population

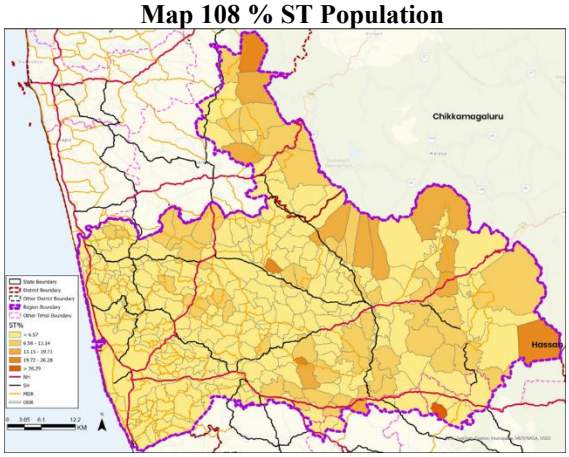


Source 168 Compiled by author

Map 107 % SC Population



Map 108 % ST Population



Source 169 Generated by author

Work-force participation

WFPR of the region is **46%,** which is More than state & District average. 90% of the Work force is main workers.

Figure 54 WFPR

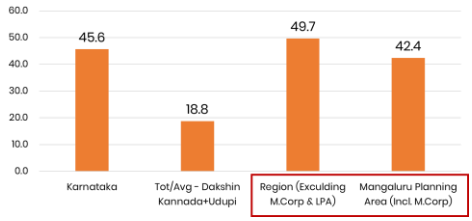


Figure 55 Workers' composition

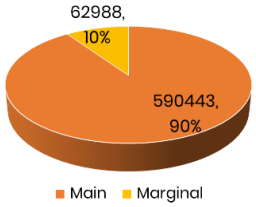


Figure 56 Gender composition in work force

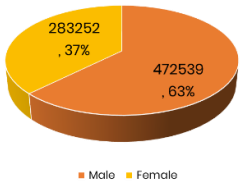
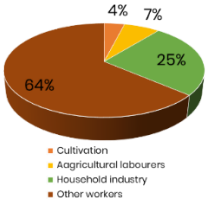


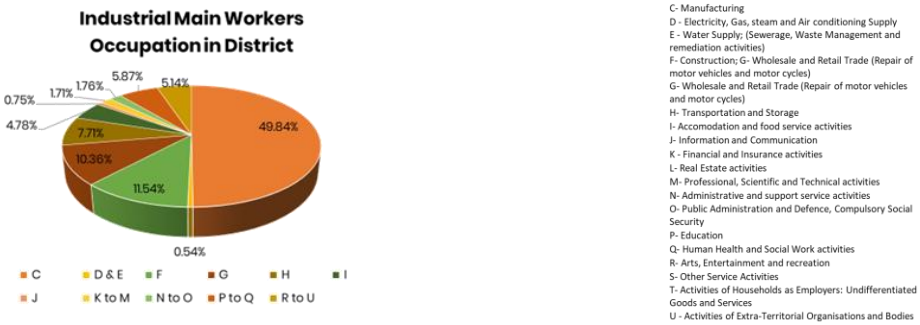
Figure 57 Occupation of workers



Source 170 Compiled by Author

63% of the working population is male. **64%** of the workers are under the "other workers category".

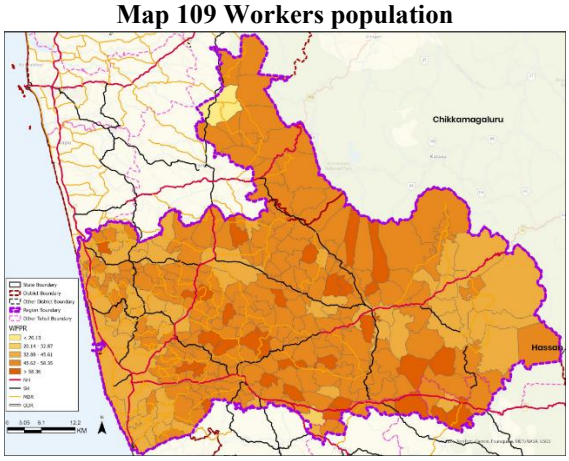
Figure 58 Occupation of the main "other workers" of Dakshin Kannada district



Source 171 Compiled by author

49.8% main industry workers fall under J category of main other worker, which is Information & Communication sector.

Map 109 Workers population



Source 172 Generated by author

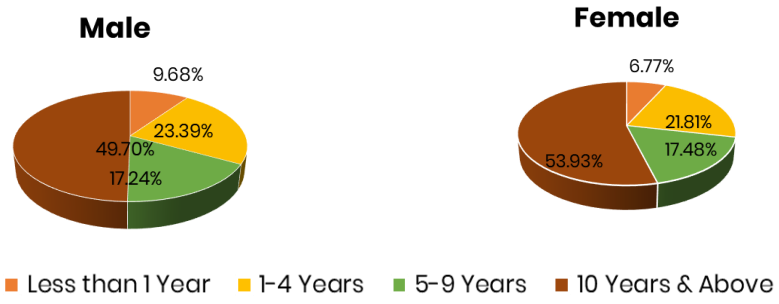
Migration

Table 35 Migration in Dakshin Kannada district

Category	Total	Male	Female
Total Population	20,89,649	10,34,714	10,54,935
Total Migrant Population	10,62,515	4,35,897	6,26,618
Total Rural Migrants	6,07,820	2,29,197	3,78,623
Total Urban Migrants	3,31,366	1,50,856	1,80,510
Total Non-Migrants	10,27,134	5,98,817	4,28,317

Source 173 Compiled by author

Figure 59 Duration of migration as per gender



Source 174 Compiled by author

The migration duration within the region is 10 years & above for both the genders.

Figure 60 Place of migration

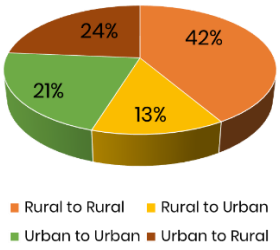
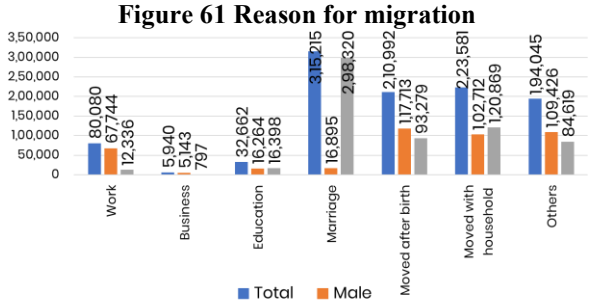


Figure 61 Reason for migration



Source 175 Compiled by author

The migration pattern in the district is **Rural to Rural**. The reason for **female population** migration is **marriage** & the **male population** is mostly **migration after birth, or moved with household and work.**

Population Estimation

Population is estimated using all three projection methods, Geometric, Arithmetic & Incremental method.

Table 36 Population estimation of Study Region (excluding LPA & M. Corp)

Study Region (Excluding LPA & M.Corp)									
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
4,94,739	5,60,681	6,34,215	6,84,908	Geometric	6,86,427	1,519	0.2	**7,35,582**	**7,53,108**
				Arithmetic	6,90,242	5,334	0.8		
				Incremental	6,77,281	-7,627	1.1		

Source 176 Author

Table 37 Population estimation of Mangaluru Planning Area (Including Mangaluru M. Corp)

Mangaluru Planning Area (Including Mangaluru M.Corp)									
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
3,39,628	4,50,402	6,20,357	7,43,689	Geometric	7,48,978	5,289	0.7	**8,84,055**	**9,39,341**
				Arithmetic	7,45,841	2,152	0.3		
				Incremental	7,22,375	-21,314	2.9		

Source 177 Author

Table 38 Population estimation of Mangaluru Municipal Corporation

Mangaluru Municipal Corporation									
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
1,93,699	2,81,161	3,99,565	4,99,487	Geometric	5,01,959	2,472	0.5	**6,02,421**	**6,43,852**
				Arithmetic	4,98,844	-643	0.1		
				Incremental	4,84,371	-15,116	3.0		

Source 178 Author

Table 39 Population estimation of other urban centres in the region

Other Urban Centres									
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
1,25,069	1,45,183	1,79,706	2,02,237	Geometric	2,03,555	1,318	0.7	2,29,557	2,40,198
				Arithmetic	2,02,954	717	0.4		
				Incremental	1,97,158	-5,079	2.5		

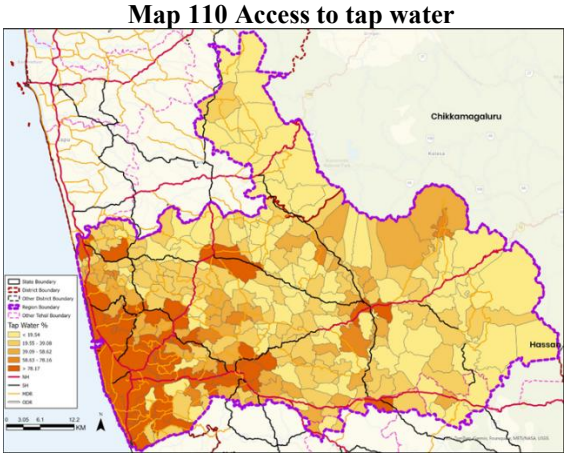
Source 179 Author

The total estimated population of the region for 2025 is **19,32,647**

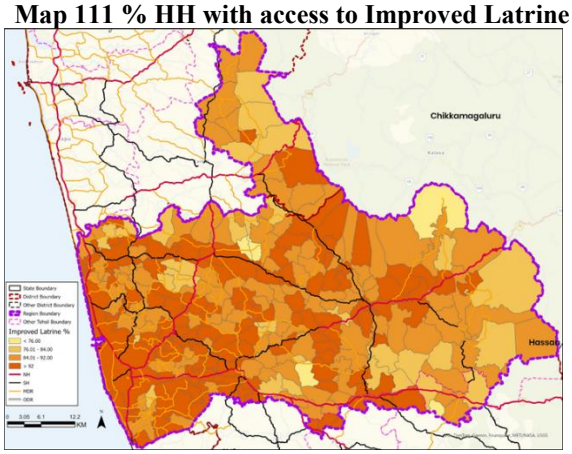
Access to Physical Infrastructure

Village wise percentage household having access to infrastructure facilities like access to tap water, Improved latrine, Septic tank, & Drainage is assessed for rural areas to understand the level of development of water related infrastructure.

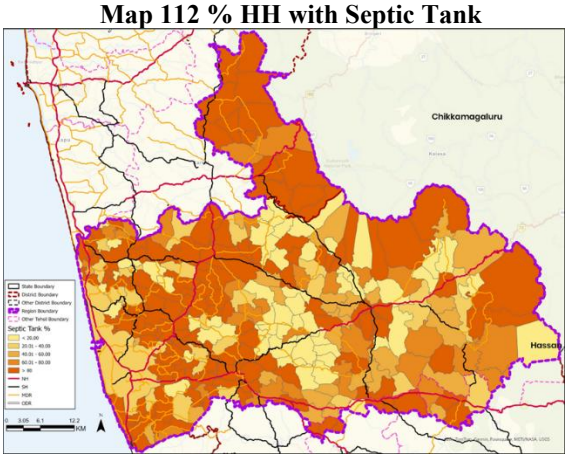
Map 110 Access to tap water



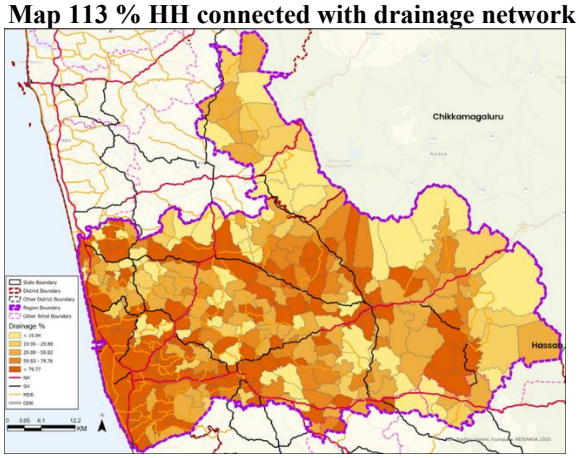
Map 111 % HH with access to Improved Latrine



Map 112 % HH with Septic Tank



Map 113 % HH connected with drainage network



Source 180 Generated by author

It can be observed that the villages along the National Highways have a greater % of households with access to water related physical infrastructure.

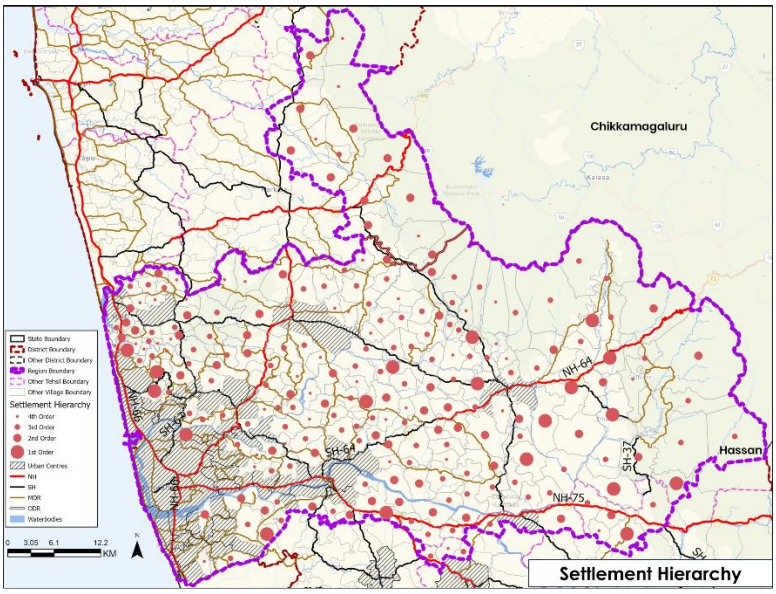
3.4.2 Scalogram & settlement hierarchy

After analysing the demographic and socio-economic aspects, including housing amenities with a focus on physical infrastructure, the social infrastructure amenities in the study region have a primary focus on educational and healthcare amenities.

The parameters considered for developing the scalogram includes Tap water, Improved latrine, Septic Tank, Drainage, Govt Primary School, Primary health sub center, Govt Middle School, Family welfare center, public bus service, Post Office, SH, Primary health care, Govt Secondary School, Maternal and child welfare, NH, Govt Senior Secondary School, Agricultural credit societies, Dispensary, Community Healthcare, Hospital Alternative, Commercial banking arranged in a hierarchical order.

The scalogram is attached in the annexure.

Map 114 Settlement Hierarchy



Source 181 Generated by author

The villages have been classified into four class orders based on the availability of essential amenities such as educational and healthcare facilities, post and telegraph services, banking, and credit societies. The pattern reveals villages along the Transport network are well equipped with the said amenities and the villages around the urban centres are dependent on them for such facilities.

3.4.3 Ecosystem Service Dependency & Livelihood Analysis

After understanding the demography & settlements in the region, an ecosystem service dependency & livelihood analysis becomes essential to determine how the population is dependent on the ecosystem services such as water, food & climate regulation to sustain their livelihood.

This section of the report will deal with understanding the above with respect to the identified ecosystems present in the rural context

1. Forest Ecosystem
2. Riverine Ecosystem

The Estuarian & Mangrove ecosystem will be dealt at the urban scale.

Ecosystem Service Dependency

The Four ecosystem Services – Provisioning, Regulating, Supporting & Cultural and their indicators are identified and scored based on Primary survey & research observations in the first stage. To understand the dependency of the rural population in the region, a questionnaire for Forest & River ecosystems was created & surveyed in the villages within the defined buffers for each ecosystem.

Table 40 Forest Ecosystem Service Dependency

Ecosystem Services		Score		Normalised Value		
		Research Observation	Primary Survey	Research Observation	Primary Survey	Average
		Out of 10	Out of 10			
Provisioning	Freshwater	8	9	0.7	1.0	0.8
	Source of food	8	8	0.7	0.8	0.7
	Timber, Fiber	8	6	0.7	0.3	0.5
	Medicines	9	8	1.0	0.8	0.9
			Total			**2.9**
Regulating	Erosion-regulation	6	5	0.0	0.0	0.0
	Micro-climate regulation	8	8	0.7	0.8	0.7
	Water quality	9	8	1.0	0.8	0.9
	Crabon sequestration	8	7	0.7	0.5	0.6
	Ground water recharge	8	7	0.7	0.5	0.6
	Flood mitigation	6	6	0.0	0.3	0.1
			Total			**2.9**
Supporting	Nutrient cycling & soil formation	8	7	0.7	0.5	0.6
	Habitat for species	9	8	1.0	0.8	0.9
	Employment generation	7	6	0.3	0.3	0.3
			Total			**1.8**
Cultural	Cultural & Religious importance	8	7	0.7	0.5	0.6
	Recreation & tourism	8	8	0.7	0.8	0.7
	Aesthetic value	8	7	0.7	0.5	0.6
			Total			**1.9**

Source 182 Compiled by author

Map 115 River Ecosystem Service Dependency

Ecosystem Services		Score		Normalised Value		
		Research Observation	Primary Survey	Research Observation	Primary Survey	Average
		Out of 10	Out of 10			
Provisioning	Freshwater	9	9	1.0	1.0	1.0
	Source of food	7	6	0.3	0.3	0.3
	Water for Navigation	8	6	0.7	0.3	0.5
	Water for Irrigation	9	8	1.0	0.8	0.9
			Total			2.6
Regulating	Erosion-regulation	6	5	0.0	0.0	0.0
	Micro-climate regulation	7	7	0.3	0.5	0.4
	Water quality	9	8	1.0	0.8	0.9
	Crabon sequestration	7	7	0.3	0.5	0.4
	Ground water recharge	9	8	1.0	0.8	0.9
	Flood mitigation	8	7	0.7	0.5	0.6
			Total			3.2
Supporting	Nutrient cycling & soil formation	8	7	0.7	0.5	0.6
	Habitat for species	9	8	1.0	0.8	0.9
	Employment generation	7	6	0.3	0.3	0.3
			Total			1.8
Cultural	Cultural & Religious importance	8	7	0.7	0.5	0.6
	Recreation & tourism	8	8	0.7	0.8	0.7
	Aesthetic value	8	7	0.7	0.5	0.6
			Total			1.9

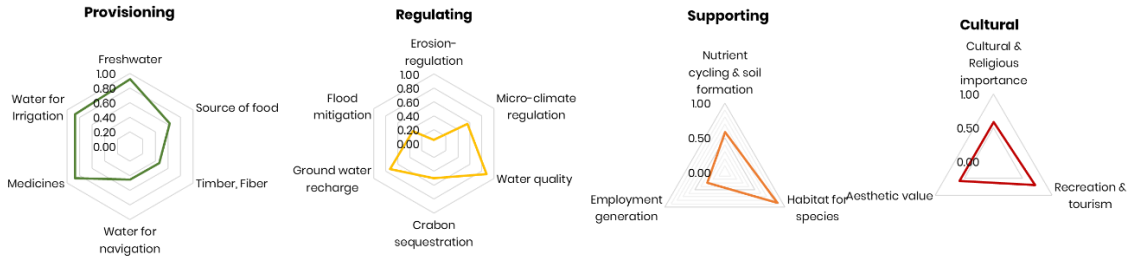
Source 183 Compiled by author

Table 41 Primary survey & research observation - River & Forest Ecosystem Comparative

Ecosystem Services		Ecosystem		Absolute value		Normalised value		
		Natural		Research observation	Primary survey	Research observation	Primary survey	Average Score
		Terrestrial Forest	Aquatic River	Out of 10	Out of 10			
Provisioning	Freshwater	2	3	8.5	9	0.8	1.0	0.9
	Source of food	2	2	7.5	8	0.5	0.8	0.6
	Timber, Fiber	3		8	6	0.7	0.3	0.5
	Water for navigation		2	8	6	0.7	0.3	0.5
	Medicines	3		9	8	1.0	0.8	0.9
	Water for Irrigation		3	9	8	1.0	0.8	0.9
						Total		4.2
Regulating	Erosion-regulation	2	3	6	5	0.0	0.0	0.0
	Micro-climate regulation	3	3	7.5	7.5	0.5	0.6	0.6
	Water quality	2	3	9	8	1.0	0.8	0.9
	Crabon sequestration	3	2	7.5	7	0.5	0.5	0.5
	Ground water recharge	3	3	8.5	7.5	0.8	0.6	0.7
	Flood mitigation	2	3	7	6.5	0.3	0.4	0.4
						Total		3.0
Suppporting	Nutrient cycling & soil formation	3	3	8	7	0.7	0.5	0.6
	Habitat for species	3	3	9	8	1.0	0.8	0.9
	Employment generation	1	2	7	6	0.3	0.3	0.3
						Total		1.8
Ciltural	Cultural & Religious importance	1	3	8	7	0.7	0.5	0.6
	Recreation & tourism	2	2	8	8	0.7	0.8	0.7
	Aesthetic value	3	2	8	7	0.7	0.5	0.6
		38	42			Total		1.9

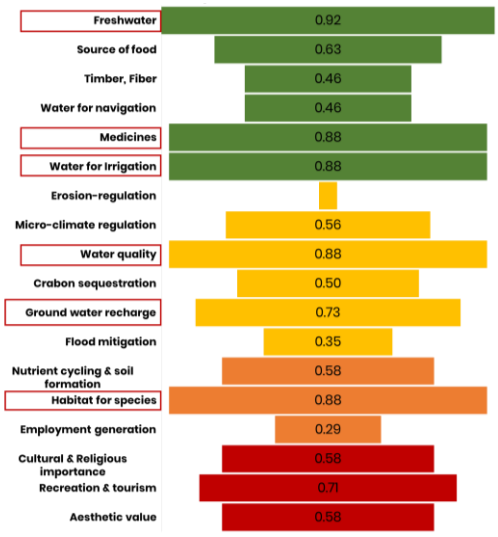
Source 184 Compiled by author

Figure 62 Score of Ecosystem service indicators as per primary survey & research observation



Source 185 Compiled by author

Figure 63 Ecosystem services



Source 186 Author

The villages are dependent on the **Forest & River ecosystem for Freshwater, Medicine, water for irrigation & ground water recharge.** Therefore, **Provisioning and Regulating services** are found to be having the highest score and hence to be Prioritised

The second stage includes scoring the identified indicators on a scale of 1 to 3, with 1 being least dependency & 3 being highest dependency. Analytical Hierarchy Process (AHP) is adopted to score the indicators and the values are normalized.

Case 1: For **Forest ecosystem**, the buffer is considered as per the guidelines to establish Eco-sensitive zones with a buffer of up to 10 km, divided as 2 km, 5 km, 7 km & 10 km buffers. The villages within the 2 core areas, up to 5 km buffer are given a weightage of 3x, while the villages up to 7 km buffer are given a weightage of 2x. Furthermore, the zone with villages having an above average population have again been given an additional weightage of 2x. The scores are normalized and mapped spatially.

Map 116 Forest Buffer & Villages

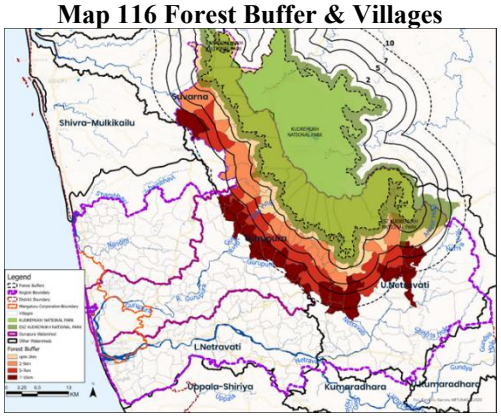
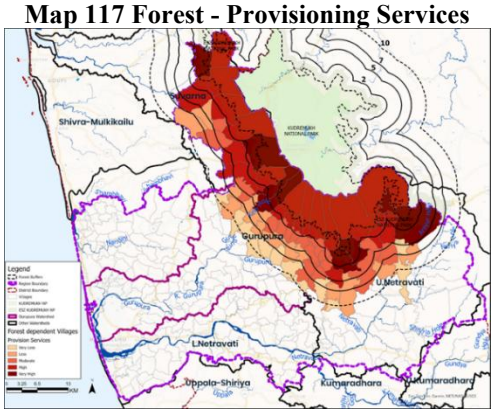


Table 42 Number of villages within the defined buffers

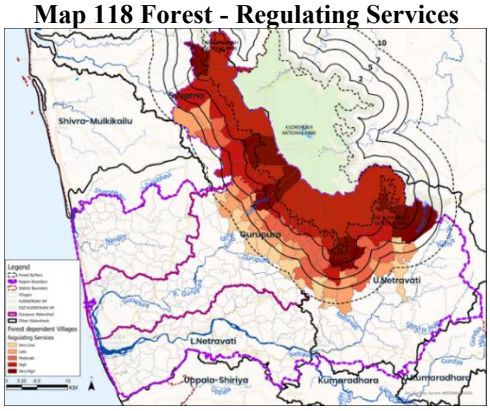
Buffer (km)	Villages
< 2	22
2 - 5	17
5 – 7	13
7 - 10	17
Total	**69**

Source 187 Author

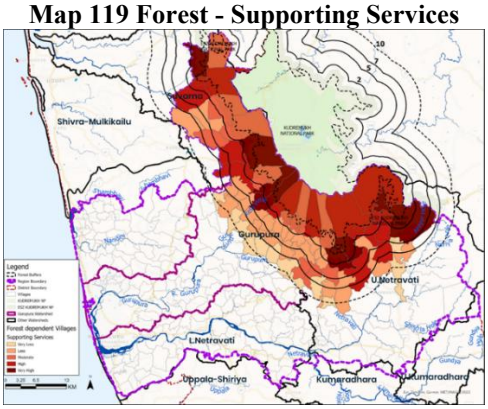
Map 117 Forest - Provisioning Services



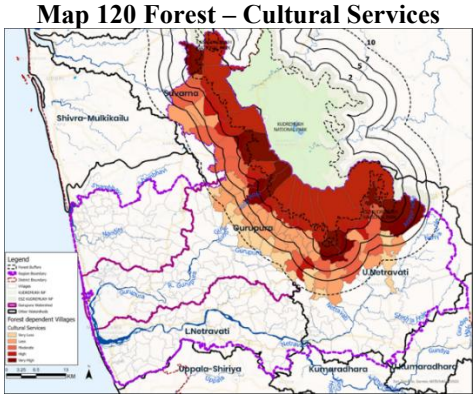
Map 118 Forest - Regulating Services



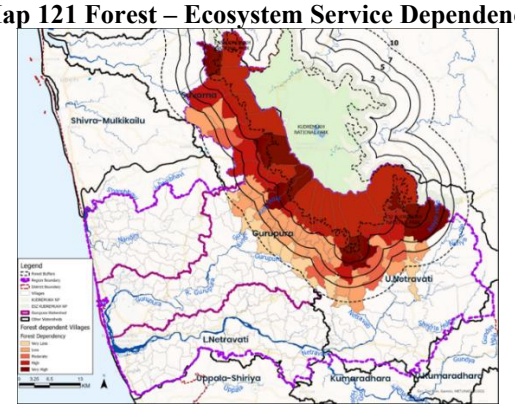
Map 119 Forest - Supporting Services



Map 120 Forest – Cultural Services



Map 121 Forest – Ecosystem Service Dependency



Source 188 Author

Table 43 Normalized score for forest ecosystem services

Eco-system Service	Service	Indicator	Scores				Average			
			Core Area upto 2km buffer	2-5 Km buffer	5-7 km buffer	7-10 km Buffer	Core Area up to 2km buffer	2-5 Km buffer	5-7 km buffer	7-10 km Buffer
Provisioning	Water	Percentage population dependent on ground & surface water sources	0.64	0.2	0.22	0.04	0.66	0.24	0.13	0.03
	Source of food	Proximity to forest	0.66	0.25	0.1	0.02				
	Timber, Fibre, & fuel	% HH using wood for cooking + % houses made of wood	0.66	0.25	0.1	0.02				
	Medicines	Proximity to forest	0.66	0.25	0.1	0.02				
Regulating	Air quality	Proximity to forest	0.67	0.25	0.1	0.02	0.66	0.23	0.14	0.03
	Micro-climate	% waterbody area + forest	0.67	0.25	0.1	0.02				
	Ground water rejuvenation	Ground water levels	0.64	0.2	0.22	0.04				
Supporting	Nutrient cycling & soil formaiton	% waterbody area + forest	0.57	0.23	0.21	0.07	0.57	0.23	0.23	0.07
	Habitat for spcies	% Forest area	0.66	0.25	0.27	0.02				
	Employment Generation	Number of workers	0.47	0.2	0.21	0.12				
Cultural	Cultural & Religious importance	Presence of pilgrim sites	0.28	0.14	0.22	0.03	0.57	0.14	0.14	0.02
	Recreation & tourism	Tourist locations & proximity to forest	0.66	0.25	0.1	0.02				
	Aesthetic value	Proximity to forest & waterbodies	0.66	0.09	0.1	0.02				
	Research & knowledge building	Proximity to forest	0.66	0.09	0.12	0.02				
Dependency Average			0.61	0.21	0.16	0.03	0.61	0.21	0.16	0.04

Source 189 Author

The analysis revels that the villages in the core buffers 0-2km & 2-5km, are highly dependent on the forest for Provisioning & Regulating services.

Similarly, Riverine ecosystem is given a buffer and 2, 5, and 7km for the purpose of analysis.

Case 2: For **Riverine ecosystem,** the villages are considered as per the micro-watersheds within the 2,5, & 7 km buffers. And the same scoring pattern has been followed. The calculations are attached in the annexure.

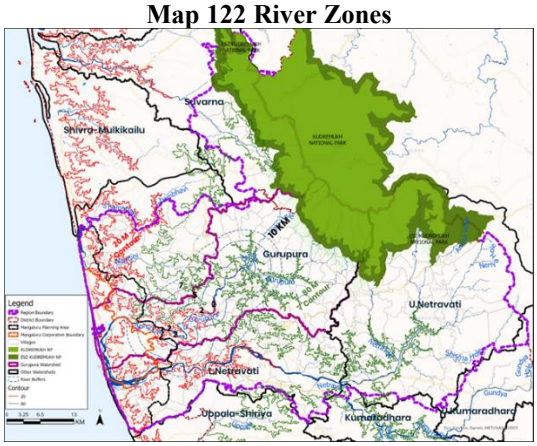
River Zones

1. **Elevation > 80M -> Head Waters** (Up to the foothill of Kudremukh national park, Source Zone)
2. **Elevation 20 – 80 -> Rural River** (Transition zone, outside the extent of Mangaluru Planning Area)
3. **Elevation <20m -> Urban River** (Deposition Zone, up to the extent of Mangaluru Planning Area)

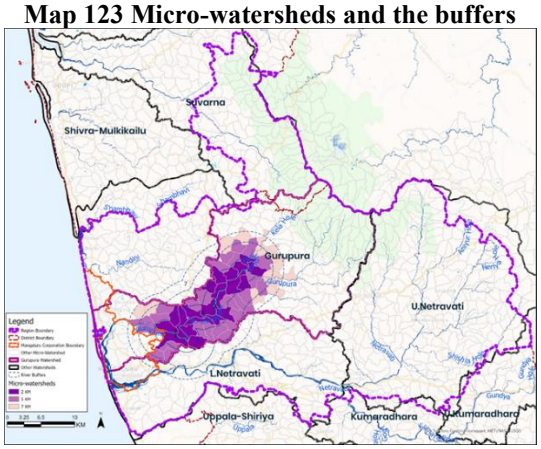
For Ecosystem Service dependency, only the micro-watersheds and villages within them along **the rural river zone** is considered. This includes only the **5th Order stream** of the Gurupura River.

Defining the **Rural River**: **-** that which flows predominantly through rural areas, interacts with, and supports rural landscapes, livelihoods & ecosystems, remaining largely influenced by agricultural, forestry & natural processes rather than intensive urbanisation

Map 122 River Zones



Map 123 Micro-watersheds and the buffers



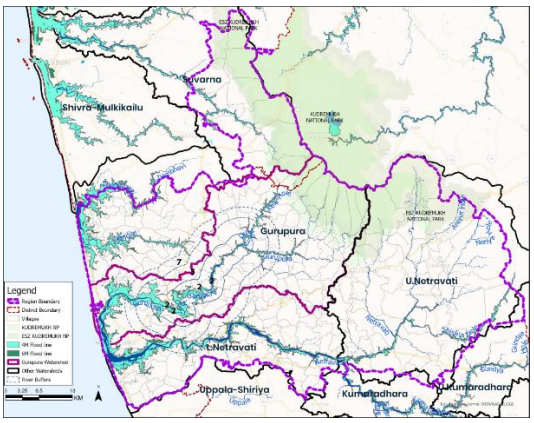
Source 190 Author

Table 44 Number of villages within the defined buffers

Buffer (km)	Micro-watershed	Villages
< 2	21	17
2 - 5	26	17
5 – 7	12	7
Total	59	41

Source 191 Author

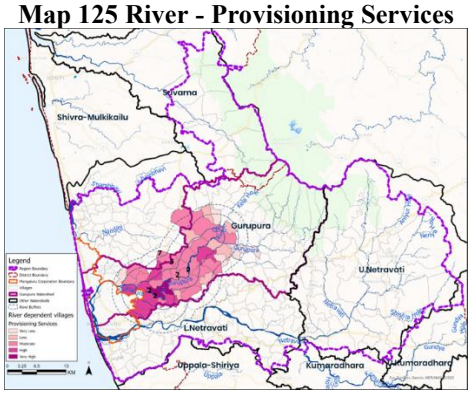
Map 124 Flood extent



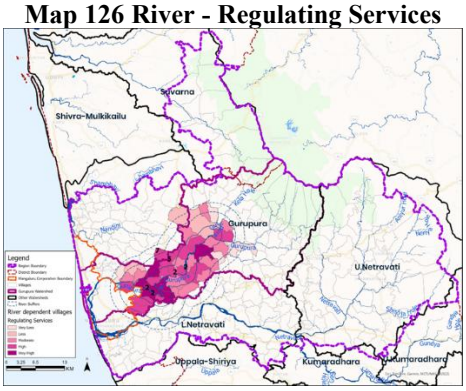
Source 192 KGIS

To understand the flood regulation of river – an aspect under the regulating services, the flooding extents within the villages is mapped using the flood extent contours which mark the 50- and 100-year flood return period.

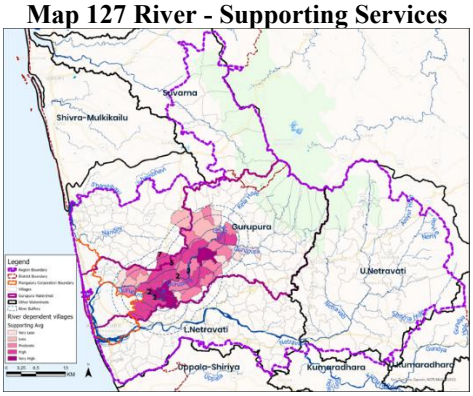
Map 125 River - Provisioning Services



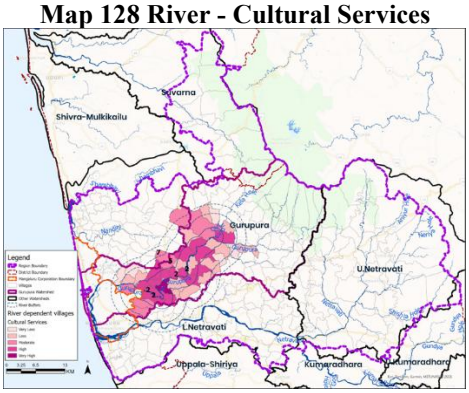
Map 126 River - Regulating Services



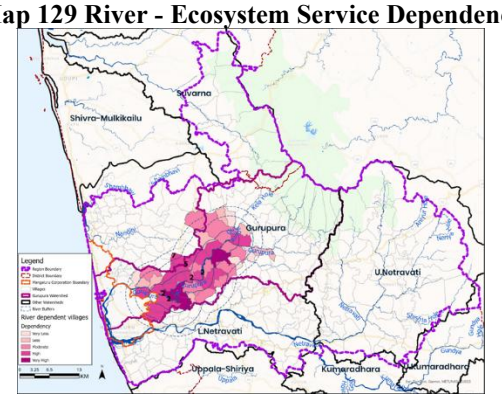
Map 127 River - Supporting Services



Map 128 River - Cultural Services



Map 129 River - Ecosystem Service Dependency



Source 193 Author

Table 45 Normalized score for River ecosystem services

Eco-system Service	Service	Indicator	Scores			Average		
			Core Area upto 2km buffer	2-5 Km buffer	5-7 km buffer	Core Area upto 2km buffer	2-5 Km buffer	5-7 km buffer
Provisioning	Fresh water	Percentage population dependent on ground & surface water sources	0.4	0.2	0.1	0.47	0.23	0.30
	Fishing	Proximity to river	0.6	0.3	0.1			
	Irrigation	Area under irrigation	0.4	0.2	0.7			
Regulating	Water quality & flooding regulation	% forest area + flooding extent	0.6	0.3	0.1	0.65	0.25	0.065
	Carbon sequestration	% waterbody area	0.7	0.2	0.03			
	Micro Climate Regulation	Proximity to waterbody	0.7	0.2	0.03			
	Ground water regulation	Ground water levels	0.6	0.3	0.1			
Supporting	Nutrient cycling & soil formaiton	% waterbody area + forest	0.7	0.1	0.03	0.50	0.20	0.08
	Habitat for species	% Forest area	0.4	0.3	0.1			
	Employment Generation	Number of Agricultural workers	0.4	0.2	0.1			
Cultural	Cultural & Religious importance	Temples and festivals along the river	0.5	0.1	0.1	0.60	0.13	0.07
	Recreation & tourism	Tourist locations & proximity to forest	0.5	0.1	0.1			
	Aesthetic value	Proximity to forest & waterbodies	0.7	0.1	0.03			
	Research & knowledge building	Presence of pilgrim sites and proximity to waterbody	0.7	0.2	0.03			
Dependency Average			0.56	0.20	0.12	0.55	0.20	0.13

Source 194 Author

The villages in the core areas and the buffer area up to 5km are dependent on the river for **Regulating and provisioning services.** The Regulating service is predominant as the villages depend on the river for flood regulation

Sustainable Livelihood Analysis

The analysis is based on the Sustainable Livelihood Framework established by the United Nations in 2015, that offers a comprehensive approach in assessing livelihoods within the framework of sustainable development. This framework was created as part of the UN's initiatives to reduce poverty and encourage sustainable development on a global scale. It recognizes the multifaceted characteristics of livelihoods and highlights the relation among various elements that influence livelihood outcomes.

The Sustainable Livelihoods Framework categorizes five essential types of livelihood assets that individuals and households can utilize to achieve their livelihood strategies:

1. **Natural Capital:** refers to the stocks of natural resources (such as soil, water, air) that can be harnessed as inputs to generate additional benefits, including food chains, protection against soil or coastal erosion, and other resources supporting livelihoods.
2. **Human Capital:** This encompasses the skills, experience, work competencies, and overall health conditions that, when combined, empower populations to pursue diverse strategies and meet their livelihood goals.
3. **Physical Capital:** This includes the infrastructure and production resources necessary to sustain livelihoods.
4. **Social Capital:** This includes the social resources - refers to local social capital, encompassing networks, associations, local authorities, local officials, and the broader population benefiting from program assistance.

5. **Financial Capital:** This refers to the financial resources that populations utilize to reach their livelihood goals.

This section includes a village-level livelihood analysis based on selected indicators representing each of the five capitals to map and comprehend the livelihood assets across the villages situated in Forest & Riverine ecosystems within the region, thereby deepening the understanding of the relationship between the assets and the villages.

Analytical Hierarchy Process (AHP) is adopted to score the indicators and the values are normalized.

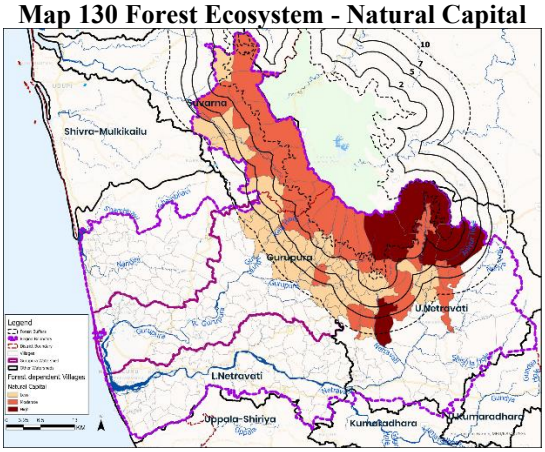
Table 46 Livelihood Capital & indicators

Sustainable Livelihood Capital	Indicators
Natural Capital	Area under forest
	Area under Waterbody
	Barren Land
Human Capital	Literacy Rate
	Total Workers
Physical Capital	Percentage of permanent houses
	% of tap water connection
	% Drainage
	% Septic Tank
	% Improved Latrine
	Wells & Tubewells
	Access to road
	Education
	Healthcare
Social Capital	Self-Help Groups
	Nutritional centres & Anganwadis
	ASHA Status
Financial Capital	Mandis
	Bank
	Agricultural Credit Societies

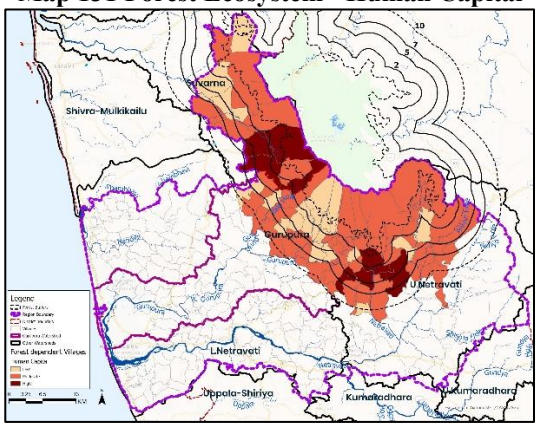
Source 195 Author

Forest Ecosystem – Sustainable Livelihood Analysis

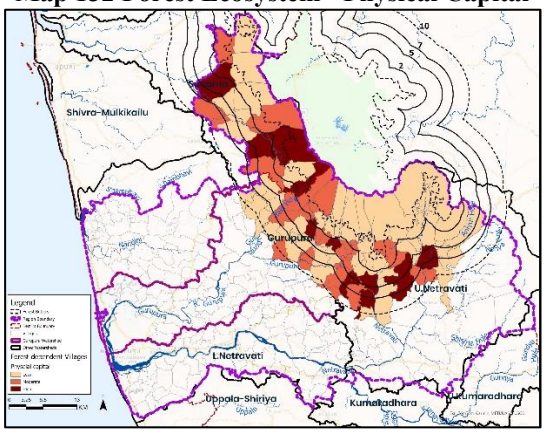
Map 130 Forest Ecosystem - Natural Capital



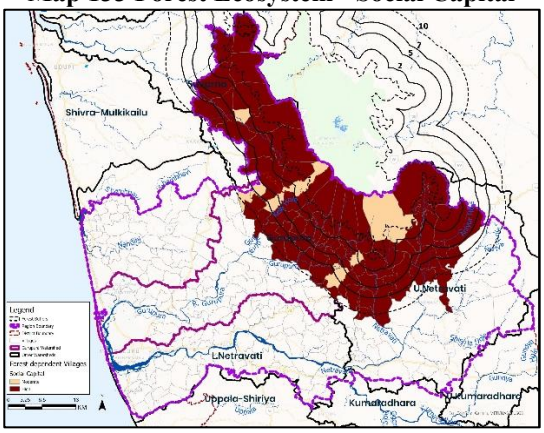
Map 131 Forest Ecosystem - Human Capital



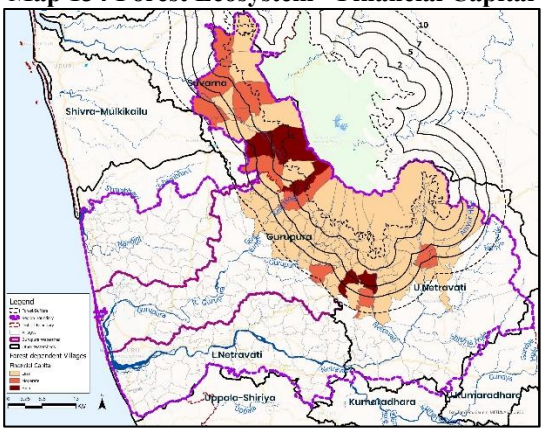
Map 132 Forest Ecosystem - Physical Capital



Map 133 Forest Ecosystem - Social Capital



Map 134 Forest Ecosystem - Financial Capital



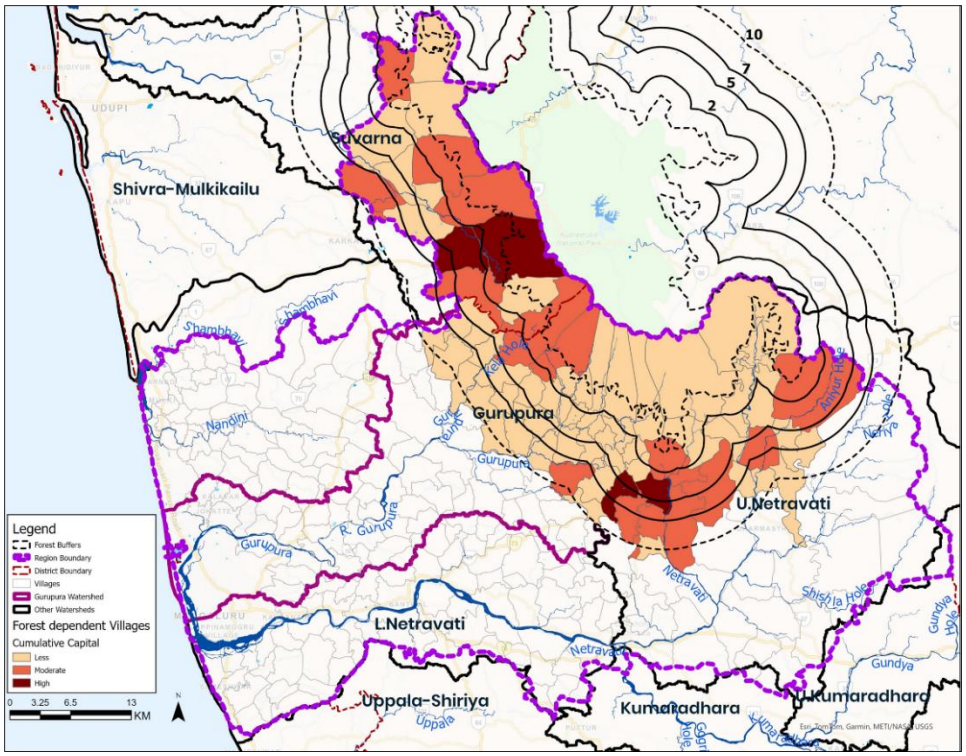
Source 196 Author

Figure 64 Livelihood dependency table for Forest ecosystem

Sustainable Livelihood Capital	Indicators	Core (<2 km)	2 - 5km buffer	5 - 7km buffer	7 - 10km buffer	Core (<2 km)	2 - 5km buffer	5 - 7km buffer	7 - 10km buffer	Average
Natural Capital	Area under forest	1	0.5	0.04	0.03	0.40	0.21	0.06	0.08	0.19
	Area under Waterbody	0.08	0.06	0.02	0.08					
	Barren Land	0.12	0.08	0.12	0.13					
Human Capital	Literacy Rate	0.89	0.85	0.91	0.91	0.55	0.5	0.57	0.54	0.54
	Total Workers	0.21	0.15	0.23	0.17					
Physical Capital	Percentage of permanent houses	0.45	0.54	0.48	0.45	0.47	0.53	0.49	0.47	0.49
	% of tap water connection	0.22	0.34	0.28	0.16					
	% Drainage	0.4	0.64	0.52	0.6					
	% Septic Tank	0.62	0.53	0.56	0.46					
	% Improved Latrine	0.65	0.7	0.72	0.7					
	Wells & Tubowells	0.42	0.3	0.39	0.36					
	Acess to road	0.41	0.59	0.31	0.47					
	Education	0.64	0.63	0.6	0.6					
	Healthcare	0.45	0.48	0.52	0.4					
Social Capital	Self-Help Groups	1	1	1	1	0.97	0.96	0.92	0.98	0.96
	Nutritional centres & Anganwadis	1	1	1	1					
	ASHA Status	0.91	0.88	0.77	0.94					
Financial Capital	Mandis	0.09	0.24	0.08	0.12	0.11	0.16	0.10	0.06	0.11
	Bank	0.23	0.18	0.15	0.06					
	Agricultural Credit Societies	0	0.06	0.08	0					
AVERAGE						0.50	0.47	0.43	0.43	0.46

Source 197 Author

Map 135 Forest Ecosystem - Cumulative Livelihood Dependency Map

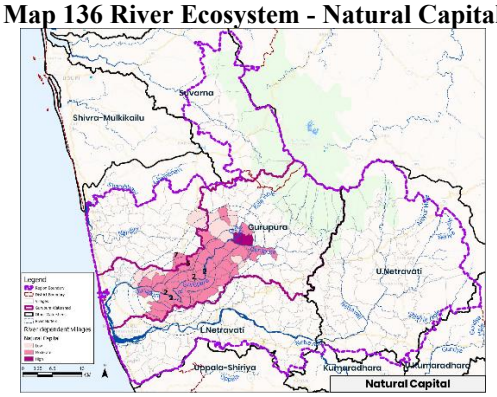


Source 198 Author

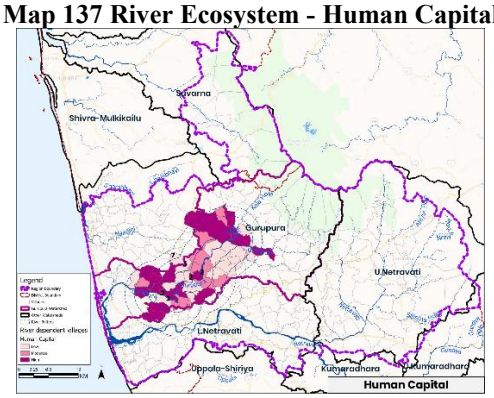
The normalized aggregate scores range between **0.06 to 0.98**, where **core area** has the **highest score** due to high **Social, physical & human capital.** All the zones score low in terms of **financial capital**, and high in terms of **social capital. Physical capital** is observed to be moderately developed in all the zones, least in the core zone. The core area scores moderately for Natural capital, because of the area under waterbody and barren land, although it has **abundant forest cover.**

River Ecosystem – Sustainable Livelihood Analysis

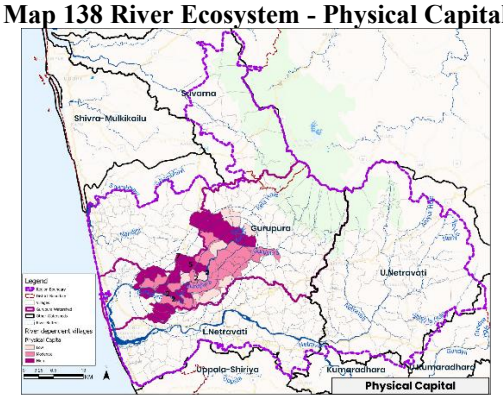
Map 136 River Ecosystem - Natural Capital



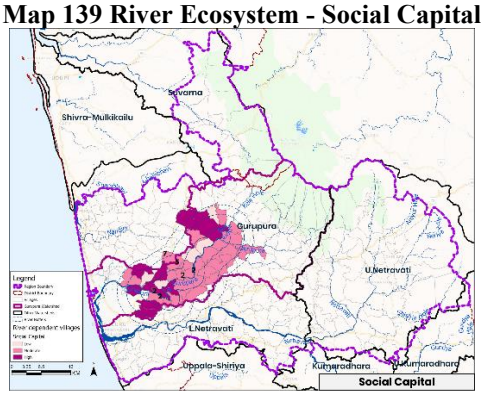
Map 137 River Ecosystem - Human Capital



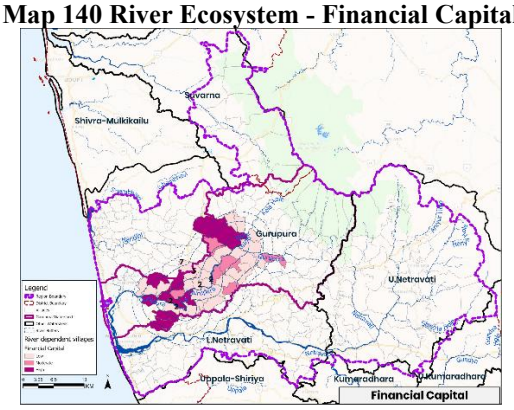
Map 138 River Ecosystem - Physical Capital



Map 139 River Ecosystem - Social Capital



Map 140 River Ecosystem - Financial Capital



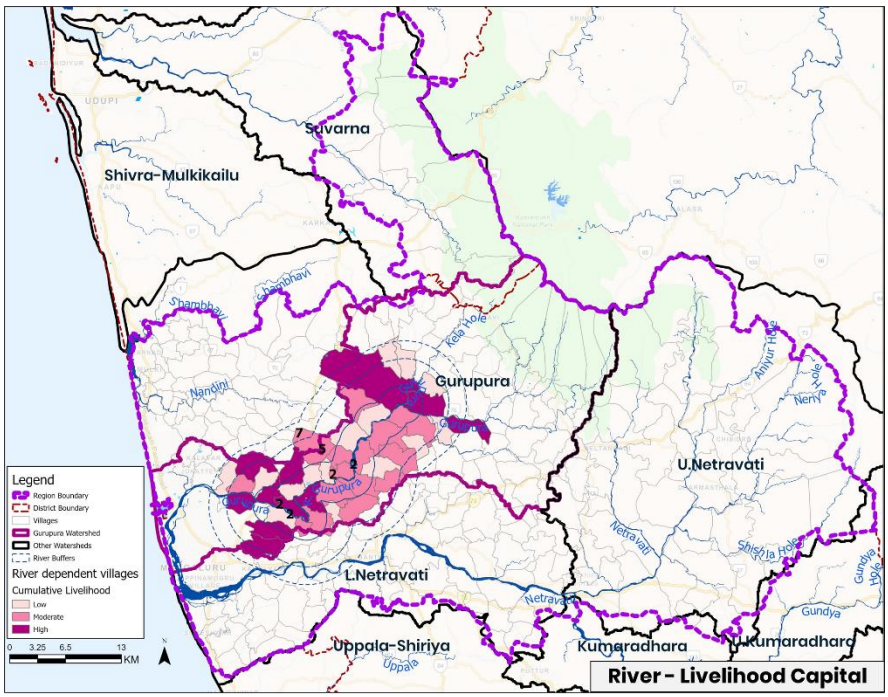
Source 199 Author

Table 47 Livelihood dependency table for Forest ecosystem

Sustainable Livelihood Capital	Indicators	Core (<2 km)	2 - 5km buffer	5 - 7km buffer	Core (<2 km)	2 - 5km buffer	5 - 7km buffer	Average
Natural Capital	Distance from the river	1	0.5	0	0.32	0.24	0.12	0.23
	Area under forest	0.07	0.22	0.31				
	Area under Waterbody	0.06	0.02	0.08				
	Barren Land	0.14	0.21	0.09				
Human Capital	Literacy Rate	0.44	0.51	0.54	0.38	0.42	0.47	0.42
	Total Agricultural Workers	0.3	0.33	0.31				
	Public transport	0.41	0.41	0.57				
Physical Capital	Percentage of permanent houses	0.61	0.55	0.46	0.62	0.60	0.63	0.62
	% of tap water connection	0.52	0.45	0.44				
	% Drainage	0.53	0.59	0.53				
	% Septic Tank	0.56	0.76	0.68				
	% Improved Latrine	0.78	0.75	0.6				
	Wells & Tubewells	0.28	0.36	0.26				
	Acess to road	0.35	0.24	0.71				
	Education	1	0.88	1				
	Healthcare	0.94	0.82	1				
Social Capital	Self-Help Groups	0.24	0.18	0.29	0.69	0.69	0.76	0.71
	Nutritional centres & Anganwadis	1	1	1				
	ASHA Status	0.82	0.88	1				
Financial Capital	Mandis	0.29	0.35	0.29	0.27	0.24	0.38	0.30
	Bank	0.29	0.18	0.43				
	Agricultural Credit Societies	0.24	0.18	0.43				
AVERAGE					0.46	0.44	0.47	0.46

Source 200 Author

Map 141 River Ecosystem - Cumulative Livelihood Dependency Map



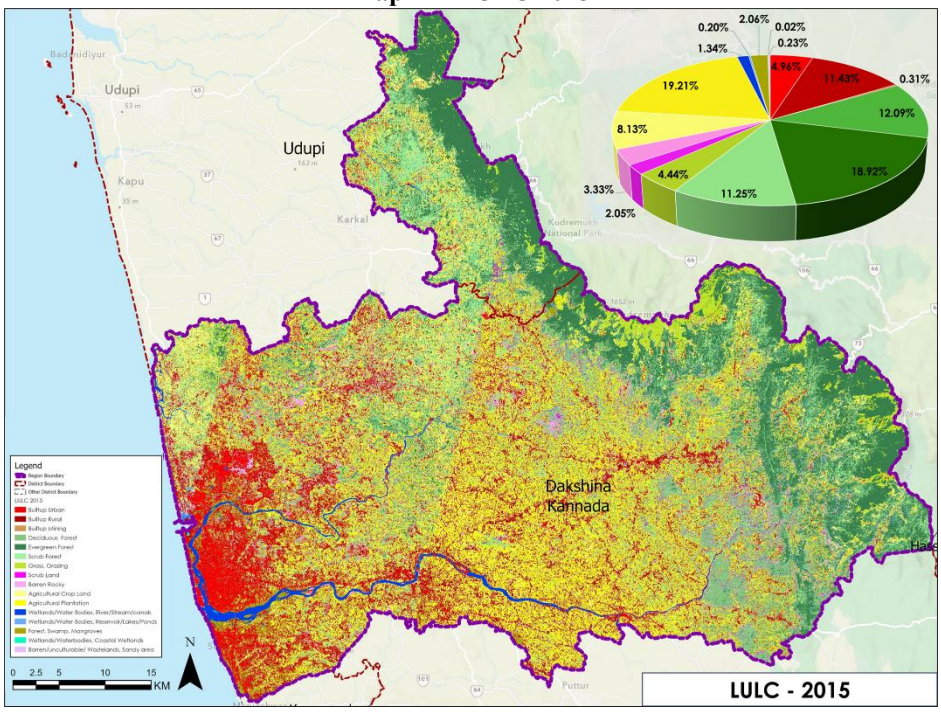
Source 201 Author

The normalized aggregate scores range between **0 to 0.94**, where **transition zone (5-7 km buffer)** has the **highest score** due to high **Social, human & physical capital.** All the zones score moderately in terms of **financial capital**, and high in terms of **social capital. Physical capital** is observed to be well developed in all the zones. The core area scores moderately for Natural capital, because of the area under forest cover, waterbody, and barren, although considering the proximity to river it scores the highest.

3.4.4 Land Use Land Cover (LULC)

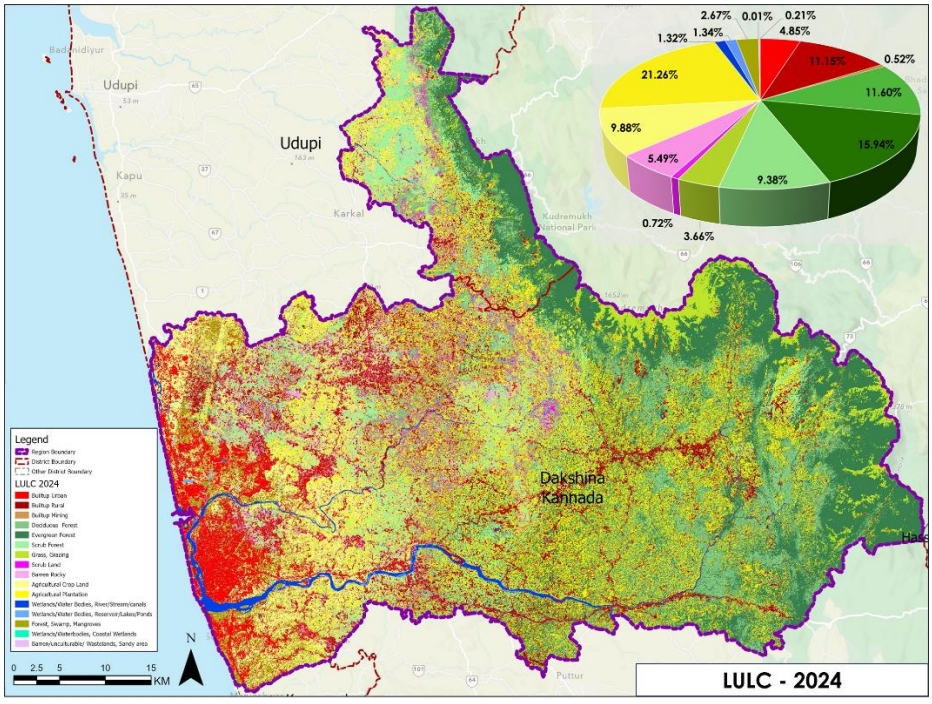
LULC change detection was performed on Landsat 8 Imageries using Supervised classification method to understand the land use change that has occurred in the region between 2015 and 2024. This helps align the impact of land use over time on the river system.

Map 142 LULC 2015



Source 202 Author

Map 143 LULC 2024



Source 203 Author

Figure 65 LULC change

Sl no	Landuse Category	Area 2015	% Area	Area 2025	% Area	Area Change	% Area Change
1	Builtup Urban	158.45	4.85	162.18	4.96	3.73	2.35
2	Builtup Rural	364.22	11.15	373.57	11.43	9.35	2.57
3	Builtup Mining	16.99	0.52	10.19	0.31	-6.80	-40.01
4	Deciduous Forest	379.15	11.60	394.92	12.09	15.78	4.16
5	Evergreen Forest	520.66	15.94	618.30	18.92	97.64	18.75
6	Scrub Forest	306.56	9.38	367.69	11.25	61.13	19.94
7	Grass, Grazing	119.74	3.66	145.14	4.44	25.40	21.21
8	Scrub Land	23.48	0.72	67.04	2.05	43.55	185.44
9	Barren Rocky	179.45	5.49	108.82	3.33	-70.63	-39.36
10	Agricultural Crop Land	322.77	9.88	265.73	8.13	-57.03	-17.67
11	Agricultural Plantation	694.51	21.26	627.68	19.21	-66.83	-9.62
12	Wetlands/Water Bodies, River/Stream/canals	43.08	1.32	43.89	1.34	0.81	1.88
13	Wetlands/Water Bodies, Reservoir/Lakes/Ponds	43.89	1.34	6.53	0.20	-37.36	-85.12
14	Forest, Swamp, Mangroves	87.18	2.67	67.20	2.06	-19.98	-22.92
15	Wetlands/Waterbodies, Coastal Wetlands	0.34	0.01	0.80	0.02	0.45	131.07
16	Barren/unculturable/ Wastelands, Sandy area	6.76	0.21	7.57	0.23	0.81	11.92
Total		**3267.25**		**3267.25**			

Source 204 Author

Inference:

Increase in Built-up Urban & Rural: The growth of urban and rural areas can be see along the rivers, suggesting increasing pressure on the riverbanks, leading to encroachment, pollution and altered hydrology.

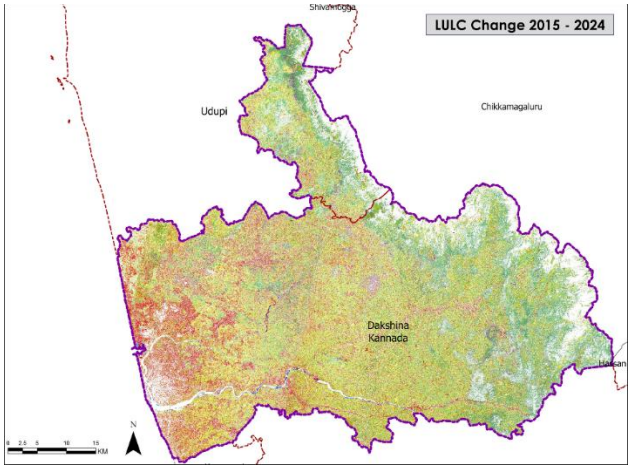
Decline in agricultural land: Decline in agricultural plantation and crop lands suggests shift towards urban use, this will increase the ground water dependency and recharge, and increases the runoff into the river.

Decrease in mining area: Indicated a positive change as it reduces sedimentation and heavy metal contamination in the rivers.

Increase in Forest cover: Increase in deciduous, evergreen and scrub forest suggest improved watershed health, enhanced soil stability and reduction in erosion.

Reduction in Waterbody and mangroves: Can lead to reduced natural flood protection and affects the aquatic species

Map 144 Land Use Change Detection



Source 205 Author

Table 48 LULC Change detection table

Sl	From Landuse	To Landuse	Transition Area (Sq.Km)
1	Builtup Mining	Builtup Urban	46.33
	Scrub Forest		
	Grass, Grazing		
	Barren Rocky		
	Agricultural Crop Land		
	Agricultural Plantation		
	Wetlands/Water Bodies, River/Stream/canals		
	Forest, Swamp, Mangroves		
	Barren/unculturable/ Wastelands, Sandy area		
2	Builtup Mining	Builtup Rural	196.27
	Deciduous Forest		
	Evergreen Forest		
	Scrub Forest		
	Grass, Grazing		
	Barren Rocky		
	Agricultural Crop Land		
	Agricultural Plantation		
	Wetlands/Water Bodies, Reservoir/Lakes/Ponds		
	Forest, Swamp, Mangroves		
3	Barren Rocky	Builtup Mining	2.44
	Agricultural Crop Land		
	Agricultural Plantation		
4	Evergreen Forest	Deciduous Forest	256.68
	Scrub Forest		
	Barren Rocky		
	Agricultural Crop Land		
	Agricultural Plantation		
5	Deciduous Forest	Evergreen Forest	260.96
	Scrub Forest		
	Agricultural Crop Land		
	Agricultural Plantation		
6	Deciduous Forest	Scrub Forest	235.19
	Evergreen Forest		
	Agricultural Crop Land		
	Agricultural Plantation		
7	Deciduous Forest	Grass, Grazing	61.88
	Evergreen Forest		
	Barren Rocky		
	Agricultural Crop Land		
	Agricultural Plantation		
8	Deciduous Forest	Scrub Land	54.48
	Evergreen Forest		
	Scrub Forest		
	Agricultural Crop Land		
	Agricultural Plantation		
9	Deciduous Forest	Barren Rocky	51.99
	Scrub Forest		
	Agricultural Crop Land		
	Agricultural Plantation		
10	Deciduous Forest	Agricultural Crop Land	115.92
	Evergreen Forest		
	Scrub Forest		
	Grass, Grazing		
	Barren Rocky		
	Agricultural Plantation		
	Forest, Swamp, Mangroves		
11	Deciduous Forest	Agricultural Plantation	303.75
	Evergreen Forest		
	Scrub Forest		
	Grass, Grazing		
	Barren Rocky		
	Agricultural Crop Land		
	Wetlands/Water Bodies, Reservoir/Lakes/Ponds		
12	Agricultural Crop Land	Wetlands/Water Bodies, River/Stream/canals	4.35
	Wetlands/Water Bodies, Reservoir/Lakes/Ponds		
	Forest, Swamp, Mangroves		
13	Agricultural Crop Land	Wetlands/Water Bodies, Reservoir/Lakes/Ponds	3.04
	Wetlands/Water Bodies, River/Stream/canals		
14	Agricultural Crop Land	Forest, Swamp, Mangroves	17.98
	Agricultural Plantation		
16	Wetlands/Water Bodies, River/Stream/canals	Wetlands/Waterbodies, Coastal Wetlands	0.41
	Forest, Swamp, Mangroves		
17	Agricultural Crop Land	Barren/unculturable/ Wastelands, Sandy area	1.71
	Wetlands/Water Bodies, River/Stream/canals		
	Forest, Swamp, Mangroves		

Source 206 Author

3.4.5 Flood susceptibility

After having understood the physical characteristics of the watershed through topography & basin morphometry, vegetation health through NDVI, surface water changes through NDWI, spatial changes via LULC, it becomes necessary to study the flood susceptibility to understand how these factors collectively influence to the flood risk in the region. This analysis helps in identifying the highly susceptible sub-watersheds in the region.

AHP method is used arrive at the weightage for each parameter. The score is normalised to arrive at the final weightage.

Table 49 Pair wise comparison matrix of flood susceptibility indicators

Pair-wise comparision Matrix for flood susceptibility indicators										
Indicator	**TWI**	**Rainfall**	**Bifurcation Ratio**	**Elevation**	**Soil Type**	**NDWI**	**NDVI**	**River Distance**	**Drainage Density**	**LULC**
TWI	1	3.00	5.00	5.00	7.00	7.00	7.00	7.00	7.00	9.00
Rainfall	0.33	1.00	3.00	3.00	5.00	5.00	5.00	5.00	5.00	7.00
Bifurcation Ratio	0.20	0.33	1.00	3.00	3.00	3.00	3.00	3.00	3.00	5.00
Elevation	0.14	0.33	0.33	1.00	3.00	3.00	3.00	3.00	3.00	5.00
Soil Type	0.14	0.20	0.33	0.33	1.00	3.00	3.00	3.00	3.00	5.00
NDWI	0.14	0.20	0.33	0.33	0.33	1.00	3.00	3.00	3.00	5.00
NDVI	0.14	0.20	0.33	0.33	0.33	0.33	1.00	3.00	3.00	5.00
River Distance	0.14	0.20	0.33	0.33	0.33	0.33	0.33	1.00	3.00	3.00
Drainage Density	0.14	0.20	0.33	0.33	0.33	0.33	0.33	0.33	1.00	3.00
LULC	0.11	0.14	0.20	0.20	0.20	0.20	0.20	0.33	0.33	1.00
Total	**2.50**	**5.81**	**11.20**	**13.87**	**20.53**	**23.20**	**25.87**	**28.67**	**31.33**	**48.00**

Source 207 Author

Table 50 Normalized matrix & weightage of flood susceptibility indicators

Normalized value for pair-wise comparision matrix												
Indicator	**TWI**	**Rainfall**	**Bifurcation Ratio**	**Elevation**	**Soil Type**	**NDWI**	**NDVI**	**River Distance**	**Drainage Density**	**LULC**	**Average**	**Weightage %**
TWI	0.40	0.52	0.45	0.36	0.34	0.30	0.27	0.24	0.22	0.19	0.33	32.91
Rainfall	0.13	0.17	0.27	0.22	0.24	0.22	0.19	0.17	0.16	0.15	0.19	19.22
Bifurcation Ratio	0.08	0.06	0.09	0.22	0.15	0.13	0.12	0.10	0.10	0.10	0.11	11.39
Elevation	0.06	0.06	0.03	0.07	0.15	0.13	0.12	0.10	0.10	0.10	0.09	9.12
Soil Type	0.06	0.03	0.03	0.02	0.05	0.13	0.12	0.10	0.10	0.10	0.07	7.44
NDWI	0.06	0.03	0.03	0.02	0.02	0.04	0.12	0.10	0.10	0.10	0.06	6.25
NDVI	0.06	0.03	0.03	0.02	0.02	0.01	0.04	0.10	0.10	0.10	0.05	5.19
River Distance	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.03	0.10	0.06	0.04	3.82
Drainage Density	0.06	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.03	0.06	0.03	2.95
LULC	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	1.70

Source 208 Author

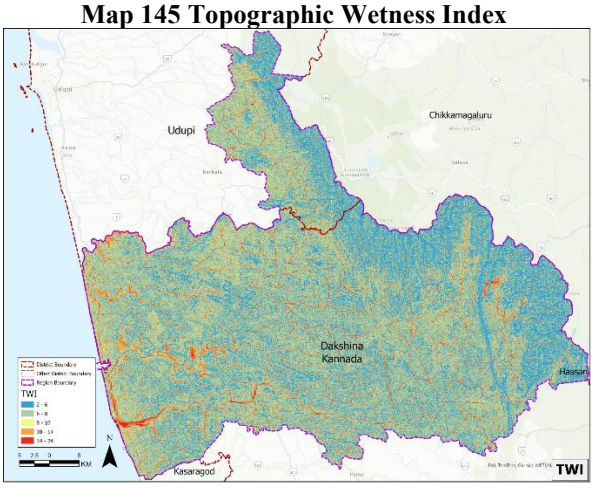
The class range for each of the parameter is assigned a susceptibility class range – Very low to Very high and rating on a scale of 1 to 5.

Table 51 Flood susceptibility Indicators - Class, Rating & weightage

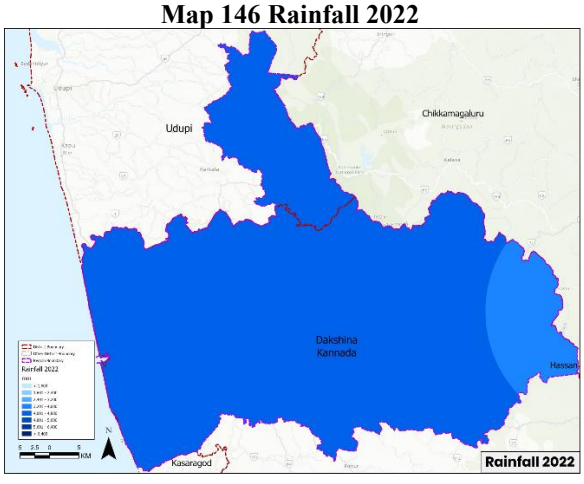
Parameter	Unit	Class	Susceptibility class range	Susceptibility class rating	AHP Weightage
Topographic wetness index (Slope + Flow Direction)	Level	2-6	Very Low	1	32.91
		6-8	Low	2	
		8-10	Moderate	3	
		10-14	High	4	
		14-24	Very High	5	
Rainfall	mm	<1600	Very Low	1	19.22
		1600-2400	Low	2	
		2400-3200	Moderate	3	
		3200-4000	High	4	
		>4000	Very High	5	
Bifurcation Ratio	Ratio	0.6 - 2.7	Very Low	1	11.39
		2.7 - 4.8	Low	2	
		1.8 - 6.8	Moderate	3	
		6.8 - 8.9	High	4	
		8.9 - 11	Very High	5	
Elevation	Meters	<50	Very High	5	9.12
		50-150	High	4	
		150-300	Moderate	3	
		300-600	Low	2	
		>600	Very Low	1	
Soil Type	Type	Clay	Very High	5	7.44
		Sandy clay, Clay Loam	High	4	
		Sandy clay loam	Moderate	3	
		Sandy Loam, Loam	Low	2	
		Sand	Very Low	1	
NDWI	Level	-0.51 - -0.31	Very Low	1	6.25
		-0.31 - 0.29	Low	2	
		-0.29 - -0.27	Moderate	3	
		-0.27 - -0.24	High	4	
		-0.24 - -0.19	Very High	5	
NDVI	Level	-1.0 - 0.0	Very High	5	5.19
		0.0 - 0.3	High	4	
		0.3 - 0.6	Moderate	3	
		0.6 - 1.0	Low	2	
River Distance	Meters	<100	Very High	5	3.82
		100-200	High	4	
		200-500	Moderate	3	
		500-800	Low	2	
		>800	Very Low	1	
Drainage Density	%	<0.26	Very Low	1	2.95
		0.26 - 0.52	Low	2	
		0.52 - 0.78	Moderate	3	
		0.78 - 1.05	High	4	
		>1.05	Very High	5	
LULC	Level	Waterbody	Very High	5	1.70
		Bare Land	High	4	
		Built	Moderate	3	
		Agriculture	Low	2	
		Vegetation	Very Low	1	

Source 209 Author

Map 145 Topographic Wetness Index

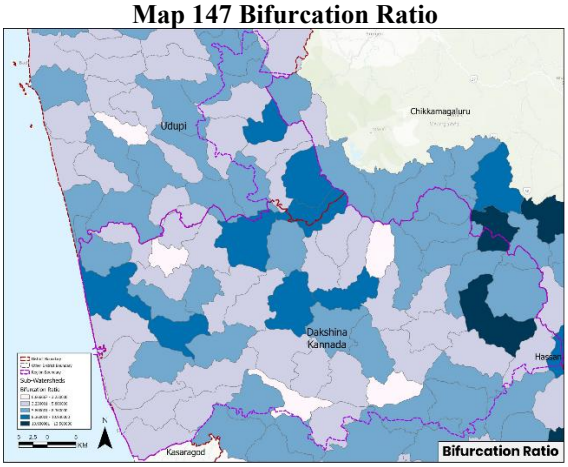


Map 146 Rainfall 2022

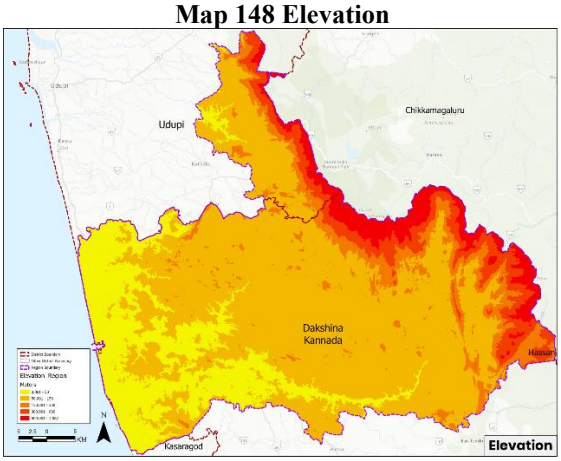


Source 210 Author

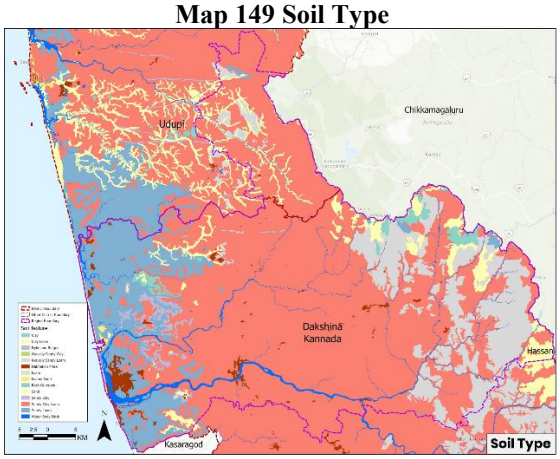
Map 147 Bifurcation Ratio



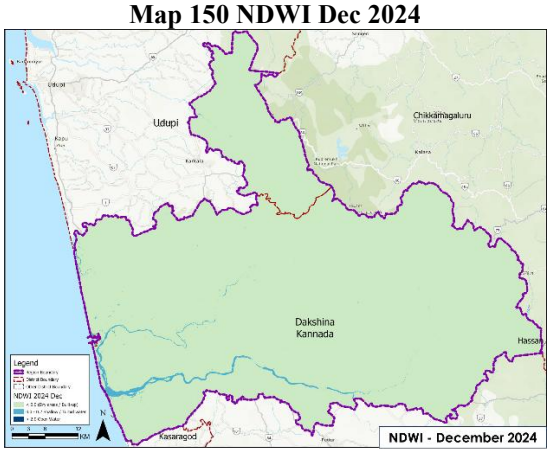
Map 148 Elevation



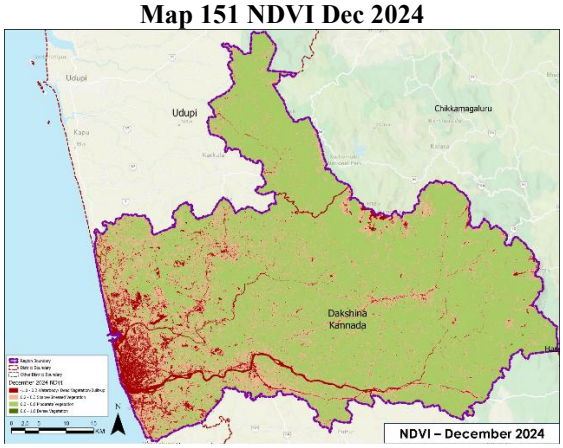
Map 149 Soil Type



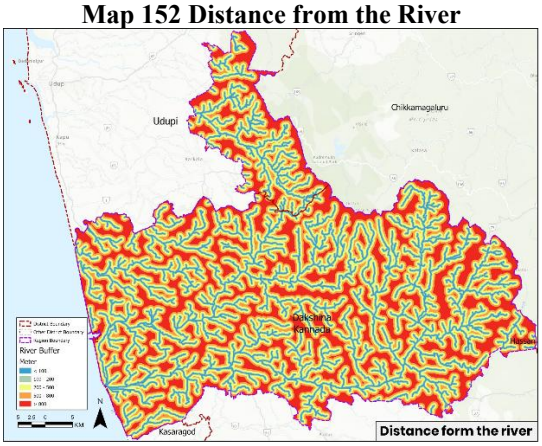
Map 150 NDWI Dec 2024



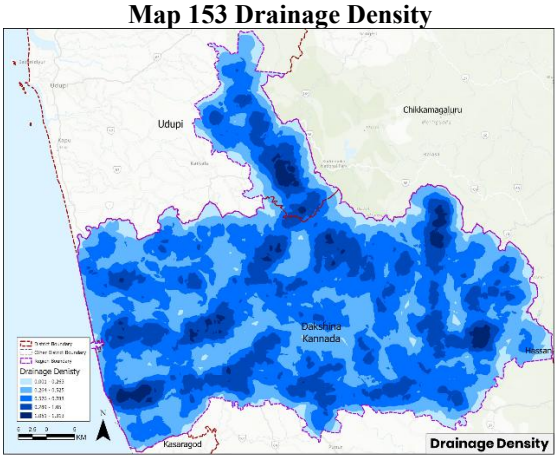
Map 151 NDVI Dec 2024



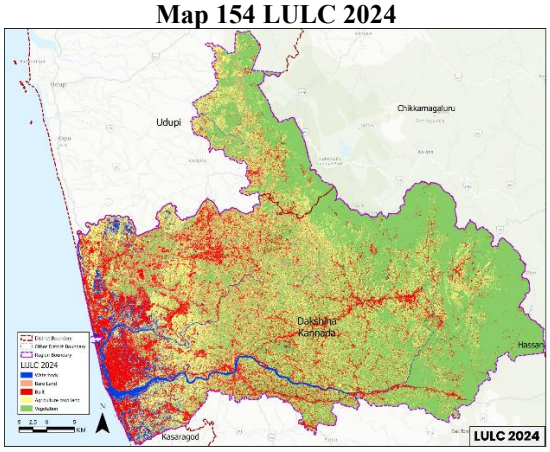
Map 152 Distance from the River



Map 153 Drainage Density

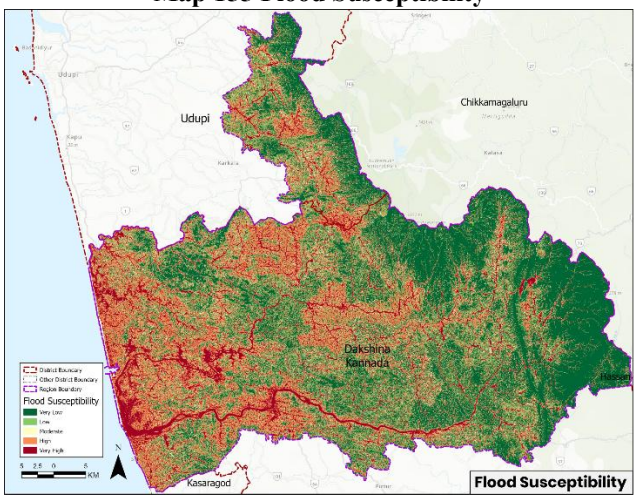


Map 154 LULC 2024



Source 211 Author

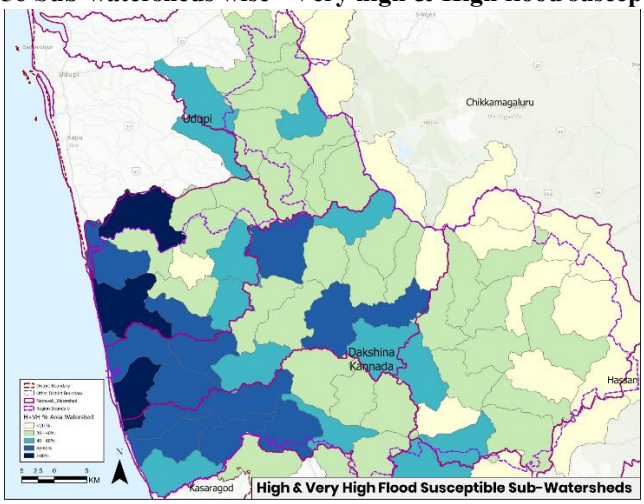
Map 155 Flood Susceptibility



Source 212 Author

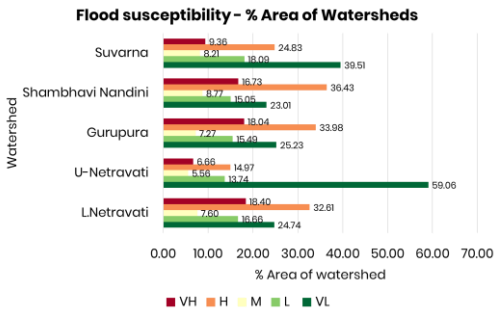
The area under Very high and High flood susceptibility is captured sub-watershed wise.

Map 156 Sub-watersheds wise - Very high & High flood susceptibility



Source 213 Author

Figure 66 Watershed wise flood susceptibility



Source 214 Author

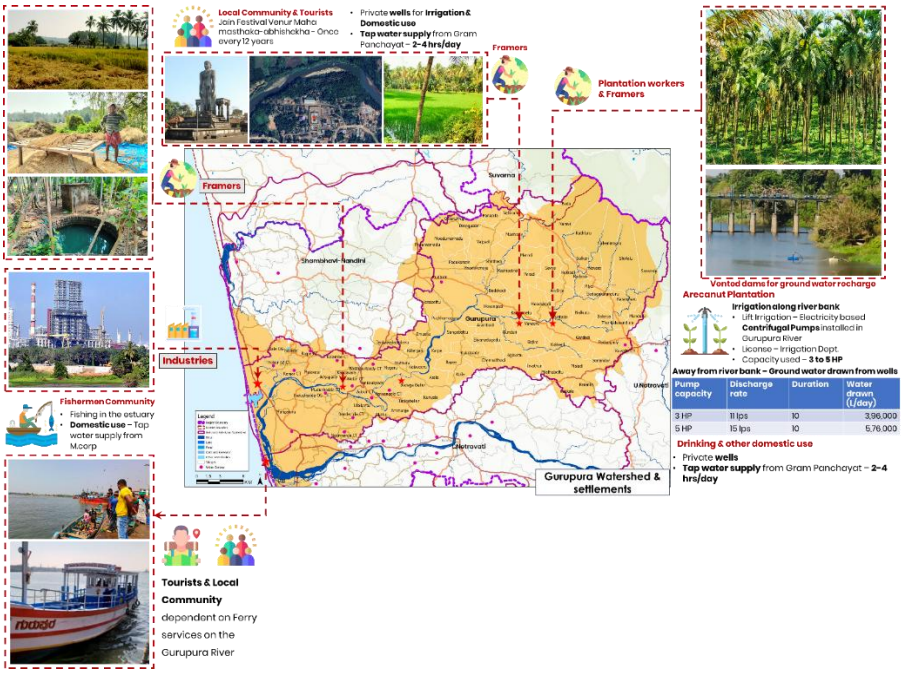
Inference:

Gurupura & Lower Netravati watersheds have the highest % area of watershed under Very high & High flood susceptibility, followed by Shambhavi – Nandini Watershed It can also be seen that the sub-watersheds along the coast have more than 60% & 80% sub-watershed area under High & Very High flood susceptibility.

3.5 Stakeholder Mapping

As part of understanding the stakeholders and their influence on the river in terms of dependency, use and decision making in the region, a stakeholder mapping is developed based on the site visit observations and interactions with the local communities in the Gurupura Watershed.

Map 157 Stakeholder mapping



Source 215 Author

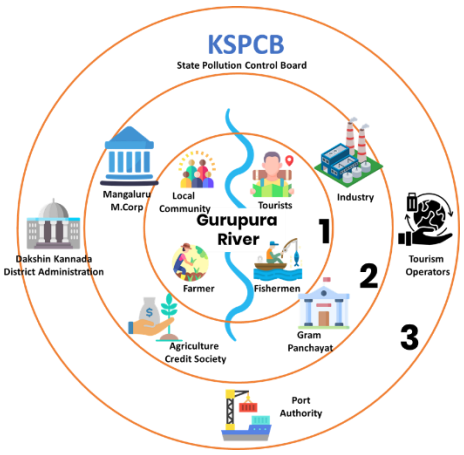
It is observed that the Stakeholders in the upstream of Gurupura River are Farmers and plantation workers, the area sees majorly Arecanut and Coconut plantations. The fields closer to the river bank draw the river water through lift irrigation via centrifugal pumps. For drinking and other domestic purposes, people depend on open wells despite having tap water supply, the reason being intermittent and un-reliable supply of treated tap water.

Closer to the city, more of paddy farms are seen, the farmers here are entirely dependent on open wells and ground water for irrigation.

As the river transcends into the city limits, Industries are said to be disposing the effluents into Gurupura River. The downstream of Gurupura river forms an Estuarian complex, where the fishermen earn their livelihood by fishing in the estuary. The Tourists and residents are seen boarding ferries to cross Gurupura river and get to the beach.

This is mapped in a concentric circle diagram that explains the degree of influence of the stakeholders.

Figure 67 Stakeholders influence on Gurupura River



Source 216 Author

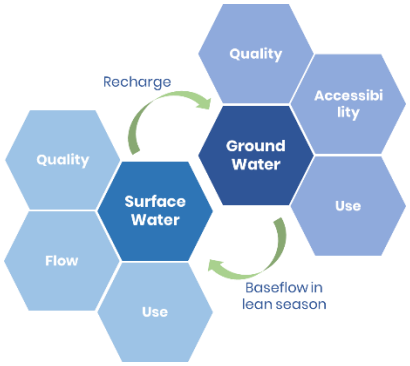
Innermost Circle (Direct Dependents): These stakeholders are most vulnerable and directly dependent on the river for their daily sustenance and livelihoods.

Middle Circle (Local Institutions & Economic Users): These groups have moderate spatial proximity and play key roles in managing, governing, and utilizing the river's resources,

Outer Circle (Regulators & Indirect Influencers): These stakeholders have high influence and decision-making power over river policies despite limited direct interaction with the river.

The diagram below captures the dependence of the stakeholders on the two most important sources of water in the region – The surface water (in this case Gurupura River) and Ground water. It illustrates the interconnected dynamics between surface water and groundwater, which is directly relevant when analysing stakeholders' dependency on river systems.

The use of Surface water is dependent on the quality and flow of the river and vice-versa, while the use of ground water is dependent on the quality and accessibility & vice-versa. Both the sources support each other – Ground water maintain the baseflow of the river in the lean seasons, while the Surface water maintains the depth to water level through infiltration.



3.6 Economic Activities in the Region

3.6.1 Economic profile of Dakshin Kannada District

In the fiscal year **2021-22, Dakshin Kannada district** recorded a nominal GDP of **1.11 lakh crore**, to Karnataka's total GDP of **19.62 lakh crore,** ranks second after Bangaluru Urban, which contributes approximately **8.3%** to India's overall economic output in **FY 2021-22.**

GDDP of Dakshin Kannada District:

The district has a per-capita GDDP of **4.43/Yr/Person,** which is higher than the state average of **2.20L/Yr/Person.** This stands **2nd in** the state after Bengaluru Urban

Sectoral Distribution of the scoped region:

The **tertiary sector** is the cornerstone of the region's economy, with **64.06% employment**. The other workers category employs **443803** workers with **93% being main workers** with **4,10,962** persons in the workforce.

Figure 68 Sectoral contribution of Dakshin Kannada District

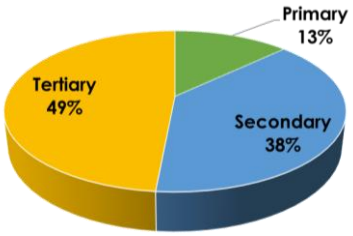
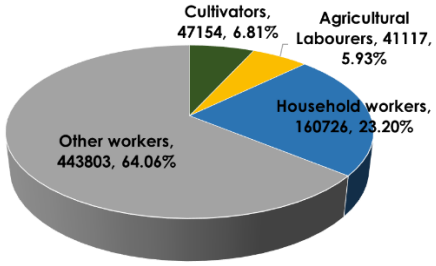


Figure 69 Number of Workers



Source 217 District Statistical Report 2023

3.6.2 Primary Sector – Agriculture

37.22% of the regions area is under Agriculture and plantations. LULC shows the area under agriculture and plantations has reduced by 12.18% from 2015 to 2024.

Table 52 Agriculture Land Use Change

Sl no	Landuse Category	Area 2015	% Area	Area 2025	% Area	Area Change	% Area Change
1	Agricultural Crop Land	32276.88	31.73	26573.4	29.74	-5703.48	-17.67
2	Agricultural Plantation	69450.66	68.27	62767.71	70.26	-6682.95	-9.62
Total		**101727.54**		**89341.11**		-12386.43	-12.18

Source 218 Author

Table 53 Land utilization of Dakshin Kannada District FY 2021 - 22

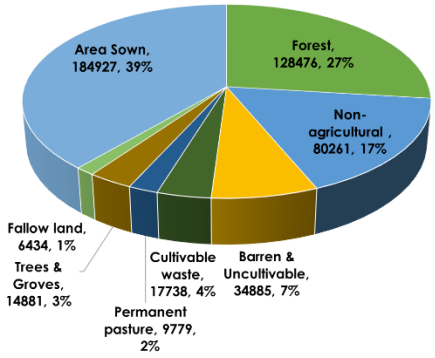


Table 54 Area (Ha) under cultivation FY 2021-22

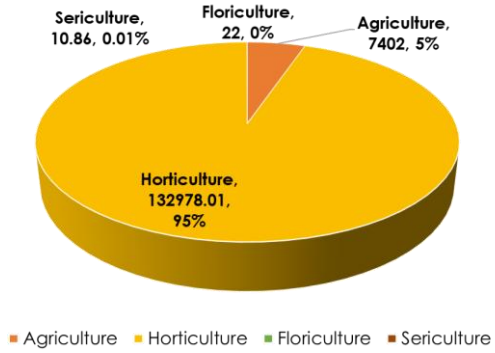
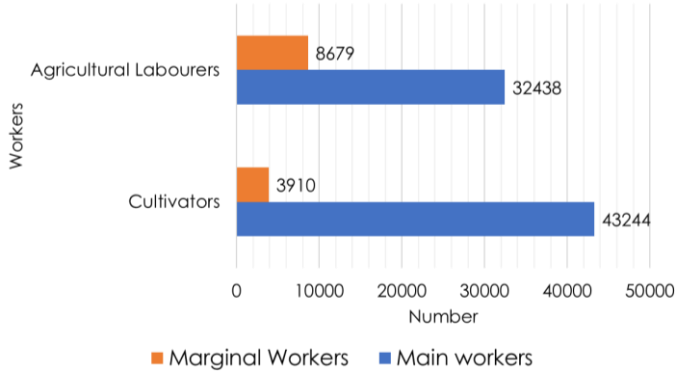


Figure 70 Primary sector workforce in the region



Source 219 District Statistical Report 2023

The region has a total of **88,271** workers employed in the **primary sector,** of which **47,154 (53%)** are **cultivators** and **41,117 (47%)** are **agricultural labourers.**

Figure 71 Cultivated area statistics for Dakshin Kannada District

Agricultural land use	Area (Ha)
Net Irrigated area	161863
Area irrigated more than once	3564
Gross irrigated area	**165427**
Net Sown Area (NSA)	184927
Area sown more than once	4895
Gross cropped area (GCA)	**189822**
Cropping intensity (GCA/NSA*100)	**102.65 %**

Figure 72 Production of crops

Crop	Area (Ha)	Production (MT)
Food crops	7402	20891
Vegitable crops	17	23
Fruit crops	5849	121322
Spices	-	82704
Commercial crops	230876	615456
Floriculture	22	-

Source 220 District Statistical Report 2023

The cropping intensity shows that double cropping is low in the area. Commercial crops occupy the largest share of area and production – this includes Arecanut and Coconut Plantations, Spices, and cashew.

Figure 73 Agricultural Calendar in the region

Season	Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kharif	Paddy												
	Cow-pea												
	Mango												
	Okra												
	Green chilli												
	Bottle Gourd												
	Pumpkin												
	Cucumber												
	Bitter gourd												
	Ridge Gourd												
	Oil seed												
Rabi	Paddy												
	Tobacco												
	Green Chilli												
	Oil seed												
Zaid	Cow-pea												
	Okra												
	Green Chilli												
	Bottle Gourd												
	Pumpkin												
	Cucumber												
	Bitter gourd												
	Ridge Gourd												

Source 221 Author

Crops grown throughout the year: Banana, Lemon, Pineapple**,** Sapodilla, Papaya, Sugarcane, Spices (Pepper), Coconut and Arecanut, Leafy vegetables, Cashew

Major crops

Figure 74 Season wise crop production

Crop Season	Area(Ha)	Production (MT)	Yield (Kg/Ha)
Khari	9750	45533	4670
Rabi	1675	6514	3889
Zaid	160	560	3500
Total	**11585**	**52606.575**	**12059**

Source 222 District Statistical Report 2023

Figure 75 Area under major crops

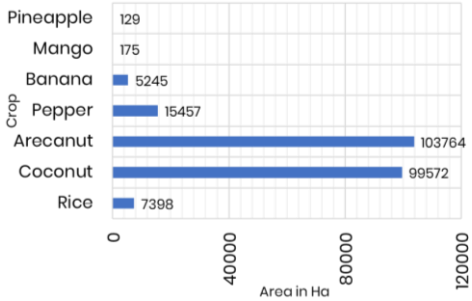
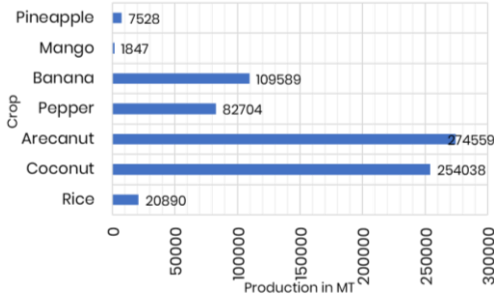


Figure 76 Production of major crops



Source 223 District Statistical Report 2023

Irrigation

The irrigation in the region is dependent on rainfall and groundwater. Groundwater extraction occurs mostly through open wells, tube wells, river water is drawn through lift irrigation. The primary source of irrigation includes Tube wells, covering 58% of Net & gross irrigated area.

Figure 77 Gross irrigated area: Irrigation sources

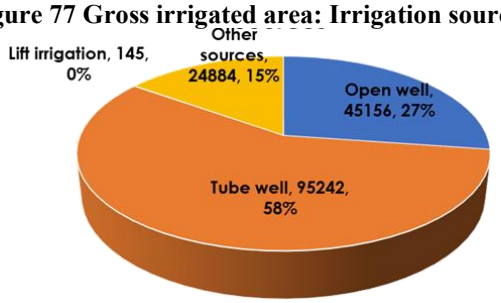
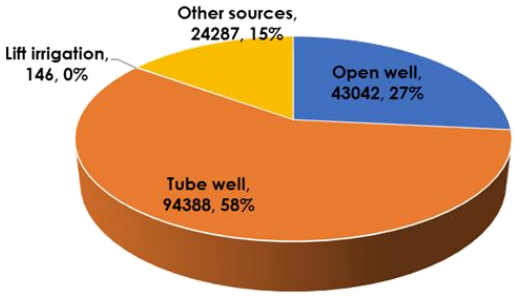
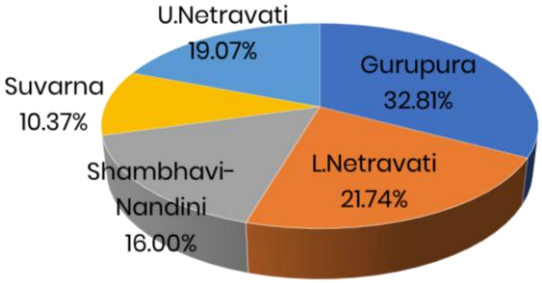


Figure 78 Net irrigated area: Irrigation sources



Source 224 District Statistical Report 2023

Figure 79 % Agricultural area in Watersheds



Source 225 Author

Table 55 Fertilizers types and % run-off

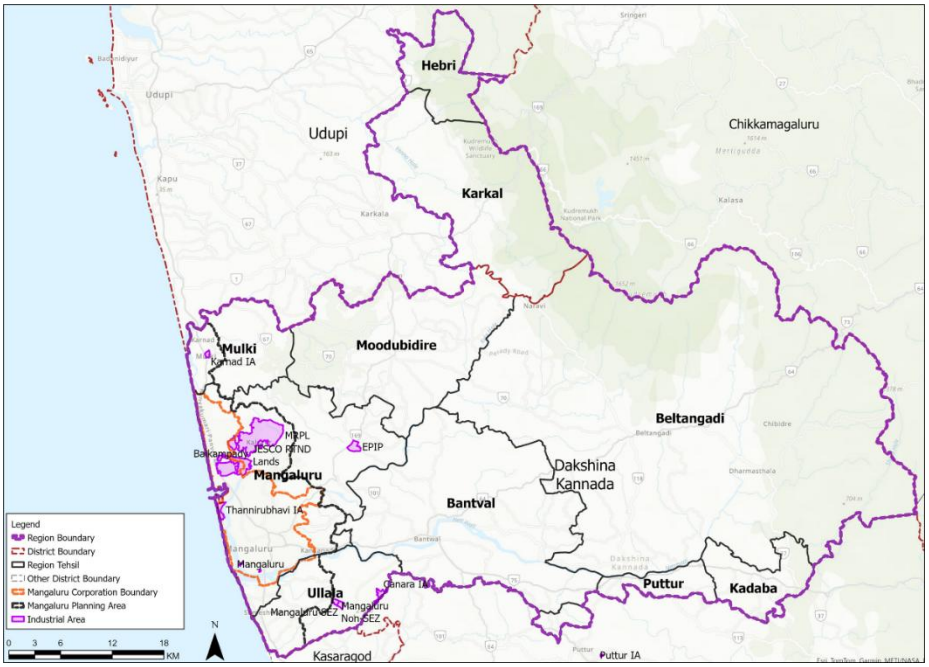
Fertilizer Type	Common Name	Amount Distributed (MT)	% in Run-off	Run-off to the river
Urea	Urea	563	25	140.75
DAP	Diammonium Phosphate	37	10	3.7
MOP	Muriate of Potash	1312	5	65.6
NPK	Nitrogen, Phosphorus, Potassium Mix	2954	15	443.1
SSP	Single Superphosphate	8	10	0.8
Total		**4874**		**653.95 (13.42%)**

Source 226 Agriculture department

Gurupura watershed has the largest share of agriculture & plantation area – **32.81%,** assuming same % of fertilizer run-off, ≈ **87.76 MT** of fertilizer reaches the river.

3.6.3 Secondary Sector – Industries

Map 158 Industries in the Region



Source 227 KIADB

There are 6 Industrial areas in the region and 3 Industrial Estates within the region. Karnataka Industrial Area Development Board (KIADB) established all the industrial areas except Mangalore Refineries and Petrochemical Limited which was jointly established by Hindustan Petroleum Corporation Ltd, with Aditya Birla group, now is a subsidiary of ONGC.

The region has 98% of Micro scale industries and 97% White category industries. Micro scale industries also employ the largest share of workforce in the region.

Figure 80 Scale of industries

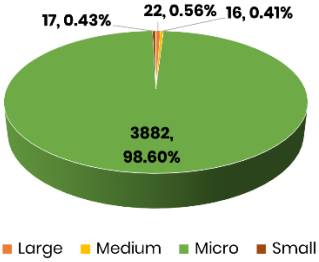


Figure 81 Pollution classification

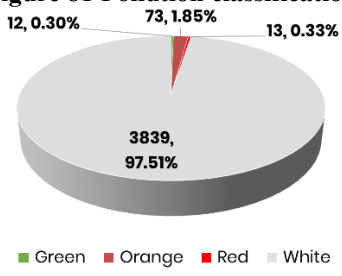


Figure 82 Scale wise pollution potential

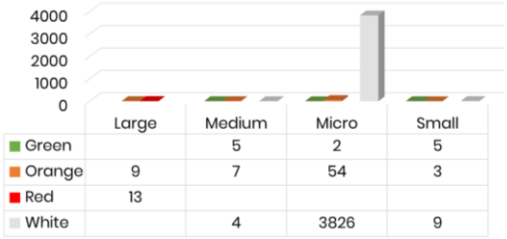
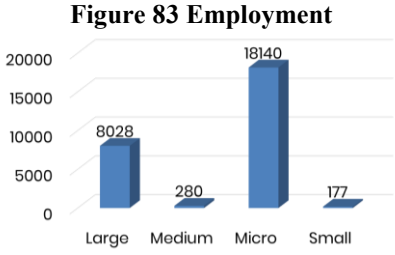


Figure 83 Employment



Source 228 District Industries Centre, & CPCB Pollution classification of industries

There are 3937 Industries in the Region (Across scales). **Baikampady IA** is allowed to have **orange** category industry, other industrial areas are permitted to have only **Green** industries

Types of industries:

Agro based, Soda water, Cotton textile, Wooden silk & artificial thread-based clothes, Jute and Jute based, Wood/Wooden based furniture, Paper & paper products, Leather based, Chemical/Chemical based, Rubber, Plastic & petro based, Mineral based, Metal based (Steel Fab), Engineering units, Electrical machinery & transport equipment, Repairing and servicing, & Oil refineries.

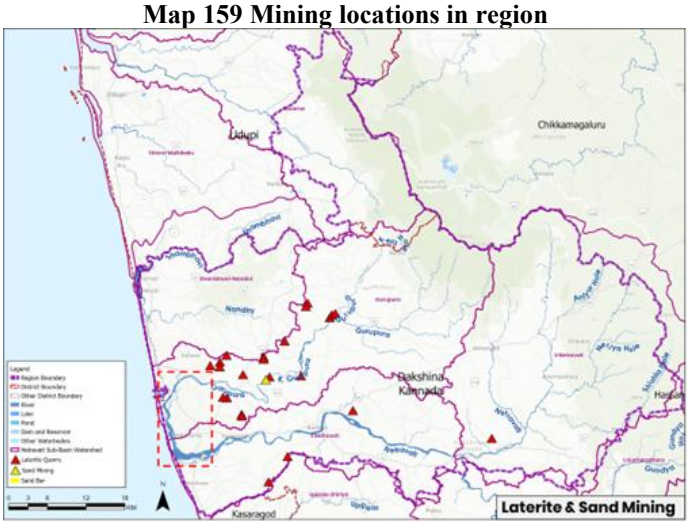
Table 56 Details of industrial Area

IA Name	IE if any	Total Area (Ha)	Industrial Area (Ha)	Number of plots	Alloted plots	Pollution Category Allowed
Baikampady	JESCO & Baikampady	216.6	183.19	548	524	Orange
EPIP	EPIP	83.02	61.06	86	40	Green
Thannirbhavi	-	50.38	21.25	14	6	Green
Canara	-	237	138.47	163	4	Green
Karnad	-	26.64	20.28	100	95	Green
SEZ/Non-SEZ	-	82	68.2	44	20	Green
MRPL	-	644	456	-	-	-

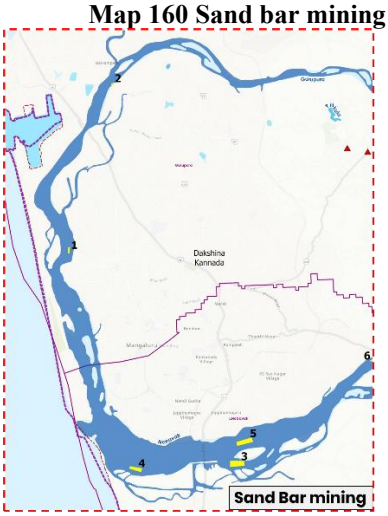
Source 229 KIADB

3.6.4 Secondary Sector – Mining

Map 159 Mining locations in region



Map 160 Sand bar mining



Source 230 District Geology and Mining department

Table 57 Mining statistics

Mineral	Quantity Extracted	Year
Laterite Stone	52,214 metric tonnes	2010–2011
River Sand (non-CRZ)	75,444 metric tonnes (stock at yards)	2023
River Sand (non-CRZ)	~40,000 metric tonnes (available stock)	2024
River Sand (CRZ)	148 permits restored, 54 new issued	2022

Source 231 District geology and mining department

In Dakshina Kannada district, **major minerals** include **granite, sillimanite, and potentially bauxite**, while **minor minerals** include **laterite, quartz, and other silica minerals.**

Mining Activities

Quarrying: The district has numerous quarry leases for building stones and laterite stones, with detailed permits issued for various taluks like Bantwal, Belthangady, Mangaluru.

Sand Mining: Non-CRZ sand block quarry leases are also prevalent, indicating a significant focus on sand extraction for construction purposes.

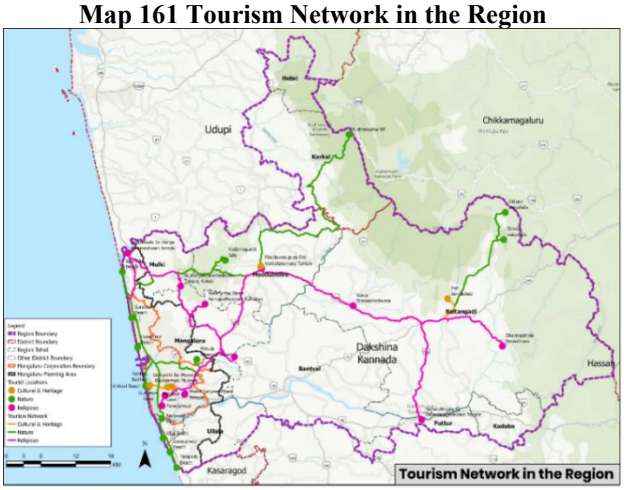
Sand bar mining in CRZ area is also practiced in the region for ordinary sand. **River sand deposition** ranges from **0.50 to 1.5 meters** in the coastal river channels.

The process of extraction involves **scooping methods using labor**. The sand is collected in baskets and poured onto boats or rafts. It is then carried to the shore and transported to the destination in trucks.

Despite being rich in mineral deposits, **Laterite Quarry & Sand mining** are the prominent mining activity in the district.

3.6.5 Tertiary Sector – Tourism

Map 161 Tourism Network in the Region



Source 232 Dakshin Kannada Tourism Department

Figure 84 Category wise tourist footfall in the region 2024

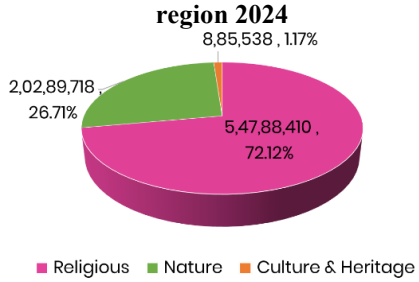
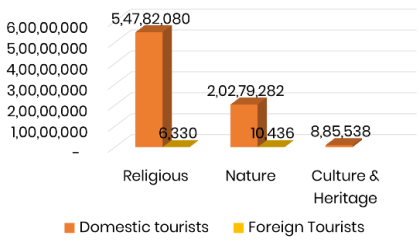
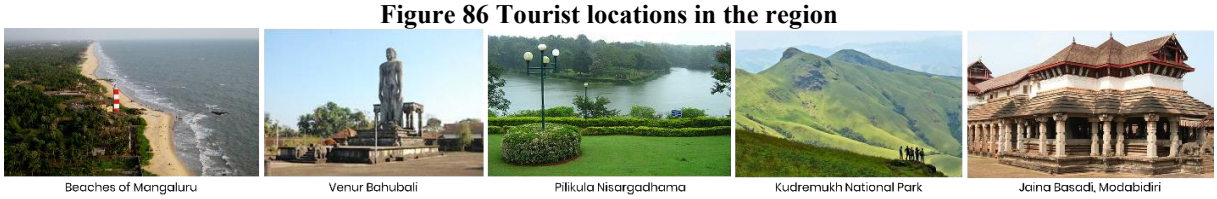


Figure 85 Category wise tourist footfall in the region



Source 233 Dakshin Kannada Tourism Department

Figure 86 Tourist locations in the region



Source 234 Compiled by Author

Figure 87 Accommodation in the region

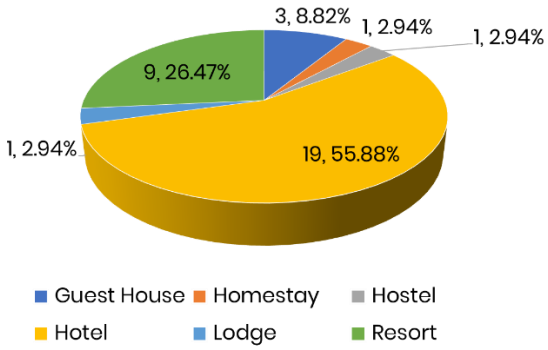
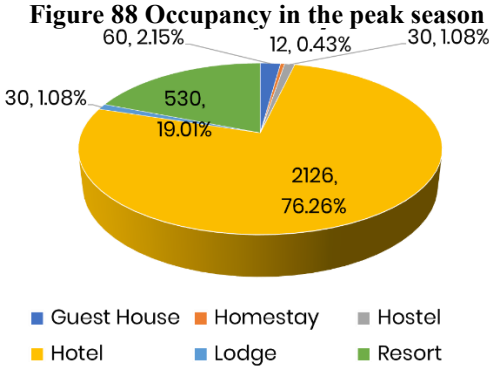
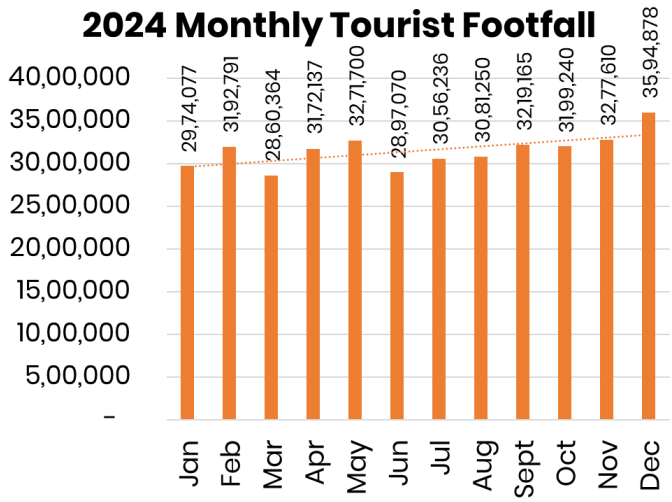


Figure 88 Occupancy in the peak season



Source 235 Compiled by author

Figure 89 Monthly tourist footfall trend in 2024



Source 236 Dakshin Kannada Tourism Department

The region sees a steady footfall throughout the year, highest in the month of December.

72.12% visit for **Nature tourism,** with the city's beaches being the key attraction.

Accommodation in the region is all concentrated in the Mangaluru city & its outskirts. Tourist generally travel for attractions outside the city and return for the stay. There are diverse options including 19 hotels, 1 homestay, 9 resort, 3 Guest house, 1 Hostel & 1 lodge hosting 2788 tourists in peak season.

3.6.6 Impact Matrix

After a detailed study of the economic activities, it becomes essential to assess the impact of economic activities on various environmental components, an impact matrix is developed, that would guide in various development interventions and decision making. An impact matrix is a tool used for this purpose where the environmental components are listed in the vertical axis, while the impacting activities and their sub activities identified through baseline, analysis and primary survey are listed in the horizontal axis.

Figure 90 Impact Matix of economic activities in the region

Affected Aspect		Economic Activities																			
		Agriculture				Industry							Mining				Tourism					
Category	Components affected	Ploughing & flooding	Use of chemical fertilizers & pesticides	Irrigation using river water	Average	Manufacturing (chemicals, paper, food, etc.)	Use of boilers (firewood, diesel)	Effluent discharge to water bodies	Handling of produce	Solid/hazardous waste handling	Industrial transport & logistics	Average	Site clearing and material extraction	Use of diesel machinery and transport	Stockpiling and open storage of material	Average	Beach and river-based tourism (boating, recreation)	Heritage site visits & cultural festivals	Hotel and resort development	Tourist waste generation	Road transport & parking	Average
Physical Environment	Air	2	2	1	1.67	1	1	1	1	1	2	1.17	2	3	2	2.33	2	1	2	1	2	1.60
	Inland Rivers	3	3	3	3.00	1	1	1	3	1	1	1.33	2	2	3	2.33	3	1	2	3	2	2.20
	Inland waterbodies	3	3	3	3.00	1	1	1	2	1	1	1.17	1	2	1	1.33	1	1	2	2	1	1.40
	Ground water	2	3	1	2.00	1	1	1	2	1	1	1.17	2	1	2	1.67	2	1	2	2	1	1.60
	Land & Soil	3	3	2	2.67	1	1	1	1	1	1	1.00	3	2	3	2.67	2	1	3	3	2	2.20
	Micro-climate	2	1	2	1.67	1	1	1	1	1	1	1.00	1	2	1	1.33	2	1	2	1	2	1.60
Biological Aspect	Terrestrial Flora	2	3	2	2.33	1	1	1	1	1	1	1.00	3	2	2	2.33	2	1	3	2	2	2.00
	Terrestrial Fauna	2	3	2	2.33	1	1	1	1	1	1	1.00	2	2	2	2.00	2	1	2	2	2	1.80
	Aquatic Flora	1	3	3	2.33	1	1	1	1	1	1	1.00	2	1	3	2.00	3	1	2	3	2	2.20
	Aquatic Fauna	1	3	3	2.33	1	1	1	1	1	1	1.00	2	1	3	2.00	3	1	2	3	2	2.20
Socio-cultural Aspect	Livelihood	1	1	1	1.00	2	1	1	2	1	2	1.50	2	2	2	2.00	2	1	2	2	2	1.80
	Health	1	1	1	1.00	1	1	1	1	1	1	1.00	2	3	2	2.33	2	1	2	3	2	2.00
	Culture	1	2	1	1.3	1	1	1	1	1	1	1.00	1	1	1	1.00	1	2	2	1	1	1.40
Average		1.8	2.4	1.9	26.67	1.1	1.0	1.0	1.4	1.0	1.2	14.33	1.9	1.8	2.1	25.33	2.1	1.1	2.2	2.2	1.8	24.00

Source 237 Author

1 – 1.67	Low
1.68 – 2.33	Moderate
2.33 - 3	High

The impacts are scored on a scale of 1 to 3 (Low to High) in a matrix based on the observation, baseline analysis and primary surveys conducted on site. The higher the impact, higher is the score. The impact considered here is in terms of the negative implications of the activities on the environmental components.

Findings:

Agricultural activity is observed to have highest impact. The most impacted aspects are Inland River (In this case, Gurupura river) from the agricultural-run-off, Land & Soil environment due to use of fertilizers & modern ploughing tools. This results in chemical infiltration in to ground water.

Figure 91 Impact Matrix - Observations

Affected Aspect		Total score	Economic Activities							
			Agriculture		Industry		Mining		Tourism	
Category	Components affected		Average	Observation	Average	Observation	Average	Observation	Average	Observation
Physical Environment	Air	6.8	1.67	The agricultural practice in the region is contaminating the surface & ground water resources, modifying river flow through irrigation & chemical use	1.17	No significant impact in the region	2.33	Mining degrades land, pollutes air and water, and slightly alters micro-climate.	1.60	Waste generation, land use changes, increased vehicular emissions, and strain on local air, water, and soil quality.
	Inland Rivers	8.9	3.00		1.33		2.33		2.20	
	Inland waterbodies	6.9	3.00		1.17		1.33		1.40	
	Ground water	6.4	2.00		1.17		1.67		1.60	
	Land & Soil	8.5	2.67		1.00		2.67		2.20	
	Micro-climate	5.6	1.67		1.00		1.33		1.60	
Biological Aspect	Terrestrial Flora	7.7	2.33	Intensive agriculture & plantation reduces biodiversity & harms non-targegt terrestrial & aquatic species & alters habitat die to chemical run-off	1.00		2.33	disturbs flora and fauna through habitat loss and sediment runoff.	2.00	Habitat disturbance from construction and tourist footfall stresses local flora and fauna, especially in sensitive riverine and coastal zones.
	Terrestrial Fauna	7.1	2.33		1.00		2.00		1.80	
	Aquatic Flora	7.5	2.33		1.00		2.00		2.20	
	Aquatic Fauna	7.5	2.33		1.00		2.00		2.20	
Socio-cultural Aspect	Livelihood	6.3	1.00	Chemical intensive farming endangers farmers & public health. The region sees a weak traditional farming knowledge which induces long term risks to sustainable rural livelihood	1.50		2.00	affects health and livelihoods moderately; cultural impact is minimal.	1.80	Boosts local income and cultural visibility but can commercialize traditions and strain infrastructure.
	Health	6.3	1.00		1.00		2.33		2.00	
	Culture	4.7	1.3		1.00		1.00		1.40	
Average			26.67		14.33		25.33		24.00	

Source 238 Author

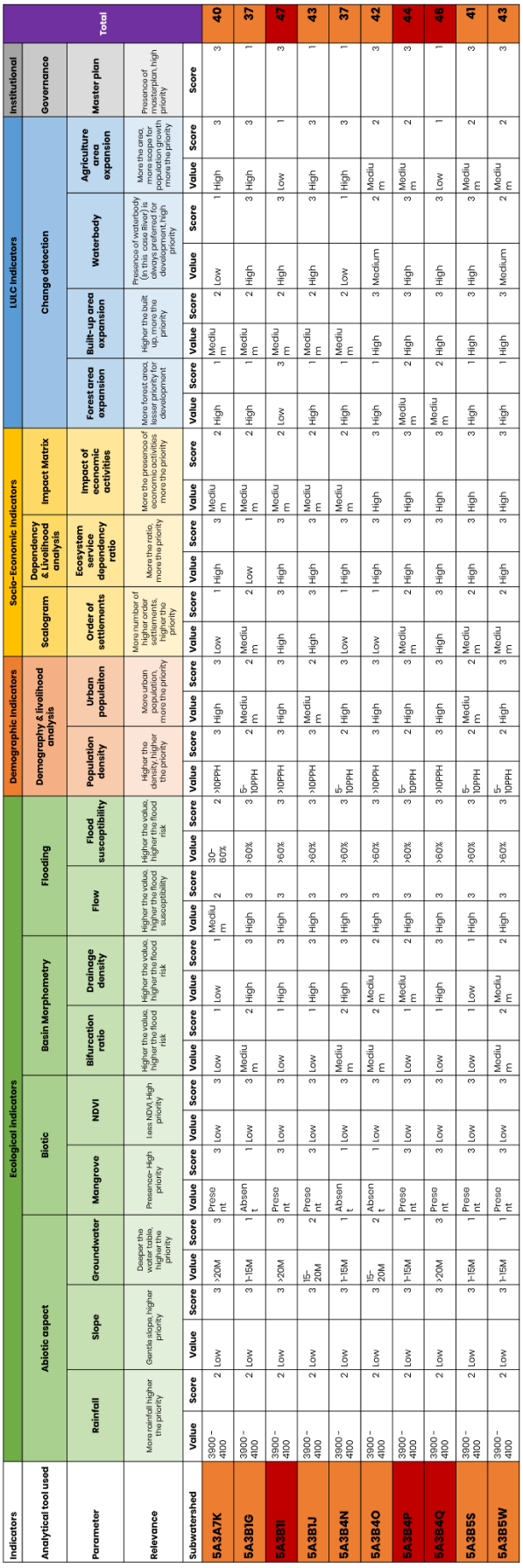
3.6.7 Prioritization of Sub-watersheds

The 3rd objective of the study is to arrive at the critically degraded sub-watersheds, that contain urban settlement and have a bearing on the river water ecology. To identify the critical sub-watersheds, various sectors studied as part of baseline and their findings were listed in a table and given a value (High, Medium & Low) and a corresponding score between 1 to 3 was assigned. This is done at the sub-watershed level.

Findings:

The sub-watersheds along the coast of the Gurupura Watershed score the highest and hence prioritised for further study. Additionally, the next set of high scoring sub-watersheds can be seen encompassing the Mangaluru Planning Area. These are termed semi-critical sub-watersheds for further reference. The 3 critical sub-watersheds comprise of the Mangaluru Municipal Corporation Area.

Figure 92 Prioritization of Sub-watersheds

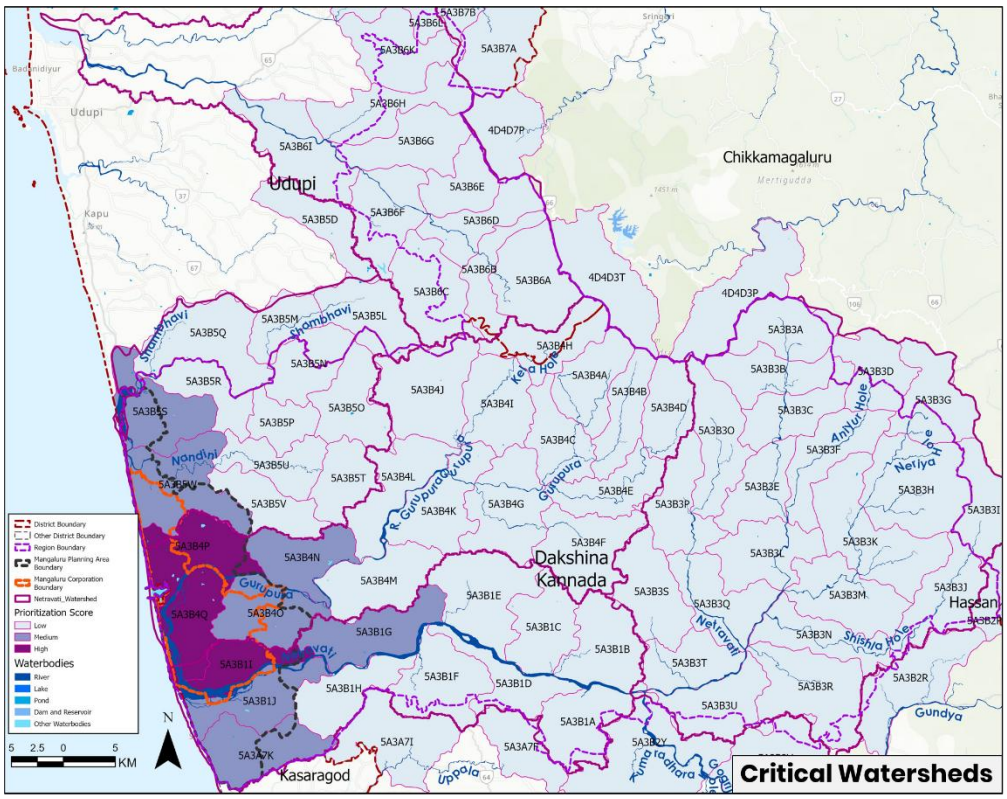


Indicators	Ecological Indicators																		Demographic Indicators				Socio-Economic Indicators						LULC Indicators								Institutional		Total
Analytical tool used	Abiotic aspect				Biotic		Basin Morphometry			Flooding									Demography & livelihood analysis				Scalogram		Dependency & Livelihood analysis		Impact Matrix		Change detection								Governance		
Parameter	Rainfall		Slope		Groundwater		Mangrove		NDVI	Bifurcation ratio		Drainage density		Flow		Flood susceptibility			Population density		Urban population		Order of settlements		Ecosystem service dependency ratio		Impact of economic activities		Forest area expansion		Built-up area expansion		Waterbody		Agriculture area expansion		Master plan		
Relevance	More rainfall higher the priority		Gentle slope, higher priority		Deeper the water table, higher the priority		Presence-High priority		Less NDVI, High priority	Higher the value, higher the flood risk		Higher the value, higher the flood risk		Higher the value, higher the susceptibility		Higher the value, higher the flood risk			Higher the density, higher the priority		More urban population, more the priority		More number of higher order settlements, higher the priority		More the ratio, more the priority		More the presence of water consuming activities more the priority		More forest area, lesser priority for development		Higher the built up area, more priority		Presence of waterbody (in this case River) is always good for development, high priority		More the area, more scope for population growth more the priority		Presence of master plan, high priority		
Subwatershed	Value	Score	Value	Score	Value	Score	Value	Score	Value	Value	Score	Value	Score	Value	Score	Value	Score		Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Score	
5A3A7K	3900 - 4100	2	Low	3	>20M	3	Present	3	Low	1	Low	1	Medium	2	>10PPH	3	High	3	Low	1	High	2	Medium	1	High	2	Low	1	High	3		40
5A3B1G	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	High	3	>60%	3	5-10PPH	2	Medium	2	Low	1	Medium	2	High	2	High	1	Medium	3	High	3		37
5A3B1I	3900 - 4100	2	Low	3	>20M	3	Present	3	Low	1	High	3	High	3	>60%	3	>10PPH	3	High	3	High	3	Medium	2	Low	3	High	3	Medium	2	High	3	Low	1		47
5A3B1J	3900 - 4100	2	Low	3	15-20M	2	Present	3	Low	1	High	3	High	3	>60%	3	>10PPH	3	Medium	2	High	3	High	3	High	3	High	1	Medium	2	High	3	High	3		43
5A3B4N	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	High	3	>60%	3	5-10PPH	2	High	3	Low	1	High	3	Medium	2	High	1	Medium	2	Low	1	High	3		37
5A3B4O	3900 - 4100	2	Low	3	15-20M	2	Absent	1	Low	3	Medium	2	Medium	2	High	3	>60%	3	>10PPH	3	High	3	Low	1	High	3	High	1	High	3	Medium	2	Medium	2		42
5A3B4P	3900 - 4100	2	Low	3	1-15M	1	Present	3	Low	3	Low	1	Medium	2	High	3	>60%	3	5-10PPH	2	High	3	Medium	2	High	3	High	2	High	3	High	3	Medium	2		44
5A3B4Q	3900 - 4100	2	Low	3	>20M	3	Present	3	Low	3	Low	1	High	3	>60%	3	>10PPH	3	High	3	High	3	High	3	High	3	High	2	High	3	High	3	Low	1		46
5A3B5S	3900 - 4100	2	Low	3	1-15M	1	Present	3	Low	3	Low	1	Low	1	High	3	>60%	3	5-10PPH	2	Medium	2	High	3	High	3	High	1	High	3	High	3	Medium	2		41
5A3B5W	3900 - 4100	2	Low	3	1-15M	1	Present	3	Low	3	Medium	2	Medium	2	High	3	>60%	3	5-10PPH	2	High	3	Medium	2	High	3	High	1	High	3	High	3	Medium	2		43

Source 239 Author



Map 162 Critical Watersheds



Source 240 Author

Table 58 Identified Critical Sub-watersheds

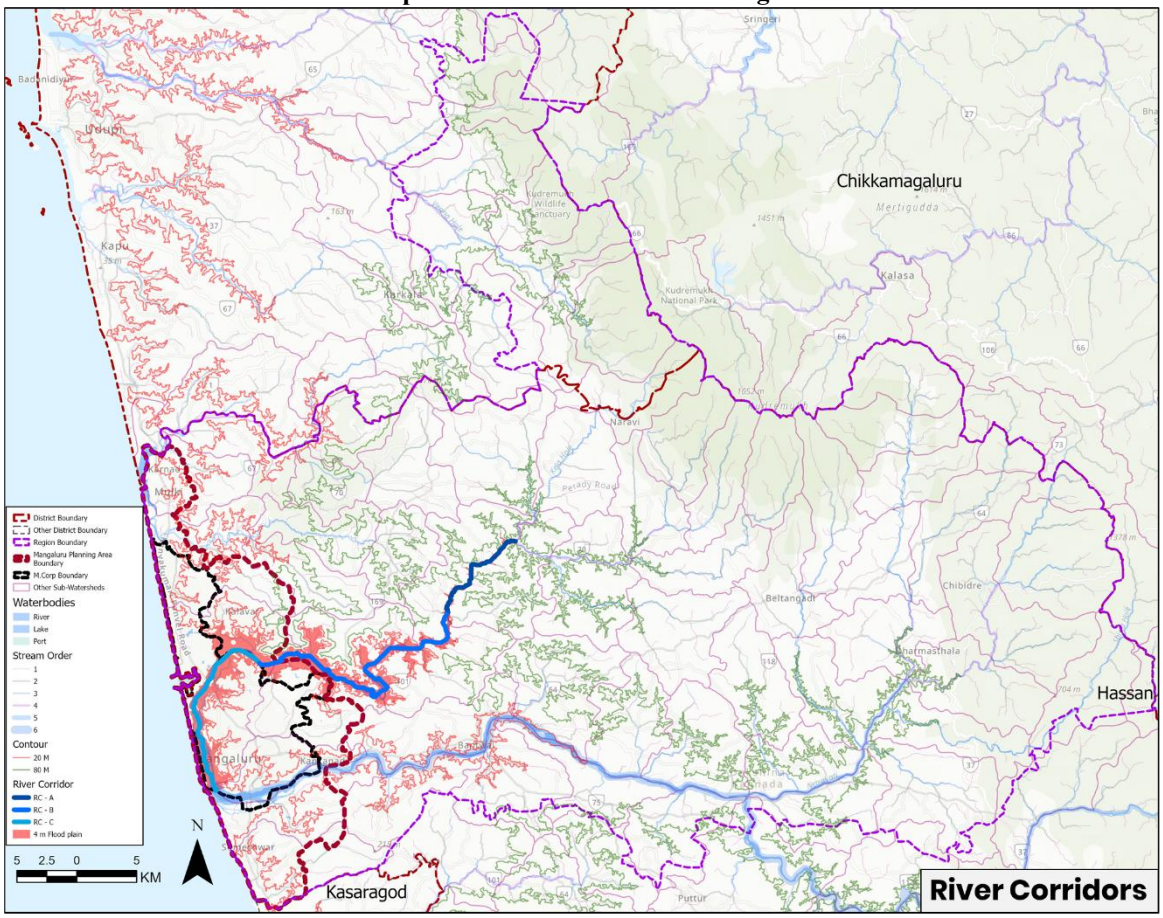
Sub-watersheds	Sub-watershed code	Watershed	Area (Sq.km)	% area of watershed	Major economic Activity
Critical sub-watersheds	5A3B4P	Gurupura	55.19	5.9	Industry, Fishing
	5A3B4Q		48.38	5.2	
	5A3B1I	Netravati	34.69	6.0	
Semi-critical sub-watersheds	5A3B5S	Shambhavi-Nandini	56.76	10.4	Agriculture, Fishing
	5A3B5W		72.07	13.23	
	5A3B4N	Gurupura	46.49	4.9	Agriculture
	5A3B40		52.41	5.6	
	5A3B1G	Netravati	58.74	10.2	Agriculture, Fishing
	5A3B1J		49.85	8.7	
	5A3A7K		53.25	9.3	

Source 241 Author

Further, the **River Corridors (RC) are** identified based on the stream order, contour and administrative boundary – All the river corridors identified for **Gurupura river** are of **Stream order 5,** & **land area up to 4m flood line** is considered

1. **RC – A** between 20 – 80m contour,
2. **RC – B** 20m contour to planning area boundary
3. **RC – C** 20m contour within planning Area Boundary

Map 163 River Corridors in the region



Source 242 Author

4. Mangaluru Planning Area

The prioritized sub-watersheds contain the areas that have potential for further development and hence have the highest potential to impact and be impacted by the Gurupura River. These sub-watersheds contain the Mangaluru Planning Area.

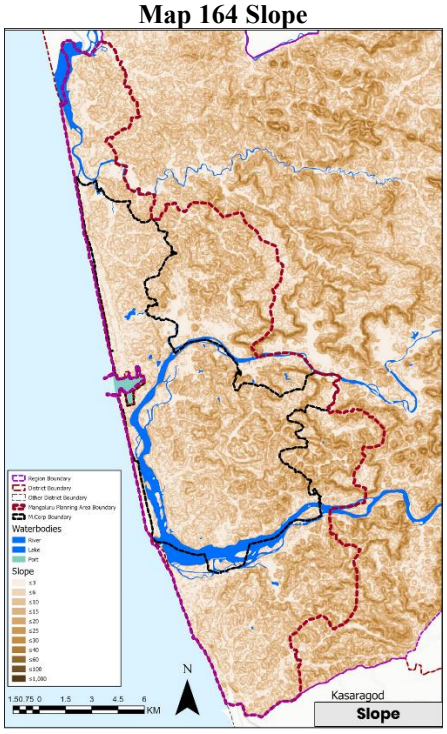
4.1 Environmental Resources

After a thorough study and analysis of the region, it is observed that Mangaluru Planning Area shares most environmental resources with the region.

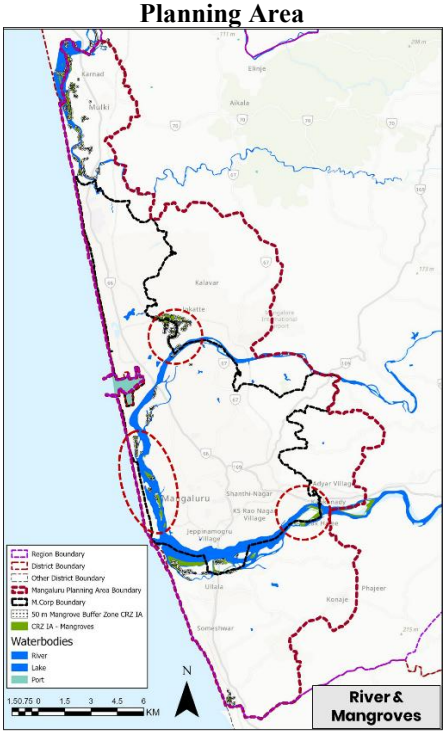
Low gradient slopes: Gradual variation in slope, forming a natural gradient from the elevated interior plateaus to the low-lying coastal fringe.

River: Confluence of the Major Rivers – **Gurupura & Netravati & Shambhavi & Nandini** with the Arabian Sea.

Map 164 Slope



Map 165 River & Mangrove in Mangaluru Planning Area



Source 243 Author

Estuarine Complex & Mangrove: Supports Mangroves in the Gurupura & Netravati Estuary and The Shambhavi & Nandini Estuary. Currently, the mangrove area is encroached by fishermen for fish net drying – indicating mangrove degradation/ altering of river channel.

Map 166 Encroached Mangrove Area

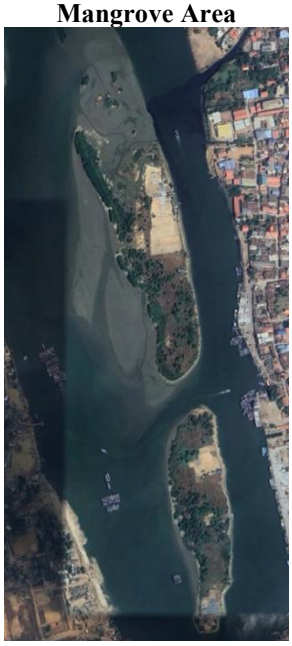


Figure 93 Mangrove species in the Planning Area

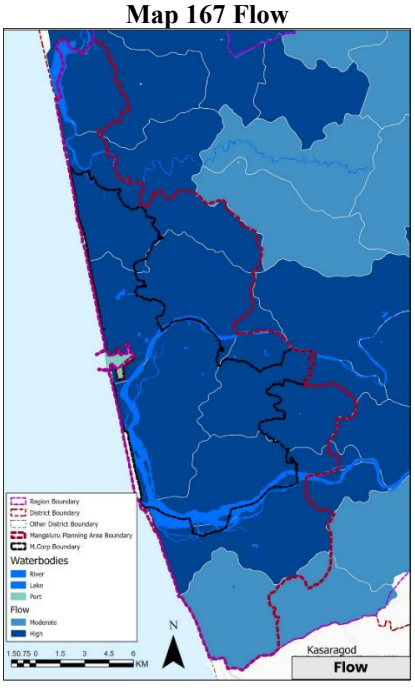


Source 244 Compiled by Author

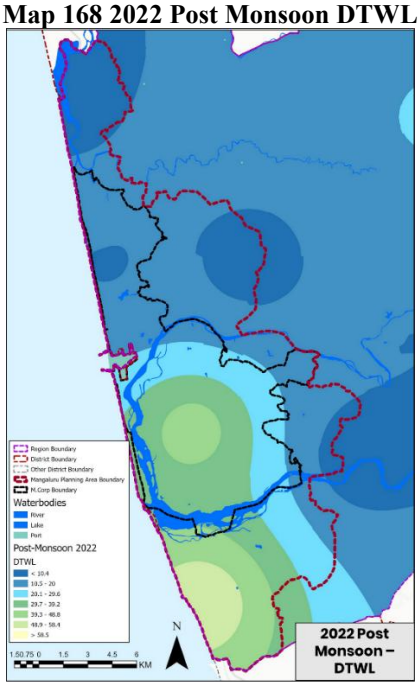
Flow: Comprises of High flow watersheds with high run-off, contributing to seasonal flooding

Ground Water Levels: Compared to the rest of the region where the water table is high, the coastal area of Mangaluru has water table ranging from **10 to 58.4m** below sea level. As discussed in the ground water study, the coastal area shows high levels of EC & Chloride levels in one village (Ullal Area) which can be an indicator of high salinity levels due to sea water intrusion

Map 167 Flow

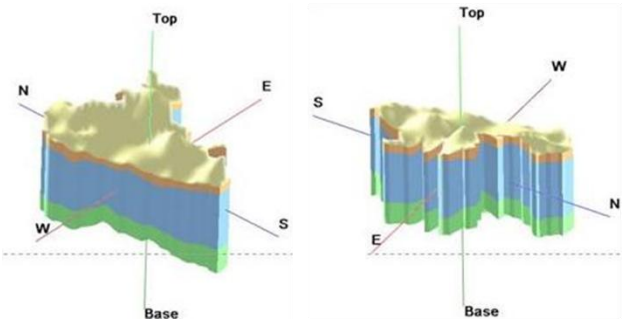


Map 168 2022 Post Monsoon DTWL



Source 245 Author

Figure 94 Aquifer disposition of Mangaluru Taluk

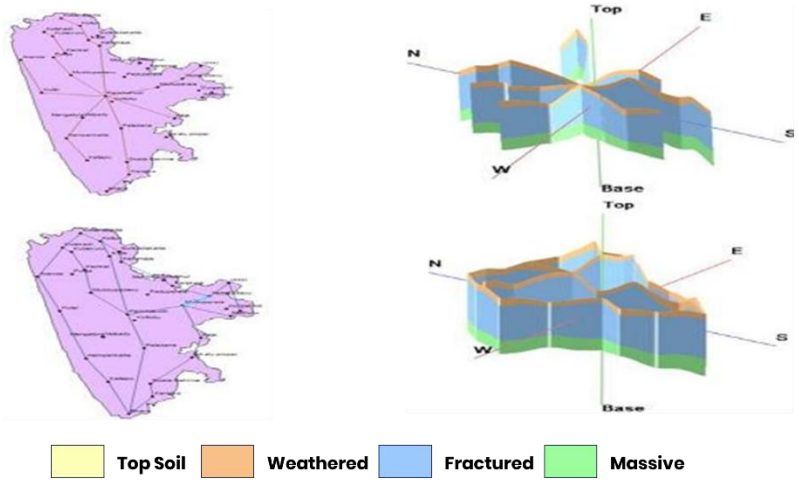


Source 246 CGWB report on Mangaluru Taluk

Mangaluru Tehsil has a Shallow and deep aquifers system

Shallow Aquifers are found in alluvial deposits, lateritic formations, and weathered/fractured crystalline rocks. **Deep Aquifers** also called confined aquifers are found in fractured and jointed granite, gneiss, and schist formations.

Figure 95 Fence Diagram of Mangaluru Tehsil



Source 247 CGWB report on Mangaluru Taluk

Top Layer (Top Soil & Laterite): Consists of lateritic soil -> porous and has a good infiltration capacity, supporting groundwater recharge, particularly in coastal and elevated regions.

Weathered Zone (0–40 m depth): Allows moderate groundwater storage. It consists of decomposed rocks (mainly gneiss and granite), which enhance porosity and permeability.

Fractured Aquifer (up to 165 m depth): Extending to a depth of approximately **165 m** below ground level, consists of fractured granite, gneiss, and basalt, which allow groundwater flow and storage in cracks.

Massive Formation: Negligible porosity and restricts groundwater movement, acts as the base layer, preventing further infiltration.

Ground water stage

The agricultural sectors utilise 55.3% of the gross ground water extraction in the Mangaluru Tehsil, the rest is utilised for domestic & industrial purposes. It can be observed that the stage of ground water extraction is **more** during **2017 and less in 2020** and again the stage of ground water extraction **increases in 2022.**

Table 59 Aquifer wise resource availability and extraction (2022) – Mangaluru Tehsil

Annual Extract GW resource (ham)	Existing Gross GW extraction for Irrigation (ham)	Existing Gross GW extraction for domestic and industrial water supply (ham)	Existing Gross GW extraction for all uses (ham)	Allocation for domestic and industrial use for the next 25 years (ham)	Net GW availability for future Irrigation development (ham)	Stage of GW development (%)	Category
10242.29	2806.17	2265.609	5071.78	2550.21	4877.18	49.51	Safe

Source 248 Aquifer mapping and management plan, Mangaluru Tehsil

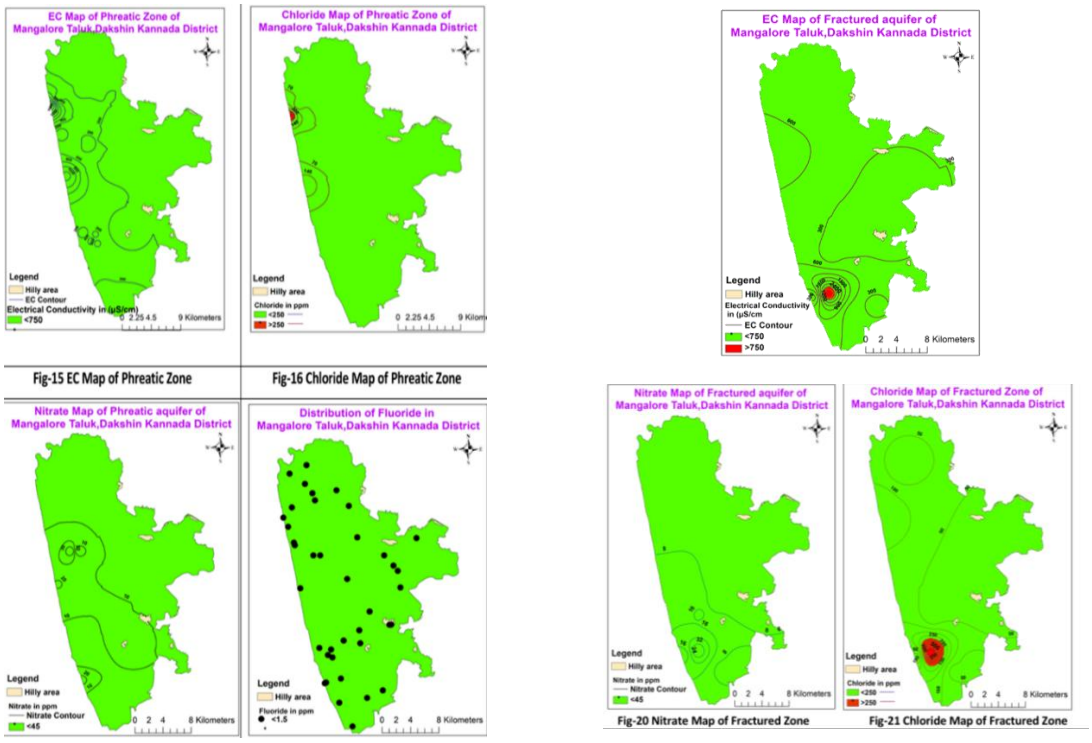
Table 60 Comparison of ground water availability and draft scenario in Mangalore tehsil

2017			2020			2022		
GW Availability	GW Draft	Stage of GW withdrawal	GW Availability	GW Draft	Stage of GW withdrawal	GW Availability	GW Draft	Stage of GW withdrawal
3598	2096	**58**	9750.13	3232.94	**33.16**	10242.29	5071.78	**49.51**

Source 249 Aquifer mapping and management plan, Mangaluru Tehsil

Ground water quality

Map 169 Parameters determining the ground water & their levels



Source 250 Aquifer mapping and management plan, Mangaluru Tehsil

Inference: Ground water quality in Mangalore Taluk is **good and potable EC & Chloride levels** are more in one village (Ullal Area) which can be an indicator of **high salinity levels due to sea water intrusion** and all other samples are found within permissible limit. Ground water samples have been found suitable for agriculture & irrigation purposes.

4.2 Demography & Socio-economics

Area of Mangaluru Local Planning Extent = 30600 Ha

The total population of Mangaluru Planning Area is 7,43,689. The population is growing at an increasing rate from 32.62% from 1991 to 2001 to 42.51% from 2011 to 2021. The estimated 2025 population is 9,39,341.

Table 61 Demographic statistics of Mangaluru Planning Area

Aspects	Villages	Urban Centres	Total
Number	16	17	33
Population	42,772	700917	7,43,689
Male population	21,334	3,48,778	3,70,112
Female Population	21,438	3,54,434	3,75,872
Population Density (Avg)	8.40	17.98	13.19
Sex Ratio (Avg)	1,002	1,013	1007.5
Literacy Rate (Avg)	88.25	90.11	89.18
WFPR (Avg)	45.17	44.52	44.84

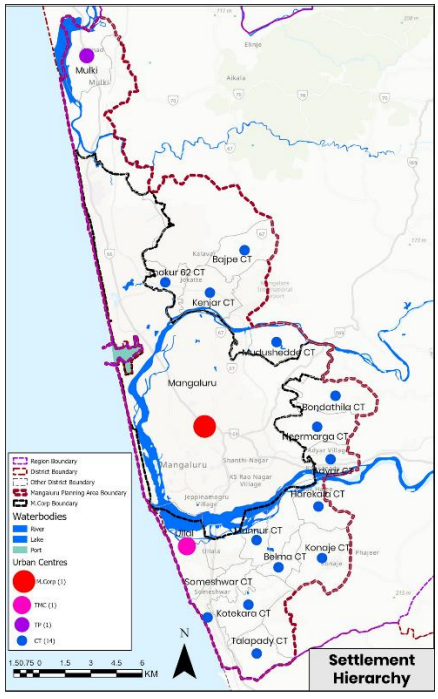
Source 251 Census of India, 2011

Table 62 Estimated population of Mangaluru Planning Area 2025

Mangaluru Planning Area (Including Mangaluru M.Corp)									
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
3,39,628	4,50,402	6,20,357	7,43,689	Geometric	7,48,978	5,289	0.7	**8,84,055**	**9,39,341**
				Arithmetic	7,45,841	2,152	0.3		
				Incremental	7,22,375	-21,314	2.9		

Source 252 Census of India, 2011

Map 170 Settlement Hierarchy in Mangaluru Planning Area



Source 253 Compiled by Author

Mangaluru Planning area has **1 M. Corp (Mangaluru), 1 TMC (Mulki), 1 TP (Ullal), and 14 Census Towns**

4.3 Land Use and Development Plan Analysis

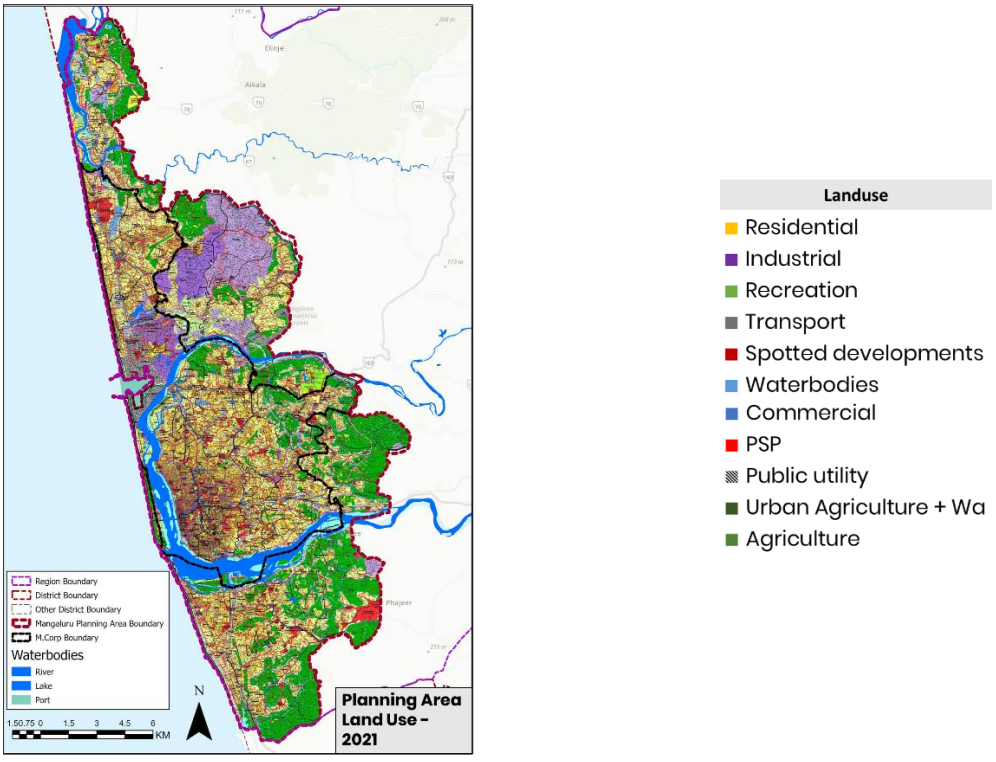
The Mangaluru Planning Area is largely residential with 37% area under residential area, followed by 17.556% under Agriculture and 11.52% area under Urban Agriculture. Industrial land use forms 9.12% of the total land use, indicating that waste water from domestic sector, agricultural run-off and industrial effluent discharge determine the water quality of the Gurupura River.

Table 63 Land Use of Mangaluru Planning Area

Landuse	Area in Ha
Residential	11317.59
Commercial	892.97
Industrial	2790.71
PSP	1047.64
Recreation	2005.74
Public utility	45.8
Transport	2629.48
Urban Agriculture + Waterbodies	3525.8
Total Built up	**24255.73**
Spotted developments	468.06
Agriculture	5372.62
Waterbodies	503.59
Grand total	**30600**

Source 254 Mangaluru Planning Area Master Plan 2021

Map 171 Mangaluru Planning Area Landuse Map



Source 255 Mangaluru Planning Area Master Plan 2021

Figure 96 Landuse of Mangaluru Planning Area

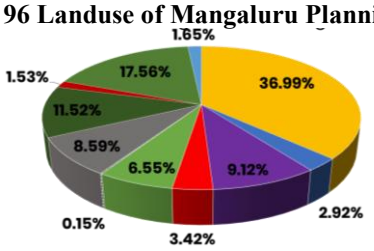
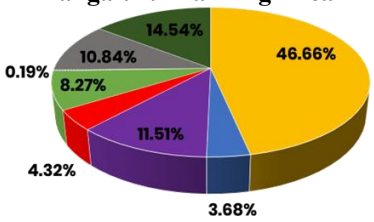


Figure 97 Landuse of Built-up areas of Mangaluru Planning Area



Source 256 Author

Development Plan Analysis

The sectors of the Mangaluru planning Area Master Plan report were studies, their spatial and non-spatial proposals were analysed. The industrial area expansion may lead to effluent discharge further polluting the river, while expansion of IT Park would mean added load on the STP's to treat the Waste water generated. Physical infrastructure augmentation and complete coverage is proposed, which aligns with the URDPFI guidelines. The implications of each on the Gurupura River and Urban River Management is stated in the table below.

Table 64 Sector wise analysis and their implications on the Gurupura River

Sector	Spatial Planning Proposals	Non-Spatial Proposals	Implications on Gurupura River & Urban River Management
Industrial Areas	- SEZ in Kalavar, Bala, Kenjar, Permude, Bajpe - Ancillary units near Harekala, Marakada, etc.	- IT Park support by KIADB (e.g., Infosys expansion)	May contribute to effluent discharge; proximity to Gurupura increases risk of water pollution. Need for buffer zones.
Solid Waste	- Landfills: Kudupu, Pachnadi, Ullal, Mulki	- MCC manages disposal; landfill sites planned for 30-year horizon	Landfills near river catchments could leach into groundwater or Gurupura unless protected with liners/leachate systems.
Water Supply	- Based on intake from Nethravathi (Thumbe)	- Integration with KUIDFC project (ADB assisted)	Over-extraction from Nethravathi may stress basin recharge, indirectly affecting Gurupura.
Sewage / Stormwater	- Existing UGD coverage 20–25% only - Kavoor and Jeppinamogaru STPs	- ₹157 cr ADB-funded sewer network upgrade	Direct sewage outfall into Gurupura at unserved areas; delay in STP upgrades may worsen pollution.
Green Zones	- 2005.74 Ha of open space (9.68% of development area)	- CMZ and CRZ-based protection measures	Buffer function for Gurupura banks; needs stricter encroachment control.
Blue-Green Network	- CRZ I–III zones along Gurupura identified - Buffer lands proposed	- Based on MoEF notifications; regulated by local authority	Strengthens flood resilience and pollution buffering; implementation and enforcement remain key.
Development Control Regulations (FAR/FSI)	- Maximum FAR varies by area and road width: • **Intense urban areas (Area A)**: Up to **3.25 (Permissible 2.5 + Premium 0.75)** for >6000 m² sites • **Organizable plots** (non-residential >6000 m²): Up to **4.0** with 30m roads • **Integrated townships**: FAR up to **4.0**, coverage 45% (for 45m roads) • **Flatted factories**: Max FAR **1.75**, based on road width • **CRZ-I & II** (coastal/river adjacent zones): Height restrictions, typically G+1 permitted; stricter land use control; FAR severely restricted	- Premium FAR allowed with 50% mandatory TDR - CRZ rules apply within 500m of high tide line; no new development in CRZ-I	FAR relaxations in flood-prone zones can cause high-density urbanization near rivers, increasing runoff and encroachments. CRZ areas near Gurupura must maintain low-density use to safeguard the river ecosystem.

Source 257 Author

4.4 Fluvial Flood Risk

After understanding the Environmental resources and the development plan proposals of 2021, it is import to assess the flood risk to understand how the natural hazards interact with land use and population exposure considering the urban context characterised by presence of large population and infrastructure. The flood risk assessment at this scale is carried out at sub watersheds within the Planning Area (prioritized critical watersheds) which is a function of **Vulnerability, Exposure and Hazard.** This is crucial for making informed and resilient environmental strategies for both ecosystem and the communities dependent on it.

Equation used:

Risk = Vulnerability x Exposure x Hazard

Vulnerability in turn is a function of Sensitivity and Adaptive capacity.

Vulnerability = Sensitivity – Adaptive Capacity

Parameters for Sensitivity, Adaptive capacity, Exposure and Hazard were identified along with their respective indicators, selected from the baseline analysis. The absolute values for each indicator are normalised to arrive at the values for each aspect of risk and the final Risk is calculated using the above-mentioned equation.

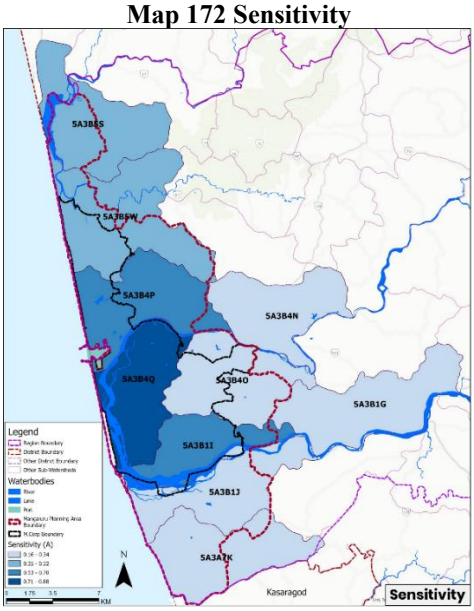
Table 65 Normalized values and risk calculation for critical sub-watersheds

Sub-Watershed Code	Sensitivity						Adaptive Capacity Parameters							Exposure		Hazard		Average Sensitivity (A)	Average Adaptive capacity (B)	Vulnerability (C = A-B)	Exposure (D)	Hazard (E)	Flood Risk (C*D*E)
	Flood	Demography & socio-cultural indicators			Infrastructure and development indicators		Ecological Indicators			Demography & socio-cultural indicators	Infrastructure and development indicators		Institutional Indicator	Demography	CRZ	Flood	CRZ						
	Run-off	Population density	SC & ST population	Agricultural workers population	Number of 3rd & 4th order settlements	Access to wells & drainage system	High infiltration potential of soil	% Forest Area	Presence of Mangrove	Literacy rate	HH with tap water access	SHG	Masterplan	Population	High Flood Line	Flood susceptibility	Hazard Line						
5A3A7K	0.04	0.12	0.00	0.28	0.00	0.62	1.00	0.20	0.50	1.00	1.00	0.00	0.50	0.23	0.33	0.00	0.33	0.18	0.60	-0.42	0.17	0.17	-0.01
5A3B1G	0.07	0.04	0.15	0.35	0.29	0.50	0.00	1.00	0.00	0.47	0.72	0.00	0.00	0.19	0.33	0.16	0.33	0.23	0.31	-0.08	0.24	0.24	0.00
5A3B1I	0.35	0.62	1.00	0.40	0.43	0.98	0.50	0.00	0.50	0.09	0.63	1.00	1.00	0.50	1.00	0.57	1.00	0.63	0.53	0.10	0.78	0.78	0.06
5A3B1J	0.02	0.16	0.04	0.00	0.00	0.72	1.00	0.15	0.50	0.93	0.91	0.00	1.00	0.34	1.00	0.16	1.00	0.16	0.64	-0.49	0.58	0.58	-0.16
5A3B4N	0.00	0.00	0.32	0.75	0.43	0.21	0.50	0.83	0.00	0.85	0.62	0.00	0.00	0.00	0.00	0.59	0.00	0.28	0.40	-0.12	0.30	0.30	-0.01
5A3B4O	0.03	0.17	0.20	0.65	0.14	0.77	0.00	0.16	0.00	0.98	0.85	0.00	1.00	0.25	0.33	0.52	0.33	0.33	0.43	-0.10	0.43	0.43	-0.02
5A3B4P	0.70	0.55	0.81	0.40	0.29	1.00	0.50	0.02	0.50	0.00	0.62	0.00	1.00	0.23	1.00	0.49	1.00	0.63	0.38	0.25	0.74	0.74	0.14
5A3B4Q	0.59	1.00	0.73	1.00	1.00	0.98	0.00	0.05	1.00	0.84	0.89	1.00	1.00	1.00	1.00	1.00	1.00	0.88	0.66	0.23	1.00	1.00	0.23
5A3B5S	0.06	0.00	0.81	0.70	0.43	0.22	1.00	0.38	1.00	0.98	0.18	0.00	0.50	0.03	1.00	0.34	1.00	0.37	0.58	-0.21	0.67	0.67	-0.09
5A3B5W	1.00	0.13	0.47	0.40	0.86	0.00	1.00	0.79	0.50	0.96	0.00	1.00	0.50	0.30	1.00	0.75	1.00	0.48	0.68	-0.20	0.87	0.87	-0.15

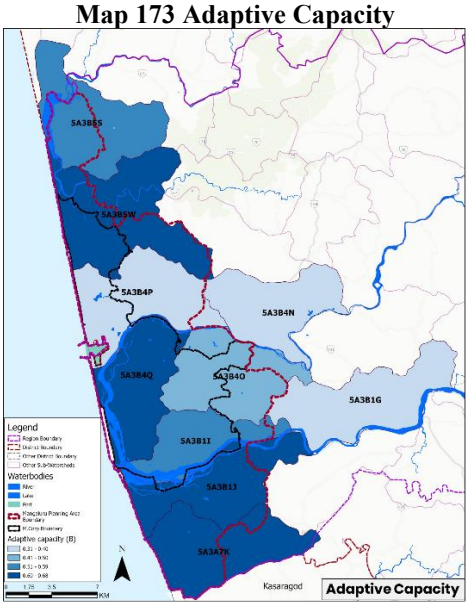
Source 258 Author

5A3B4Q is identified as the sub-watershed at risk of fluvial flooding. This sub-watershed includes ward numbers **12 to 18, 22 to 33, 38, 40 to 47, 55 to 56, & 60** of the Mangaluru Municipal Corporation and has a total population of **2,21,368.**

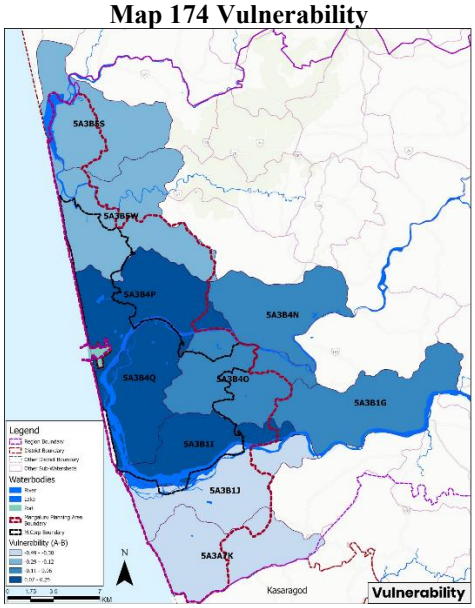
Map 172 Sensitivity



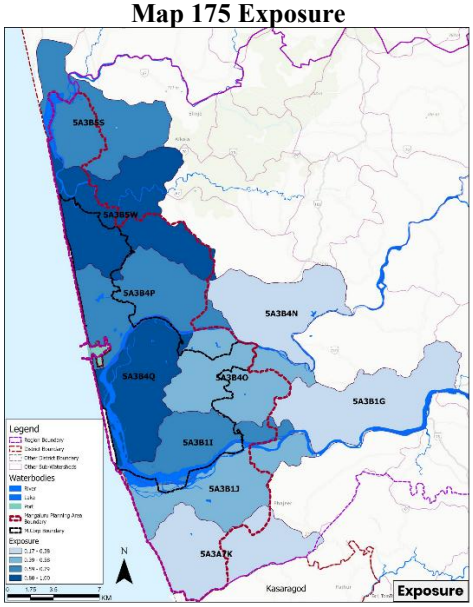
Map 173 Adaptive Capacity



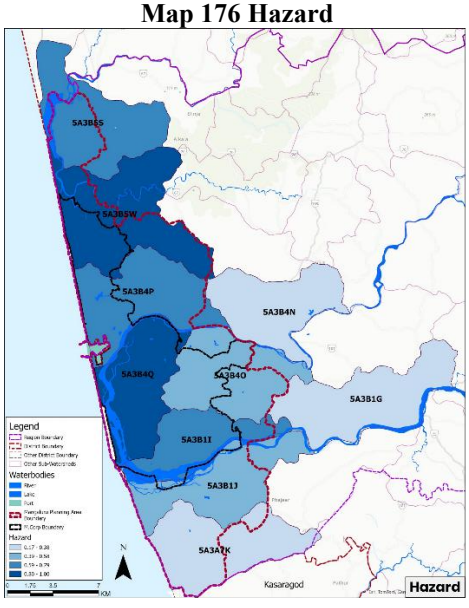
Map 174 Vulnerability



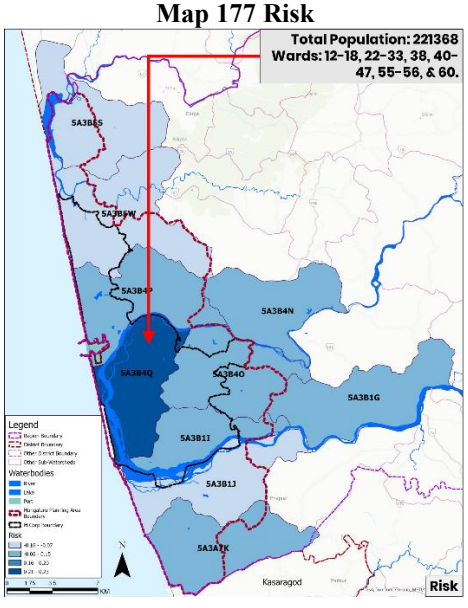
Map 175 Exposure



Map 176 Hazard



Map 177 Risk



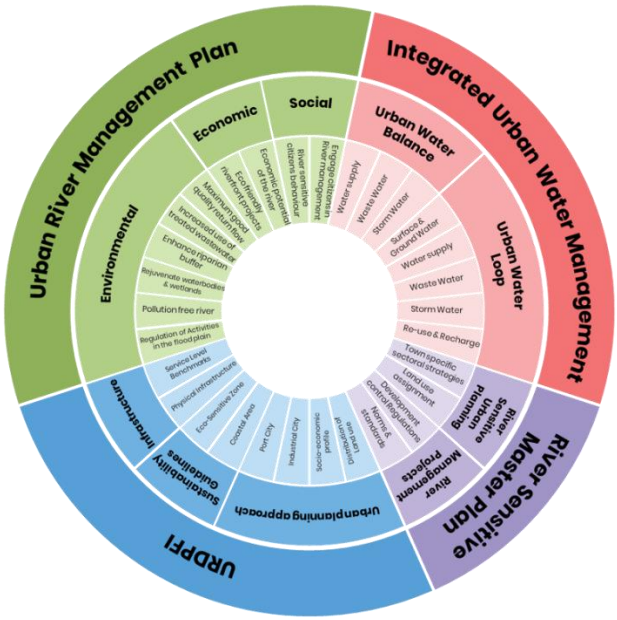
Source 259 Author

5. Mangaluru City

The fluvial flood risk analysis at the planning area scale reveals the sub-watershed with highest flood risk falls within the Mangaluru Municipal Corporation limits, shifting the focus from peri urban to urban scale. To contextualize the current conditions and challenges of the urban area, the following study begins with understanding the evolution of the city and its environmental resources.

Further, the study of the urban river in Mangaluru city is based on multi-framework approach of URMP, IUWM, River Sensitive Master Plan & URDPFI guidelines, their aspects, and respective indicators relevant to the study, ensuring all interventions align with sustainable water use and river health.

Figure 98 multi-framework approach for Urban River Management



Source 260 Diagram developed by Author

5.1 Evolution of the City

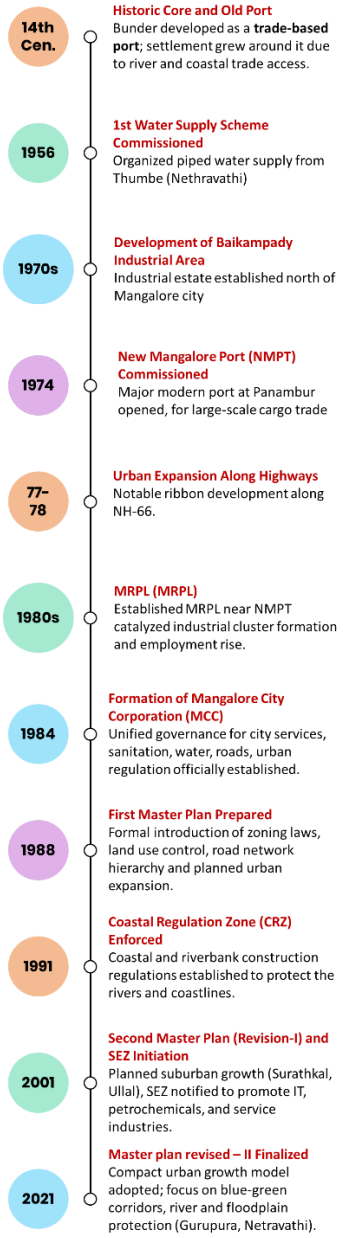
Figure 99 Gurupura River in Mangaluru City



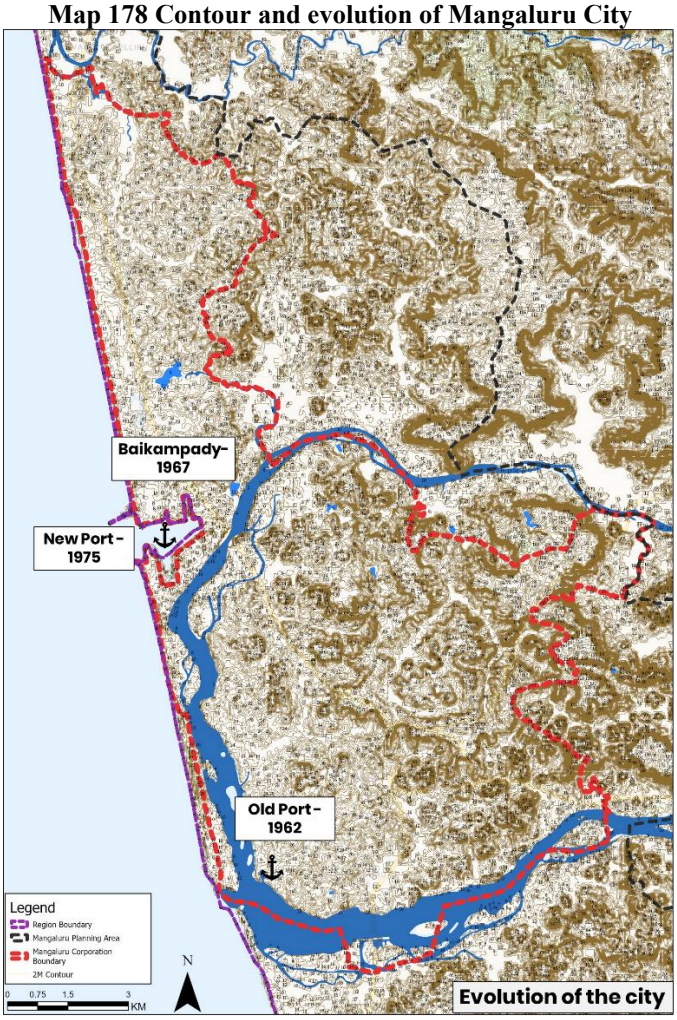
Source 261 Author

Mangalore's physical landscape is an undulating terrain with coastal area and hillocks which naturally guided how the city expanded in the **inter-fluvial zone** of **Gurupura & Netravati.** The **old town** core developed around Bunder (the old port) in the low-lying area within **20m elevation**. Early settlements grew in a ribbon - like pattern along: **Trading routes, Coastal lines,** facilitating Access to rivers for trade and transport.

Figure 100 Evolution of Mangaluru City

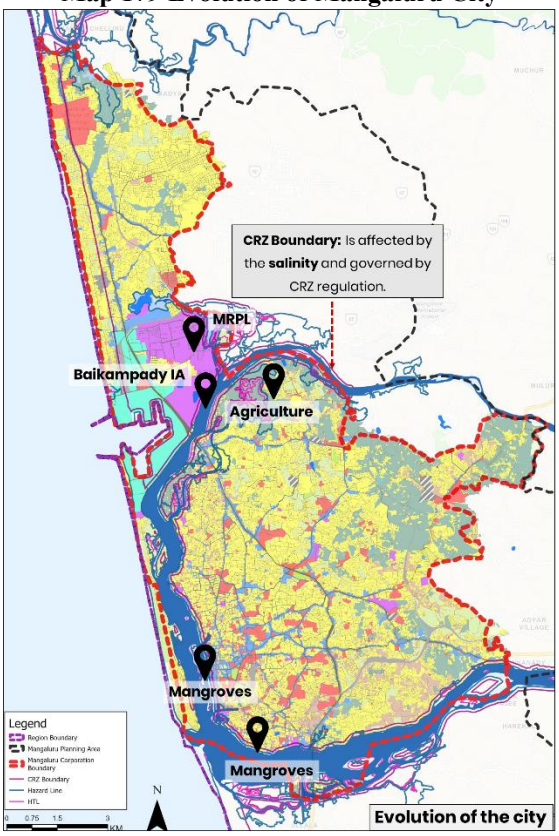


Map 178 Contour and evolution of Mangaluru City



Source 262 Author

Map 179 Evolution of Mangaluru City



Source 263 Author

As Gurupura river enters the city, it shifts from being primarily rural life-support systems ➔ **strategic urban infrastructure assets.**

Flow: Consistent high flow, with an annual rainfall of 4100 mm, dependable flows exceeding **70%** reliability (Q70) indicating availability throughout the year. Supports the industrial activity by carrying its effluent & as a source of water, transport activity through ferry services, and sustains fishermen's livelihood.

High sediment load - Sand, Silt, Clay, Organic Carbon due to run-off and tidal action – high in monsoon. The estuarian complex with Mangroves sustains the livelihood of the fishermen and acts as natural flood barrier.

5.2 Environmental Resources

5.2.1 Mangrove Ecosystem Service Dependency

Post understanding the evolution of the city and its environmental resources, it is essential to examine how the local population interact with and depend on the mangrove ecosystem present along the lower reaches of Gurupura river. A similar approach used in the Forest and River ecosystem service dependency at the region scale is used. The analysis is carried out at ward level within the Mangaluru Municipal Corporation.

The wards were considered within the sub-watersheds of 2, 5 and beyond 5km buffers. The two core area wards are given a weightage of 3x and 2x respectively and the buffer having majority wards with above average population are given an additional weightage of 2x.

Table 66 Mangrove ecosystem service dependency

Zones	No. of wards	Total Population	2X	1X	Provision				Regulating							Supporting				Cultural					Grand Total
			No. of wards with < 8000 population	No. of wards with > 8000 population	Food	Fibre, Timber, Fuel	Medicinal resources	Total	Erosion regulation	Water quality maintenance	Carbon sequestration	Flood mitigation	Micro-climate regulation	Ground water rejuvenation	Total	Nutrient cycling formation and soil formation	Habitat provision	Employment generation	Total	Cultural & religious significance	Recreation & Tourism	Aesthetics	Education & Research value	Total	
Core Area 1 - Upto 2 km (3X)	29	2,31,795	14	15	9	6	6		6	9	6	9	6	6		6	9	9		3	3	9	9		
Total								21							42				24					24	111
Core Area 2 - 2-5km Buffer (2X)	24	1,99,481	14	10	8	4	4		4	8	4	8	4	4		4	4	8		4	4	4	4		
Total								16							32				16					16	80
Transition Area - Beyond 5km (1X)	7	57,692	4	3	4	2	2		2	2	2	2	2	2		2	2	2		2	2	2	2		
Total								8							12				6					8	34
Grand Total					21	12	12	45	12	19	12	19	12	12	86	12	15	19	46	9	9	15	15	48	

Source 264 Author

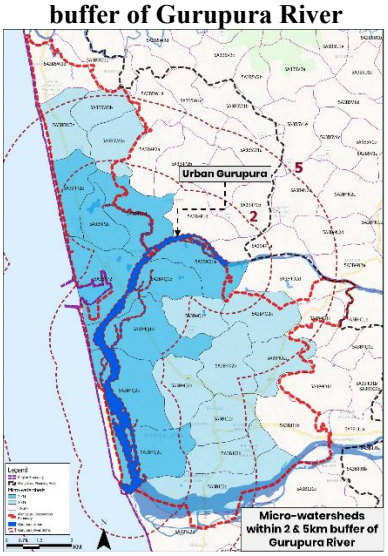
Findings:

The core area wards within 2 km buffer are found to be highly dependent on the provision service (Food provision) mangrove ecosystem. This area has the fishermen community living along the coast whose livelihood depends on fishing from the Estuarian complex where the mangroves are the nursery of the juvenile fishes.

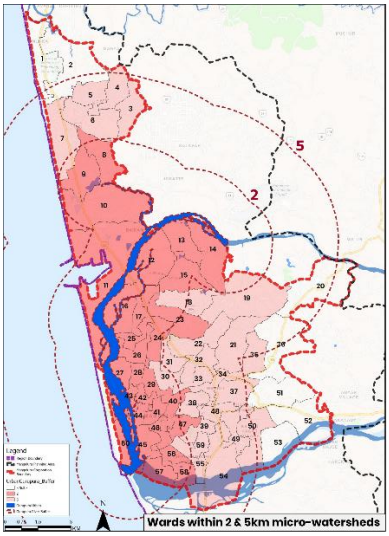
The wards within the buffer of 2 and up to 5 km that lie within the 20m elevation - prone to flooding, are found to be highly dependent on the regulating services provided by the Mangrove ecosystem, specifically for its flood mitigating and water quality regulating services.



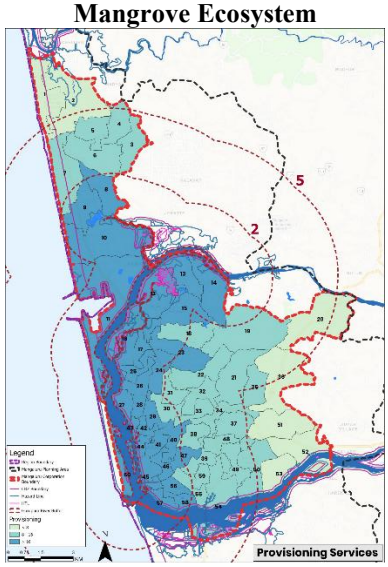
Map 180 Micro-watersheds within 2, 5 & >5km buffer of Gurupura River



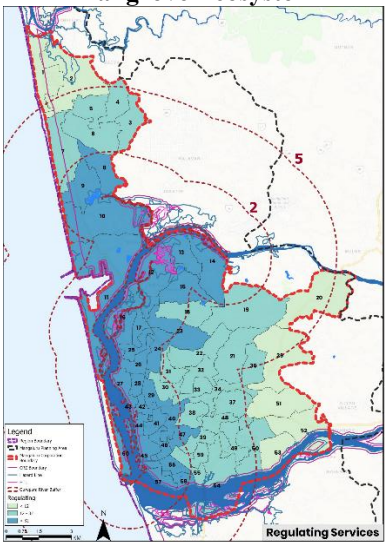
Map 181 Wards within micro-watersheds of 2 & 5km buffer



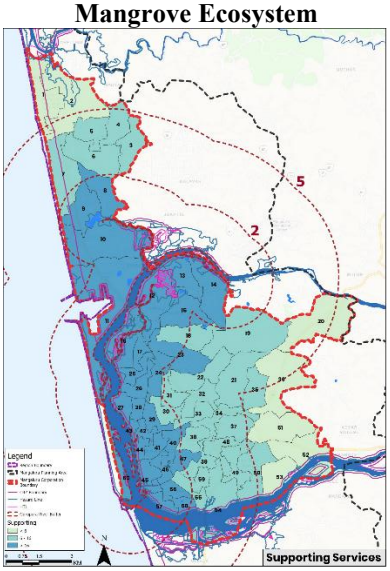
Map 182 Provisioning Ecosystem Services - Mangrove Ecosystem



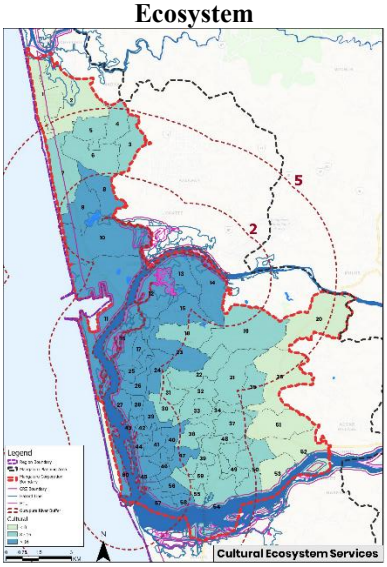
Map 183 Regulating Ecosystem Services - Mangrove Ecosystem



Map 184 Supporting Ecosystem Services - Mangrove Ecosystem

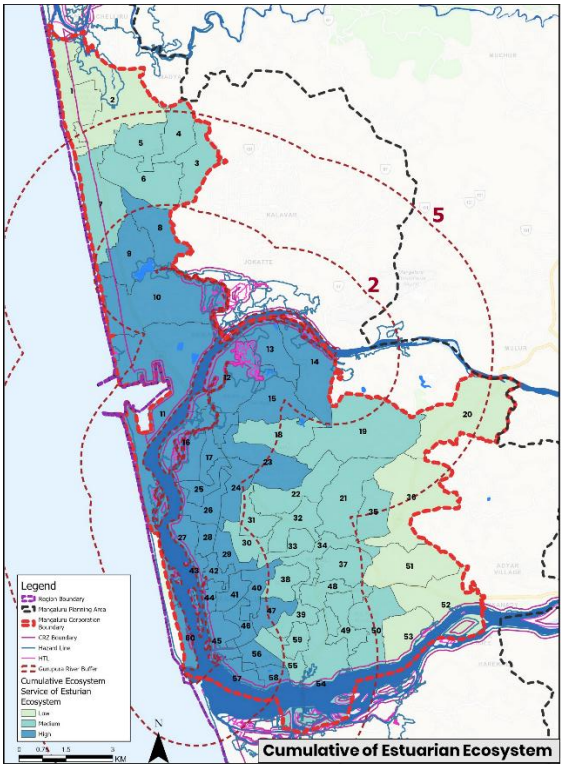


Map 185 Cultural Ecosystem Services - Mangrove Ecosystem



Source 265 Author

Map 186 Cumulative dependency on Mangrove Ecosystem Services



Source 266 Author

5.2.2 Coastal Regulation Zone

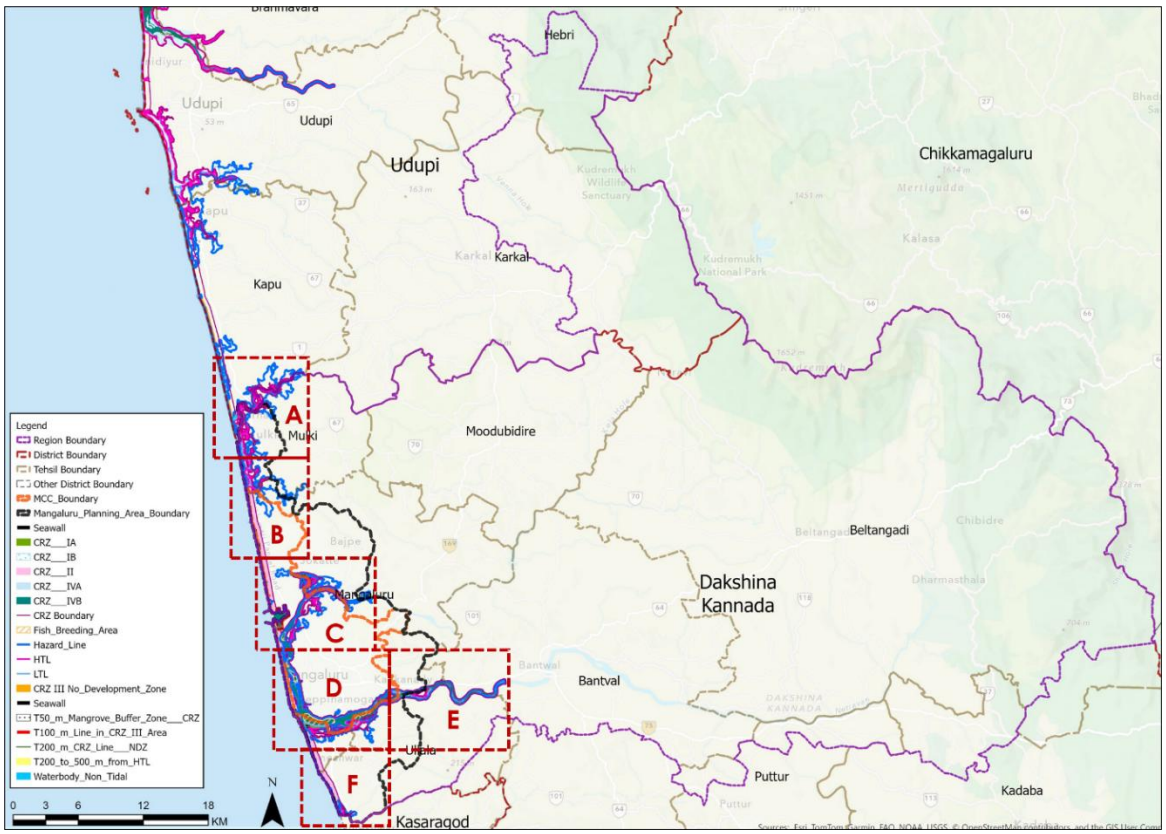
The coastal area is governed by CRZ regulations, which extends along the Gurupura & Netravati Rivers.

Table 67 CRZ Zones 2011 & 2019

CRZ Zone	Sub-Zones	Distance from HTL (2019 Notification)	Distance from HTL (2011 Notification)	Permissible Activities	Restricted Activities	Prohibited Activities
CRZ-I Ecologically sensitive areas and intertidal zones	**CRZ-IA**: Ecologically sensitive areas (e.g., mangroves, coral reefs, mudflats, national parks, sanctuaries, turtle nesting sites, etc.)	From HTL to landward side: **50m** buffer for mangroves (If mangrove area is >1000 sqm)	From HTL to landward side: 50m buffer for mangroves (>1000 sqm)	Eco-tourism activities like nature trails, tree huts (in approved areas), research activities	Pipelines, transmission lines, roads on stilts (public utilities), strategic projects with approval	New industries, disposal of hazardous substances, reclamation, discharge of untreated waste, mining, groundwater extraction
	CRZ-IB: Intertidal Zone (land between HTL and LTL)		From HTL to LTL (low tide line)	Foreshore facilities (ports, jetties, erosion control measures), desalination plants, pipelines	Land reclamation for erosion control, hatcheries, treatment plants	Alteration of sand dunes, unregulated fish processing
CRZ-II Developed land close to shore within municipal limits	-	From HTL to 500m (regulated based on existing roads/structures)	From HTL to 500m (regulated based on existing roads/structures)	Building reconstruction, development of vacant plots for hotels/tourism, public infrastructure	Expansion of existing structures as per town planning norms	New roads on the seaward side, new industries
CRZ-III Undisturbed or rural areas (low-density settlements)	**CRZ-IIIA**: High-density areas (>2161 persons/km²)	From HTL to 50m (if CZMP approved), otherwise from HTL to 200m	-	**Resorts/hotels permitted beyond NDZ (from 50m-500m)**. Housing for coastal communities, agriculture, public amenities	Fishing-related activities, eco-tourism, regulated mining	New construction (except traditional housing)
	CRZ-IIIB: Low-density areas (<2161 persons/km²)	From HTL to 200m (NDZ)	-	**Resorts/hotels permitted beyond NDZ (from 200m-500m)**. eco-tourism, housing	-	-
	NDZ in CRZ-III along tidal-influenced water bodies	From HTL to 50m or width of the creek (whichever is less) along tidal-influenced water bodies	-	Fishing, boat maintenance, small-scale tourism	Regulated infrastructure for fishing communities	Large-scale construction, land reclamation
	CRZ-III (As per 2011 Notification)		From 200m to 500m from HTL (regulated development allowed)	Hotels, beach resorts, and other tourism projects allowed	Low-impact development allowed	Large-scale industrial activities
CRZ-IV Water areas (sea, tidal-influenced water bodies)	**CRZ-IVA**: Territorial waters up to 12 nautical miles	From LTL to 12 nautical miles seaward	From LTL to 12 nautical miles seaward	Traditional fishing, port and harbor projects, pipelines	Regulation of effluent discharge, tourism	Oil spills, hazardous waste disposal
	CRZ-IVB: Tidal-influenced inland water bodies	From LTL at one bank to LTL on the opposite bank (up to salinity of 5 ppt in driest season)	From LTL at one bank to LTL on the opposite bank (up to salinity of 5 ppt in driest season)	Fishing, boat transport	Desalination plants, intake/discharge facilities	Untreated discharge, solid waste dumping

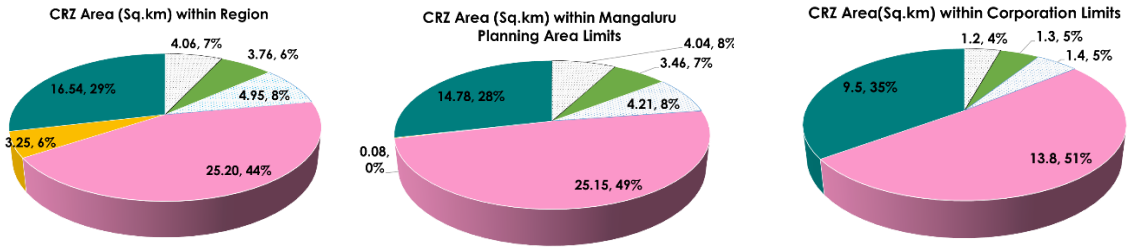
Source 267 Compiled by author

Map 187 CRZ Map



Source 268 Compiled by author

Figure 101 CRZ zones within Region, Planning Area & Municipal Area



Source 269 compiled by Author

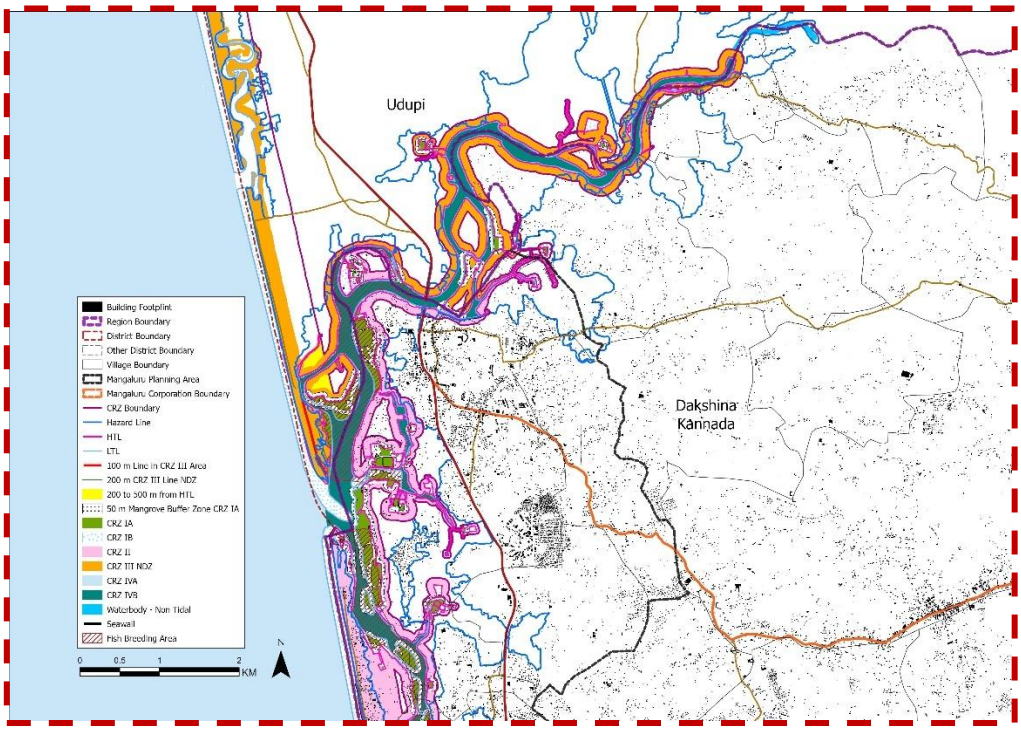
Area of Scoped Region: 3161.92 Sq.km Total CRZ area within scoped region is **57.75 Sq.km (1.8%)**

Area of Mangaluru Planning Area: 318 Sq. Km. Total CRZ Area within Mangaluru Planning Area is **51.72 Sq. Km (16.3%)**

Area of Mangaluru Municipal Corporation: 136.44 Sq.km. Total CRZ Area within Corporation limits is **27.1 Sq.km (19.84)**

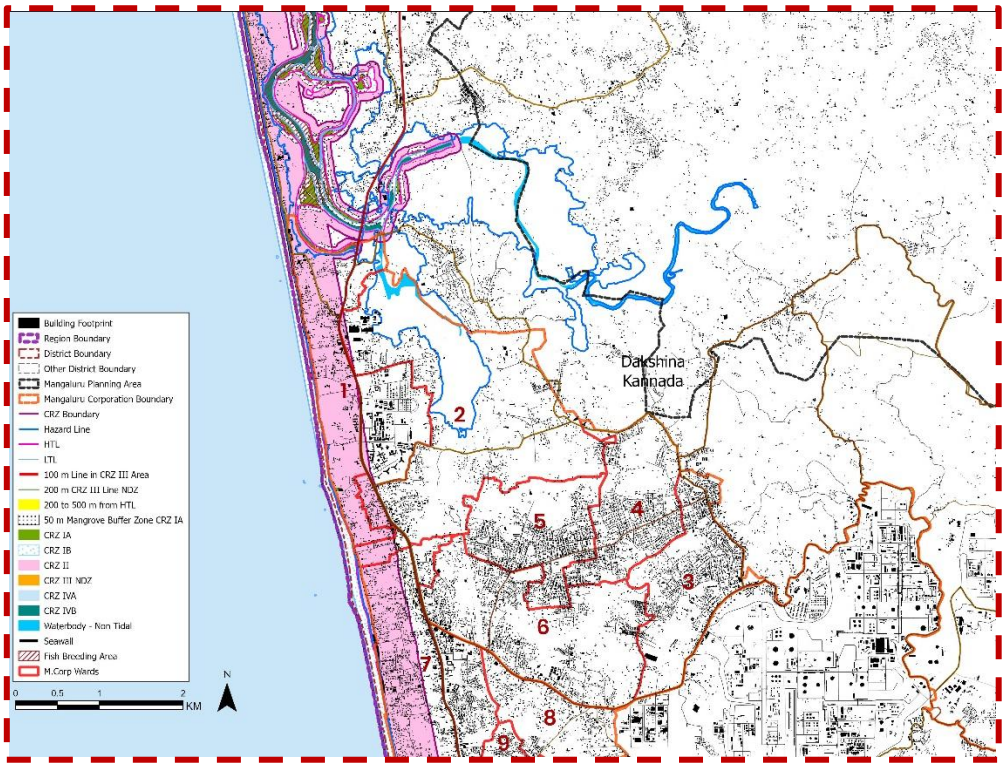
The built-up is overlayed on the CRZ map to understand the non-compliance if any in the region.

Map 188 CRZ Detail at A



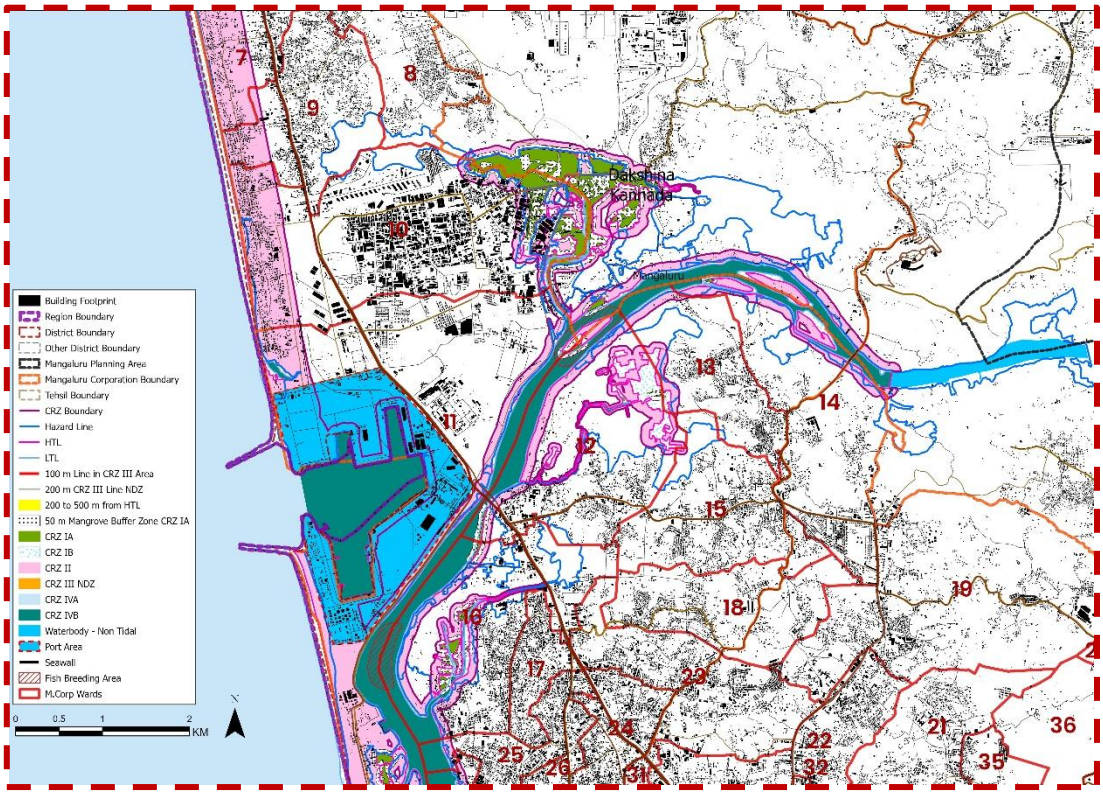
Source 270 Compiled by Author

Map 189 CRZ Detail at B



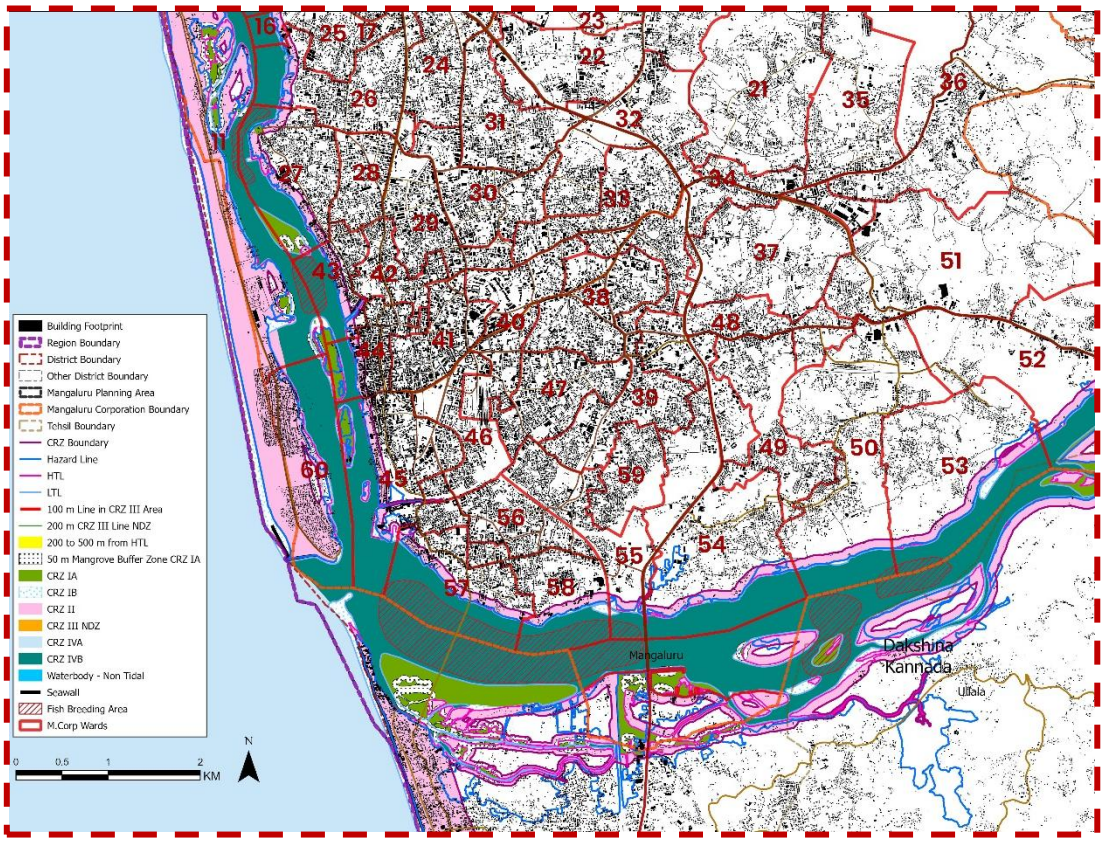
Source 271 Compiled by Author

Map 190 CRZ Detail at C



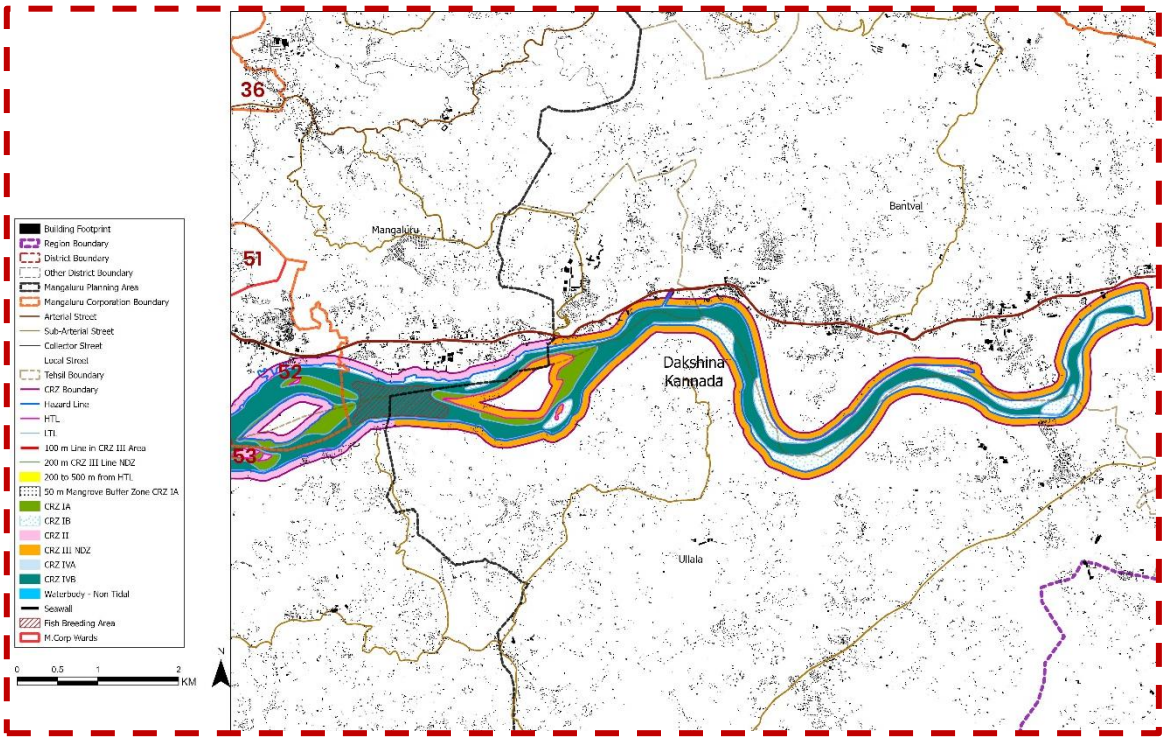
Source 272 Compiled by Author

Map 191 CRZ Detail at D



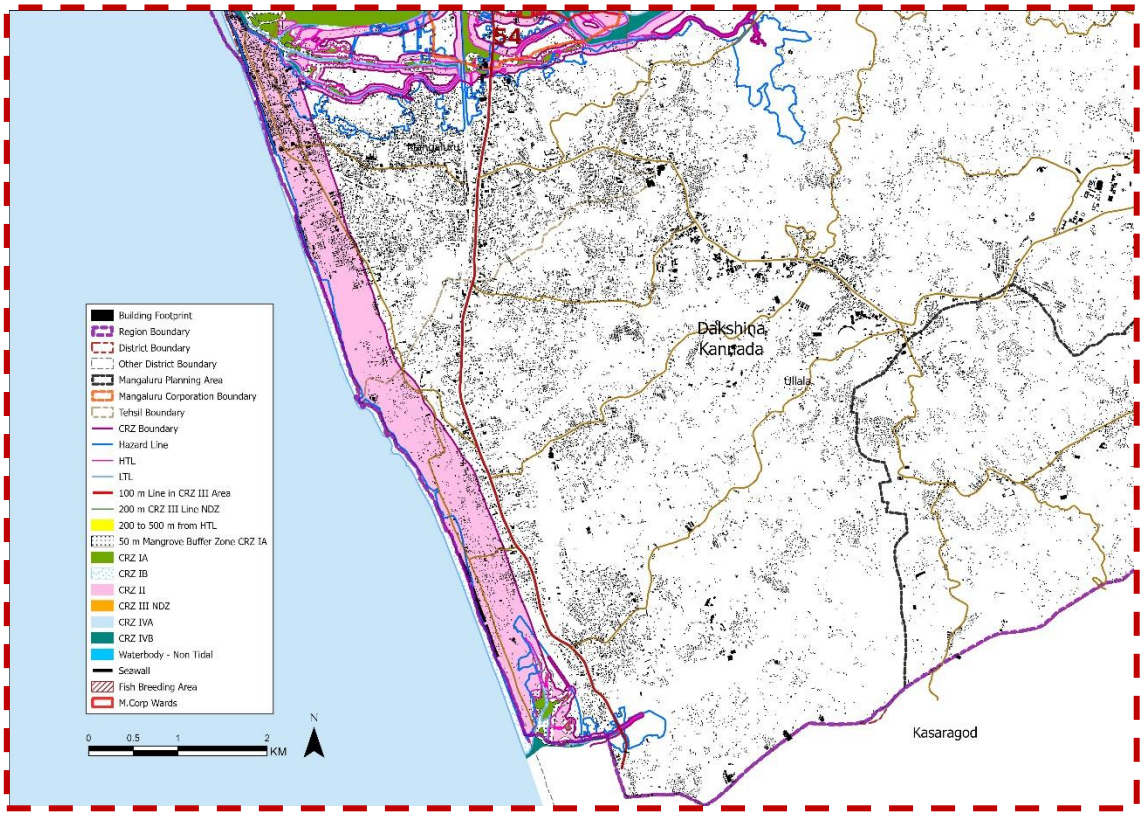
Source 273 Compiled by Author

Map 192 CRZ Detail at E



Source 274 Compiled by Author

Map 193 CRZ Detail at F



Source 275 Compiled by Author

CRZ Zones are a part of **24 of the 60 Wards** within the Mangaluru Municipal Corporation limits. The wards include: **1,2, 7, 9 to 14, 16, 25 to 27, 43 to 45, 50, 52 to 55, 57, 58 & 60**, with **1,92,775** people living within these wards.

There are **22 villages and 6 other urban centres** that are under CRZ zone and have a combined population of **1,95,495.**

Industries in CRZ II: Includes Food processing, Oil, Alcohol based, Plywood and Fish processing industries.

These have come up before the notification and hence continue their operations. These industries can undergo modernization & expansion provided they comply with environmental norms & acquire clearance from regulatory authority.

Setting up of new industries in CRZ II is prohibited with exceptions for non-polluting industries, service industries related to waterfront activities – such as fishing, coastal tourism, ports and harbours, and renewable energy projects.

Settlements on CRZ III: Houses and religious structures are built on the NDZ outside the Mangaluru Planning Area Limits

5.2.3 Coastal Hazard

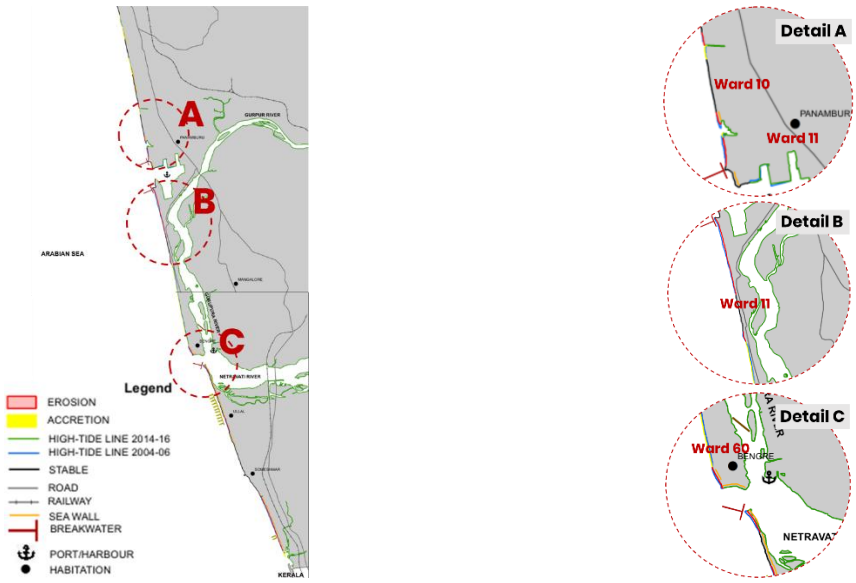
Dakshin Kannada District has **19.4%** of the total coastline of Karnataka State, and faces 48.4% of the total coastline erosion of the 3 Coastal districts of Karnataka (M. C. Deo & R.G. Patil, 2020).

Table 68 Coastal erosion statistics of Karnataka's coastal districts

District	Coastline (km)	% of total Coastline	Coastal erosion - % of District coastline
Uttara Kannada	160	50	12.3%
Udupi	98	30.6	34.7%
Dakshin Kannada	62	19.4	**48.4%**
Total	320	100	

Source 276 National centre for coastal research (M. C. Deo & R.G. Patil, 2020)

Map 194 Shoreline change map



Source 277 ISRO & Centra Water Commission (IRS LISS4 IMAGES OF 2004-06 & 2014-16)

The Shoreline change map developed my ISRO & CWC shows erosion of the coastal areas adjacent to ward 10, 11 & 60

Coastal hazard studied across 13 Major ports of India, of which New Mangalore Port is a part, Mangaluru is experiencing the follow coastal hazards (M. C. Deo & R.G. Patil, 2020):

Highest Rate of Sea Level Rise (SLR): New Mangalore Port to experience the maximum absolute SLR among Indian ports, with **5.16 mm/year** under RCP 4.5 (moderate scenario) and **7.20 mm/year** under RCP 8.5 (worst-case scenario)

Shoreline Retreat Estimates shows **10.21 m** by 2050, **24.04 m** by 2100 under RCP 4.5. **Ward 10, 11 & 60** face shoreline erosion

Beach Inundation Risk near New Mangalore Port is **34.4%** by 2050 and **81.0%** by 2100, signaling significant coastal vulnerability

Figure 102 Sea Level Rise for the year 2050

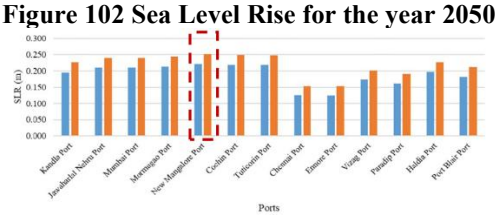
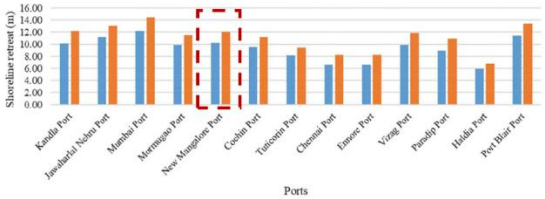


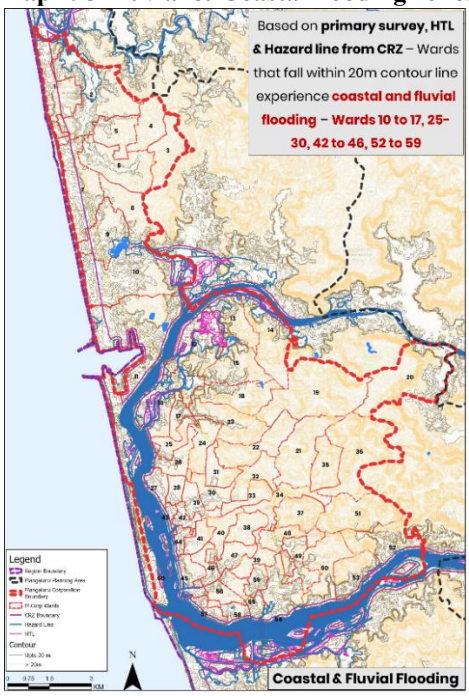
Figure 103 Shoreline retreat for the year 2050



Source 278 (M. C. Deo & R.G. Patil, 2020)

The areas that fall within 20m contour line experience coastal & fluvial flooding. This include wards 10 to 17, 25 to 30, 42 to 46 & 52 to 59 which is 37 wards of the 60 wards in the city.

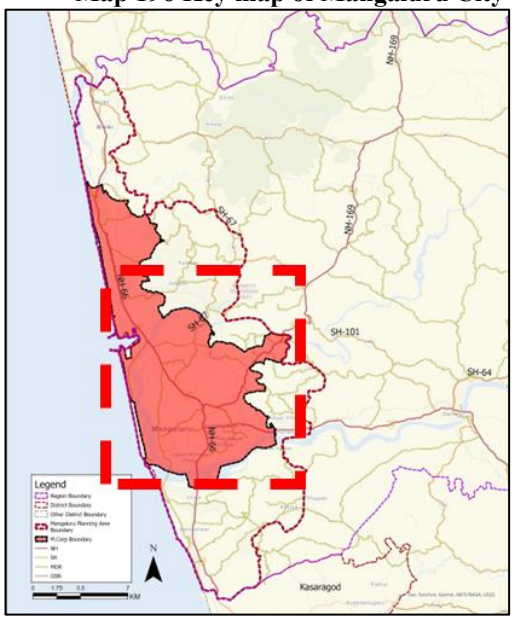
Map 195 Fluvial & Coastal flooding zones



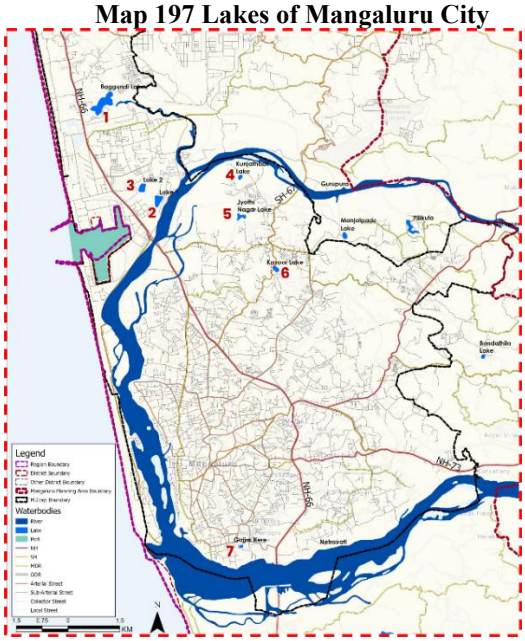
Source 279 Author

5.2.4 Water Body Analysis

Map 196 Key map of Mangaluru City



Map 197 Lakes of Mangaluru City



Source 280 Author

The city of Mangaluru has 7 prominent lakes. For this analysis they are classified based on their size, analysed the ecosystem services it provides and Shoreline density is calculated to understand the biological richness of the waterbody –value >1 indicate irregular shape that supports rich biodiversity.

Table 69 Prominent lakes in Mangaluru

Sl.no	Name	Area (Ha)	Catchment area (Ha)	Shoreline Density Index	Biotic Environment	Use/Activity	Ecosystem Sevices
1	Baggundi Lake	18.66	394.85	1.53	Cat fish **Condition:** Eutrophication	-	Supporting : Habitat Regulating : microclimate
2	Lake 1 (Near MCFL)	5.74	876.61	1.17	Cat fish, Catla	-	Supporting : Habitat Regulating : microclimate
3	Lake 2 (Near MCFL)	4.24		1.11	Eutrophication	-	Regulating : microclimate
4	Kunjathbail Lake	2.03	599.21	1.21	Eutrophication	-	Regulating : microclimate
5	Jyothi Nagar Lake	3.08	515.32	1.43	Encroached - Agricultural Land	-	Regulating : microclimate
6	Kavoor Lake	2.34	456.81	1.35	small minnows, barbs, Cyprinus carpio, Oreochromis mossambicus, and Poecilia reticulata **Condition: Eutrophication**	Irrigation, Temple, Walking track, Recreational	Provisioning : Water for irrigation Supporting : Habitat Regulating : microclimate Cultural : Temple, Recreational
7	Gujjar Kere	0.90	1094.64	1.15	Catla, Labeo	Walking track, Play area, Recreational	Supporting : Habitat Regulating : microclimate Cultural : Recreational

Source 281 Author

Shoreline density index, SDI = $L/2\sqrt{\pi A}$

L = actual shoreline length

A = surface area of the water body

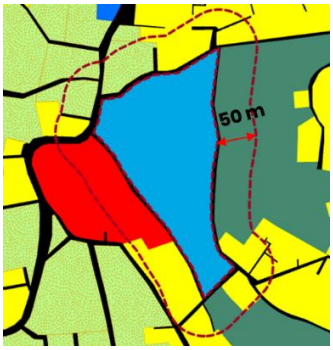
$2\sqrt{\pi A}$ = circumference of a circle with the same area

SDI = 1 → perfectly circular lake

SDI > 1 → irregular or elongated shoreline

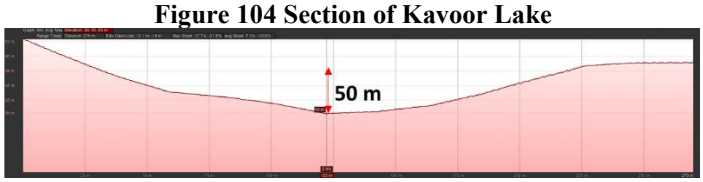
Unlike all other lakes, Kavoor Lake provides all the ecosystem services and hence is selected for further analysis. The land use in the 50m buffer around the lake is studied, which reveals it is surrounded by Agricultural fields, a temple, and residences.

Map 198 Kavoor Lake and Landuse in 50m buffer



Source 282 Author

Figure 104 Section of Kavoor Lake



Source 283 Author

Figure 105 Kavoor Lake Post monsoon and pre-monsoon



Source 284 Author

The lake dries up in Summer & eutrophication is an issue due to agricultural run-off. The maximum depth of the **Kavoor Lake** is **50m.**

The capacity of the lake is calculated considering an average depth of 25m.

- Area = 2.34 ha = 23,400 m^2
- Average Depth = 25 m
- Volume=23,400 m^2×25 m=585,000 m^3
- **Estimated Capacity = 0.585 million m^3**

Run-off calculation:

- Watershed Area = 456.81 ha = 4,568,100 m^2
- Rainfall = 4.1 m/year
- Runoff Coefficient (C) = 0.35
- Runoff = Runoff Coefficient (C) x Rainfall (R) × Watershed Area (A) = 0.35m x 4.1 m × 4,568,100 m
- **Total Run-off = 6.56 million m^3**

Kavoor Lake hold 8.91% of the catchment's total run-off, indicating its significant role in the hydrology of the catchment.

All the lakes in the city dry up in the pre-monsoon season. They play a pivotal role in mitigating flood risk and hence require attention in their restoration.

5.3 Demography

After understanding the environmental resources and ecological assets within Mangaluru city, including the estuarine zones with mangrove patches, and flood-prone sub-watersheds, it becomes essential to examine the city's **demographic profile**. This focuses on ward-level analysis of population distribution, density, literacy, and workforce participation to understand how **urban pressures align with environmentally sensitive areas**.

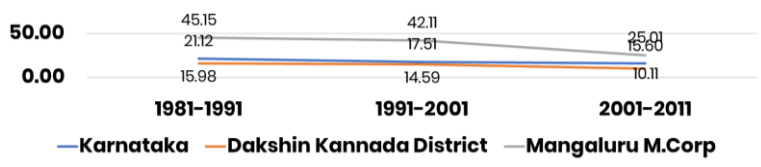
The population of Mangaluru Municipal Corporation area for 2011 is **4,99,487,** and the estimated population for 2021 is 6,02,421**.** The population is increasing at a declining rate.

Table 70 Population of Mangaluru Municipal Corporation

Year	1981	1991	2001	2011	2021
Mangaluru M.Corp	193699	281161	399565	499487	602421
Growth Rate		45.15	42.11	25.01	20.61

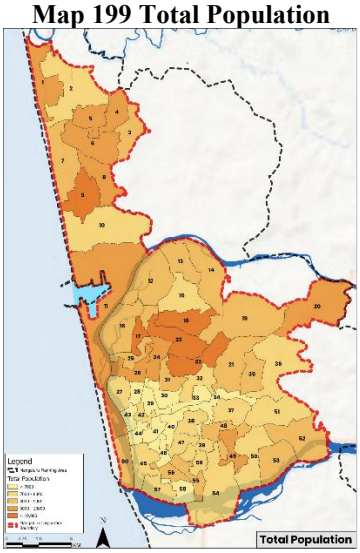
Source 285 Census of India, 2011 and estimated for 2021

Figure 106 Growth rate of Mangaluru M. Corp compared to State and district

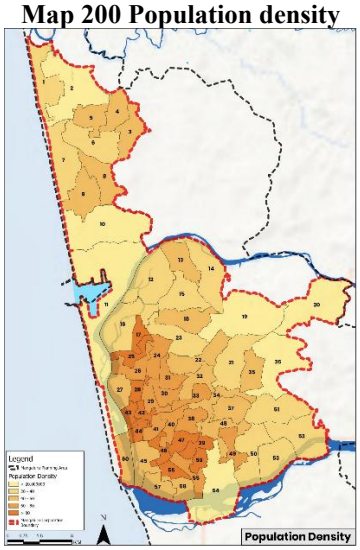


Source 286 Based on Census of India, 2011

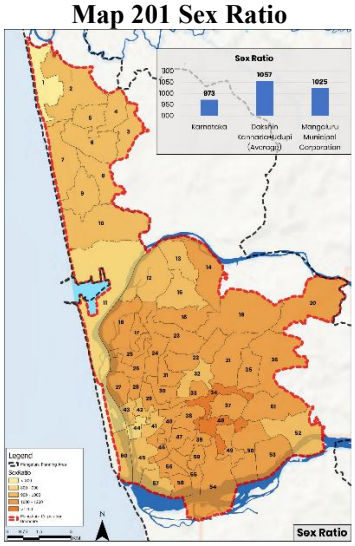
Map 199 Total Population



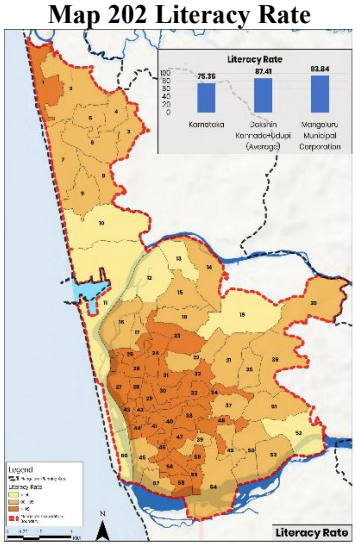
Map 200 Population density



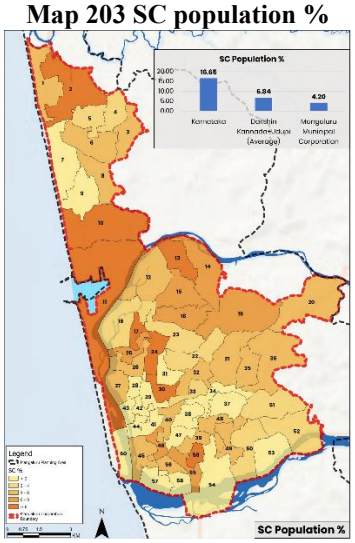
Map 201 Sex Ratio



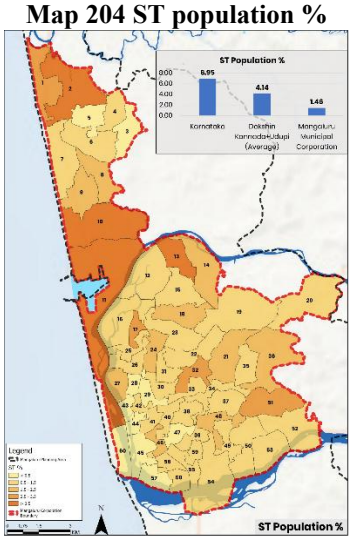
Map 202 Literacy Rate



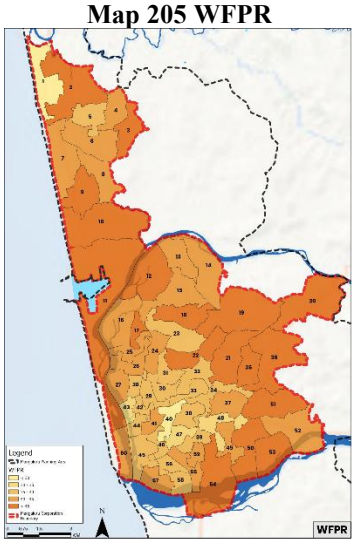
Map 203 SC population %



Map 204 ST population %



Map 205 WFPR



Source 287 Author

Wards with high population (> 10,000): 9, 17, 18, 23, 22

Wards with population density > 60 PPH: Concentrated in Low-lying core area up to **20 m** ASL have high density

Sex Ratio: **1025,** higher than state & lower than district.

Literacy Rate: **93.84%,** higher than both state & district, indicating good adaptive capacity - its ability to understand and respond to climate-related threats or ecological degradation. Literate populations are more likely to adopt early warning systems, disaster preparedness measures, and conservation strategies.

SC & ST Population lower than state & district average

Figure 107 Workers' composition

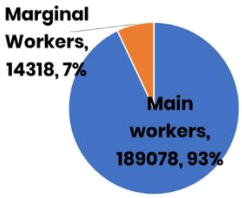


Figure 108 Composition of main workers

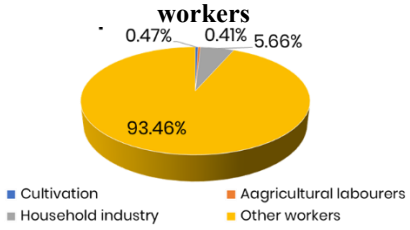
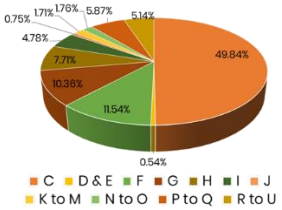


Figure 109 Industrial main workers occupation in the district



Source 288 Census of India, 2011

WFPR is **40.7%** lower than state & higher than district averages. **93%** of the Workforce are **main workers** Male Work force is **69%. 93.46%** of the main workers fall in other workers category. Occupational pattern in district suggests **50%** of other **main workers** are engaged in **Manufacturing sector** (C)**.**

Figure 110 Mangaluru Municipal Corporation - Population estimation for 2025

Mangaluru Municipal Corporation									
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
1,93,699	2,81,161	3,99,565	4,99,487	Geometric	5,01,959	2,472	0.5	**6,02,421**	**6,43,852**
				Arithmetic	4,98,844	-643	0.1		
				Incremental	4,84,371	-15,116	3.0		

Source 289 Author

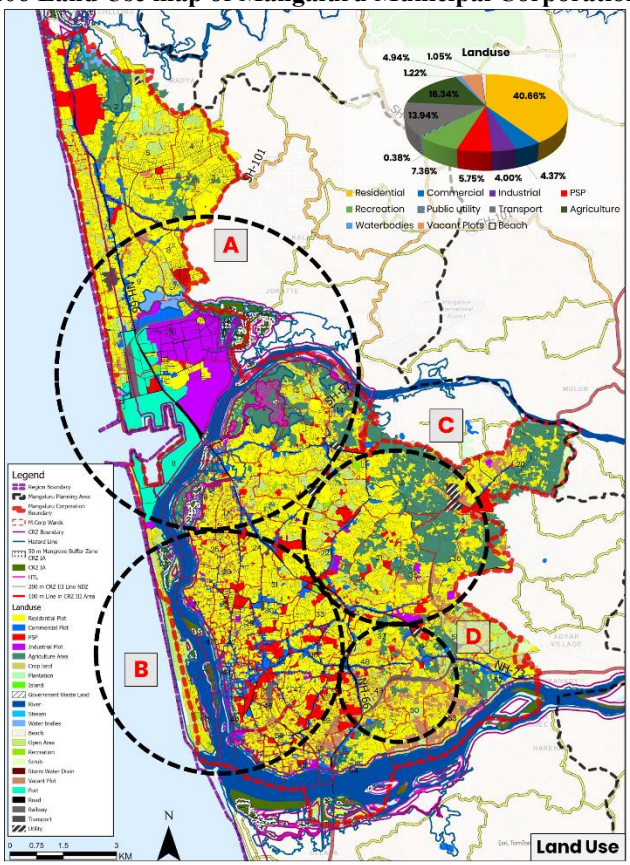
Population is estimated through Geometric, Arithmetic, and Incremental method. Arithmetic method shows the least error and hence is used to estimate the population for 2025, which is **6,43,852.**

5.4 Land Use of Mangaluru Municipal Corporation Area

Following the demographic analysis, a detail study of **land use** within Mangaluru city helps to assess how urban growth patterns interact with the Gurupura River and its ecosystems.

Area of Mangaluru Municipal Corporation = 132.45 Sq.km (43.13% of Mangaluru Planning Area)

Map 206 Land Use map of Mangaluru Municipal Corporation Area

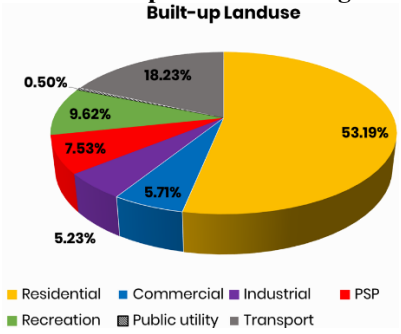


Source 290 Developed by Author based on observation and Mangaluru Planning Area Master Plan 2021

Table 71 Land use of Mangaluru city

Landuse	Area in Ha	% of built-up
Residential	5,386.06	53.19
Commercial	578.197	5.71
Industrial	529.165	5.23
PSP	762.22	7.53
Recreation	974.482	9.62
Public utility	50.1436	0.50
Transport	1,846.50	18.23
Total Built up	**10126.78**	**100.00**
Agriculture	2,164.00	
Waterbodies	161.916	
Vacant Plots	653.894	
Beach	138.414	
Total Area	**13245**	

Figure 111 Built-up lad use of Mangaluru city



Source 291 Compiled by Author

For analysis, the land use of wards in micro watersheds of 2km & 5km buffer of Gurupura River is studied in detail.

Figure 112 Land use of wards in micro watersheds of 2 km buffer around Gurupura River

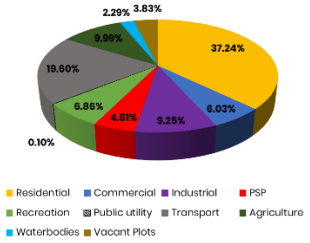


Figure 113Detail Land use at A

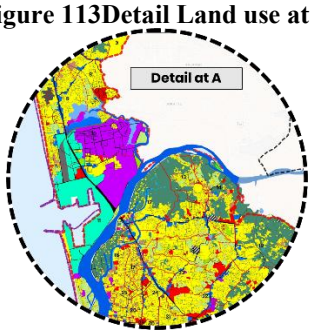
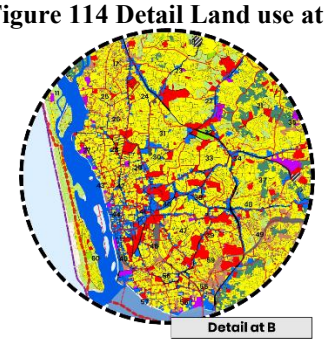


Figure 114 Detail Land use at B



Source 292 Author

There are **29 wards** in the micro-watersheds within 2 km buffer of Gurupura River.

37.24 % of the land area is under residential use, followed by **19.6%** under **Transport** sector which includes **ports** along with the **Road & Railway network.**

Agricultural use occupies **10%** of the land area, concentrated on the southern banks of the Gurupura

9.25 % of the land area is under **Industrial use**, this includes the Baikampady Industrial area on the northern banks of Gurupura, identified as critically polluted industrial area with a CEPI score of **73.68** as of 2018. **Commercial and PSP** use concentrated along the lower stretches of the river. Drains joining the river from these areas carry **industrial effluents, agricultural run-off, and domestic waste water** into the Gurupura river.

Figure 115 Land use of wards in micro watersheds of 5 km buffer around Gurupura River

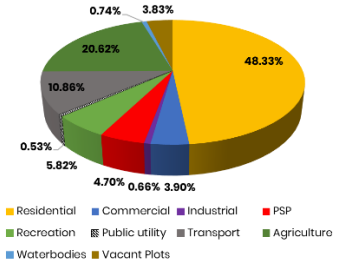


Figure 116 113Detail Land use at C

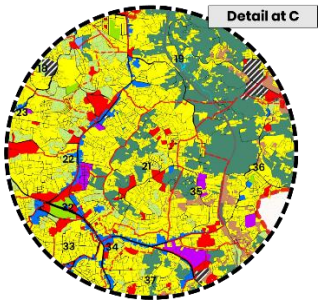
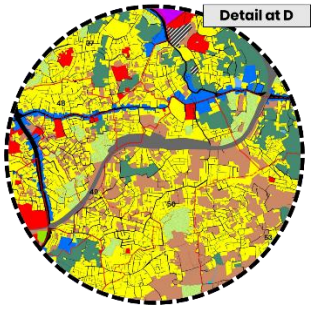


Figure 117 113Detail Land use at D



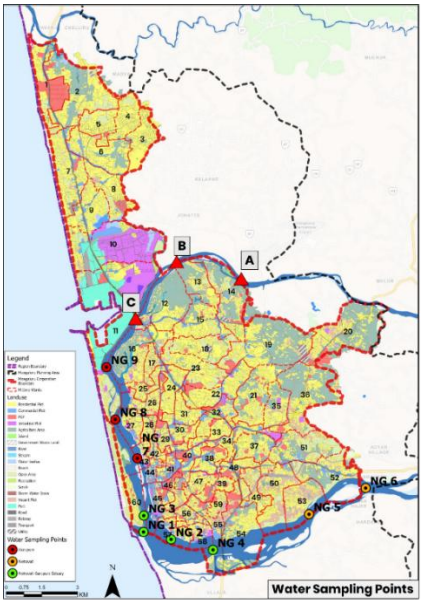
Source 293 Author

There are **24 wards** in micro-watersheds within 5 km buffer of Gurupura River. This transition zone includes **48.33%** of land under Residential use, followed by **20.62%** area under Agricultural use. The **MCC solid waste management plant** occupies **0.53%** of the land area. The run-off from this zone includes domestic wate water, and agricultural field-run off.

5.5 Water Quality

Post land use analysis, that highlights the spatial extent of urbanization, industrial activity, and declining ecological buffers along the Gurupura River, it becomes crucial to assess the **river's water quality** to understand the environmental impact of these land uses. Samples were collected at 3 locations (A, B & C) on Gurupura River during the site visit to Mangaluru city & tested for the following parameters – BOD, COD & DO. Also, water quality data of sample points on Gurupura river form a research paper published in the year 2022 was consider for the study. The sampling locations are shown in the map below.

Map 207 Water Sample points on Gurupura River



Source 294 Author

Map 208

Table 72 Water quality of Gurupura River for samples collected by author in February 2025

Parameter	Standard	Sample Points 2025 A	B	C
BOD	≤ 2.0 mg/L (Class A) ≤ 3.0 mg/L (Class B/C)	3.5	5	6.5
DO	≥ 6.0 mg/L (Class A) ≥ 5.0 mg/L (Class B/C)	6.5	5.5	4.8
COD	≤ 20–30 mg/L (BIS)	23	42	55
		Nutrient runoff present, but still fairly healthy ecosystem	Mixed impacts; moderate pollution and some oxygen depletion	High organic and chemical pollution; oxygen stress on aquatic life
Designated Best Use (DBU)		D	D	D

Table 73Water Sample points 2022 on Gurupura River

Sample Point	DO	BOD	PO_4	DBU Class
NG 7				Class D (fisheries only)
NG 8				Class D
NG 9				Class D/E

Source 295 Author

The findings of the tested water sample show poor water quality across all the 3 points, falling under Designated Best Use (DBU) of class D, which as per CPCB is suitable for Propagation of Wild life and Fisheries. The water quality at sample points NG 7 to NG 9 studied in the year 2022 shows DBU Class D, indicating no improvements in water quality over the years. The probable sources of pollution include **Agricultural run-off, Industrial effluents & Wastewater inlet.**

5.6 Economic Activities

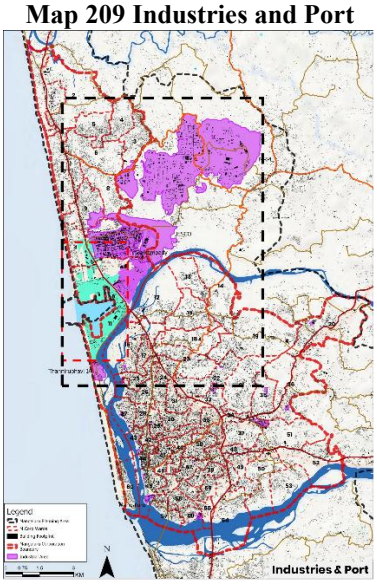
Following the assessment of water quality of Gurupura Rive that reflects the environmental pressures from surrounding land uses, it becomes important to understand the **economic activities** that both contribute to and are dependent on the river system, which includes Industries, port, fisheries, and tourism. The aim to identify sectors with potential for **sustainable transition**.

5.6.1 Industries

The Mangaluru Municipal area has the Baikampady Industrial area which is identifies as a critically polluted industrial area with a CEPI score of 73.68 in 2018, which is located on the Norther banks of the Gurupura River.

The Baikampady Industrial area is a part of Mangaluru Special Economic Zone (MSEZ) which also includes the Mangalore Refineries and Petrochemicals limited which falls in the Planning area outside the Municipal limits.

Map 209 Industries and Port



Source 296 Author

Map 210 MSEZ Mangaluru



Source 297 CEPI Action Plan for Baikampady Industrial Cluster 2019

The Baikampady industrial area has 258 industries, which includes 22 Red category with 4 industries of 17 Category industries.

Table 74 Number of industries in Baikampady Industrial Cluster

Category	Red	Orange	Green	Total
Small	7	78	137	**222**
Medium	1	4	4	**9**
Large	14	10	3	**27**
Total	**22**	**92**	**144**	**258**

Source 298 CEPI Action Plan for Baikampady Industrial Cluster 2019

17 category industries include MRPL, BASF, Mangalore Chemicals & Fertilizers, Solara active pharma science ltd.

To study the **sustainability of the industrial activities** in Baikampady industrial cluster along the Gurupura River, **Sustainability Standards for Industrial Estates** developed by GIDC is used. The analysis provides insights into how existing industries perform under various quality criteria established as per GIDC Sustainability standards, helping identify areas that require improvement for achieving a more sustainable and river-sensitive industrial ecosystem.

Table 75 GIDC Sustainability Standards calculated for Baikampady Industrial Area

Quality criteria	Sub-criteria	Weighted value
Economic Quality	Investment & Revenue	8.8
	Employment	12.5
	Competitiveness	13
	Investment Safety & branding	14
Sub-Total		**48.3**
Environmnetal Quality	Cleaner production & resource efficiency in individual	0.4
	Water preservation measures	2.1
	Storm water management	0
	Waste water management	2.3
	Waste management	4
	Emissions & air pollution	1.8
	Resource efficiency	1
	Climate change mitigation and adaptation	1.5
	Biodiversity preservation	4
	Disaster risks management/ preparedness	2
Sub-Total		**19.1**
Infrastructure Quality	Location suitability	5
	Site master plan	7
	Logistic support provision	6
	Art and architecture	3
	Building design	2
	Mobility infrastructure	21
	Environment friendly transport	0
	Power and Energy Systems	2.1
	Plantation & landscaping	3
	Common infrastructure	5
Sub-Total		**54.1**
Social Quality	Social management systems	11.9
	Social infrastructure	15
	Gender equity	6.3
	Local community well-being and community outreach	11.9
Sub-Total		**45.1**
Management Quality	Administrative & management infrastructure	14.4
	Application of standards	0
	Quality assurance & monitoring	0
	Environmental stewardship	5
Sub-Total		**19.4**
Grand Total		**37.2**

Source 299 Author

Table 76 Environmental Quality and indicators as per GIDC Sustainability Standards

Quality Criteria	Value	Sub-criterial	Weightage	Indicators	Weightage (A)	Value (0 to 100 out of 100) (B)	Weighted Value (A*B/100)	Weighted Value
Environmental Quality	100	Cleaner production and resource efficiency in individual	10	Cleaner production processes	20	0	0	0.4
				Waste/waste water recycling by industries	20	20	4	
				Industrial symbiosis and synergies	20	0	0	
				Circular economy by industries	20	0	0	
				Sustainable procurement by industries	20	0	0	
		Water preservation measures in the	10	Sustainable water supply	40	30	12	2.1
				Limited ground water extraction	30	10	3	
				Water preservation	30	20	6	
		Storm water Management	10	Storm water management system	100	0	0	0.0
		Wastewater management	10	Sewerage network	10	0	0	2.3
				Conveyance systems	10	0	0	
				Sewage treatment	15	20	3	
				Waste water treatment	15	30	4.5	
				Safe disposal	10	30	3	
				Treated wastewater recycling/reuse	10	25	2.5	
				Non-potable water	10	30	3	
				Skilled personnel	10	40	4	
				Waste water monitoring systems	10	30	3	
		Waste management	10	Hazardoud waste management	25	40	10	4.0
				Industrial solid waste management	25	40	10	
				Municipal/domestic solid waste management	25	80	20	
				Minimised use of non recyclable goods/materials	25	0	0	
		Emissions and air pollution control	10	Air pollution control systems	70	0	0	1.8
				Air pollution monitoring systems	30	60	18	
		Resource efficiency	10	Energy efficiency	50	0	0	1.0
				Resource saving infrastructure	50	20	10	
		Climate change mitigation and	10	Minimisation of GHGs	50	0	0	1.5
				CCA adaptation measures	50	30	15	
		Biodiversity preservation	10	Biodiversity preservation	100	40	40	4.0
		Disaster risks management/	10	Natural disasters	50	0	0	2.0
				Industrial disasters	50	40	20	
Sub-total			100	Sub-total				19.1

Source 300 Author

The Environmental quality scores the least of all the quality criteria. The low score is due to lack of storm water network, waste water recycling and repurposing, and lack of industrial symbiosis in the Baikampady industrial cluster.

The overall Sustainability Standard score is 37.2/100, which falls in <55 category indicating a need for improvement.

Table 77 GIDC Sustainability Standard score range

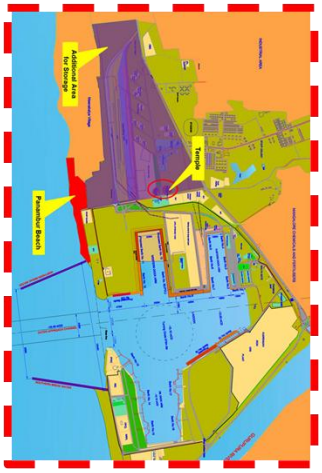
Score Range	Rating
85 – 100	Platinum
70 – 84.99	Silver
55 – 69.99	Bronze
< 55	Needs Improvement

Source 301 GIDC Sustainability Standard

5.6.2 Port

The New Mangalore Port, located in the MSEZ is one of the Major ports of the country.

Map 211 New Mangalore Plan Layout

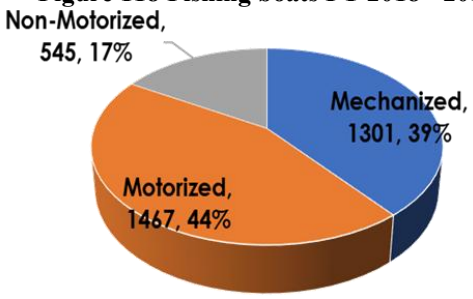


Source 302 NMPA EIA

5.6.3 Fishing

Gurupura & Netravati Estuary species: Catfish, Sillago, Platycephalus, Indian Mackerel, Salmon, Sardines, Mullets, Flounder, Bass, Barbels, Eels, & Shads.

Figure 118 Fishing boats FY 2018 - 2019



Source 303 Karnataka State Fisheries handbook 2018

83% of the boats used in marine fisheries operate on **diesel**. The primary concern here is **Diesel leaks**

5.6.4 Impact Matrix

To understand the cumulative impact of Landuse, and economic activities on the Gurupura river and its ecosystem, an Impact matrix is used to identify the priority area for interventions and supports the development of targeted, sector-specific strategies for sustainable river management. The scoring of the impact matrix is attached in the annexure

The methodology used is the same as that of Impact matrix at the region scale.

Table 78 Impact matrix for Mangaluru City

Affected Aspect		Total Score	Economic Activities											
			Agriculture		Fishing		Industry		Port		Built-up		Tourism	
Category	Components affected		Avg	Observation	Avg	Observation	Avg	Observation	Avg	Observation	Avg	Observation	Avg	Observation
Physical Environment	Air	11.0	1.7	Ground water-based irrigation is impacting DTWL, fertilizers affecting river quality	1.8	Mechanized operations & waste handling is polluting the water & generating noise	2.5	Air & Water pollution is significant. CEPI Area with73.68 score in 2018	1.8	Port operations & expansion has led to altered coastal landform though dredging & reclamation	1.5	untreated sewage inflow, solid waste dumping, and altered stormwater pathways, degrading the Gurupura's water	1.75	Waste generation, land use changes, increased vehicular emissions, and strain on local air, water, and soil quality.
	Costal waterbody & Estuarian	13.2	1.7		2.8		2.7		1.6		2.25		2.25	
	Inland Rivers	14.4	2.0		2		2.5		2.4		3		2.5	
	Inland waterbodies	10.1	2.0		1.4		1.5		1.2		2.5		1.5	
	Ground water	11.3	2.3		1.2		2.2		1.8		2		1.75	
	Land & Soil	12.4	2.3		1.8		1.8		2.2		1.75		2.5	
	Micro-climate	9.0	1.7		1.2		1.5		1.4		1.5		1.75	
Biological	Terrestrial Flora	12.0	2.3	Intensive agriculture reduces biodiversity & harms terrestrial & aquatic species & alters habitat die to chemical run-off	1.4	Mechanized trawling, pollution is degrading the habitat, reduced fish population is an issue	1.8	Chemical & effluent discharge impacts aquatic flora & fauna. Reduced mangrove area & fish deaths.	2.4	Dredging, spillage during handling & shoreline modification has impacted the biodiversity	1.75	Encroachment & pollution from built-up areas reduce mangroves, disturb aquatic life, and fragment riparian habitats.	2.25	Habitat disturbance from construction and tourist footfall stresses local flora and fauna, especially in sensitive riverine and coastal zones.
	Terrestrial Fauna	11.7	2.3		1.4		1.8		2.4		1.75		2	
	Aquatic Flora	12.8	1.7		1.8		2.0		2.6		2.25		2.5	
	Aquatic Fauna	13.0	1.7		2		2.0		2.6		2.25		2.5	
Socio-cultural	Livelihood	9.4	1.0	No significant impact noticed	1.8	No significant impact noticed	2.2	No significant impact noticed	2.4	Exposes workers to health hazards	1	No significant impact observed	1	Boosts local income and cultural visibility but can commercialize traditions and strain infrastructure.
	Health	8.3	1.3		1		1		1.4		1.25		1.25	
	Culture	8.9	1.0		1.8		1.7		2.2		1		1.25	
Average			25.0		24.6		29.0		29.4		25.8		28.8	

Source 304 Author

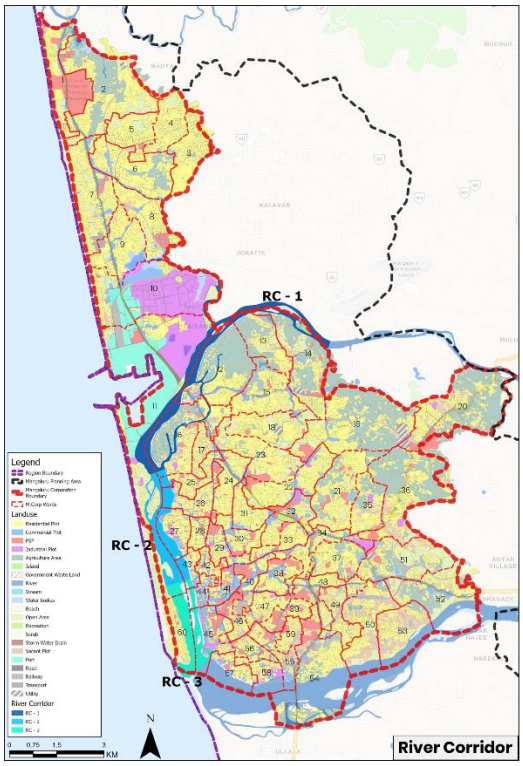
The Inland River (Gurupura), Coastal waterbodies & Estuary are most impacted components, followed by aquatic flora & fauna. The reasons include Industrial pollution, agricultural run-off, untreated sewage, and use of mechanized boats for fishing are identified as the source of pollution in Gurupura River.

5.7 Identification of River Corridors

Following the analysis of **land use, water quality, and economic activities**, river corridors along Gurupura River have been identified that serve as critical zones where ecological sensitivity overlaps with intensive land use and economic dependence, necessitating focused planning and management.

Identifying these corridors allows for a spatially differentiated approach to urban river management, where restoration, regulation, and sustainable development strategies can be tailored based on the nature and intensity of pressures in each zone. This step bridges environmental assessment with actionable planning, ensuring that interventions are not generic but are grounded in local land use dynamics and sectoral interactions.

Map 212 River Corridors in Mangaluru City



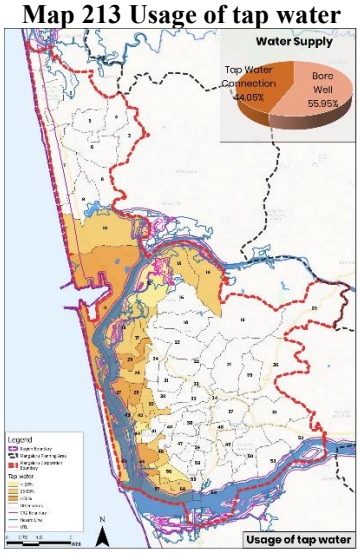
Source 305 Author

River corridors identified are **RC – 1** which is **High Impact Stretch** covering the agricultural & industrial belt falls in Class D (DBU) indicating high pollution & limited use, **RC – 2 - Moderate Impact Stretch** which passes through residential areas with Class D, **RC – 3 - Low Impact Stretch** which is Located near the estuary, surrounded by commercial, residential, & PSP land use, with water quality is in desirable limits, suggesting lower cumulative impact.

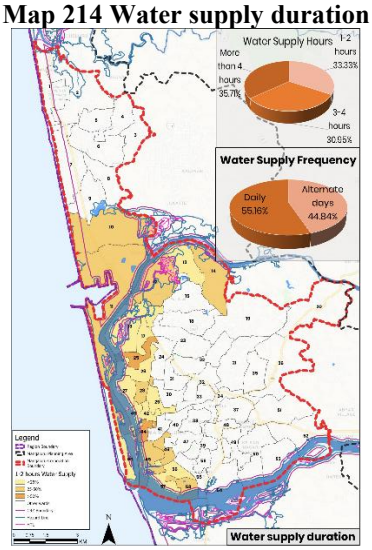
5.8Primary Survey

A primary survey was conducted on site to understand the existing situation of Social and physical infrastructure in the city. The survey was conducted in selected wards within the city, along the Gurupura River bank. Questionnaire is attached in the Annexure. The finding shows a Mix of **tap and bore water supply**, tap more common in core areas. The water supply is daily or alternate day supply for **1–4 hours**. **Tanker supply** is used in summer. Septic tanks are common in the core wards and the city has **partial sewer network coverage**. **Waste Management** is mostly **Door-to-door collection** is dominant and is collected daily in most wards. **Water logging occurs** but usually clears within a day. **Solid waste in drains is reported**; maintenance is irregular, and with respect to **Open Spaces,** there is a Lack of parks and greenery noted in several wards.

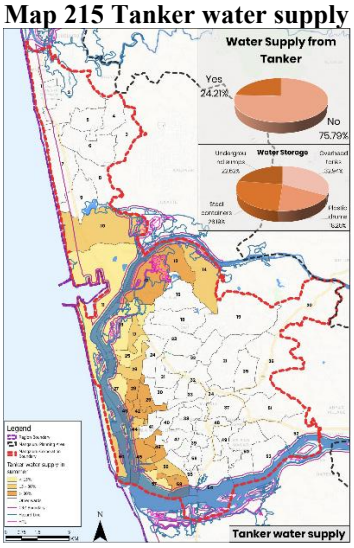
Map 213 Usage of tap water



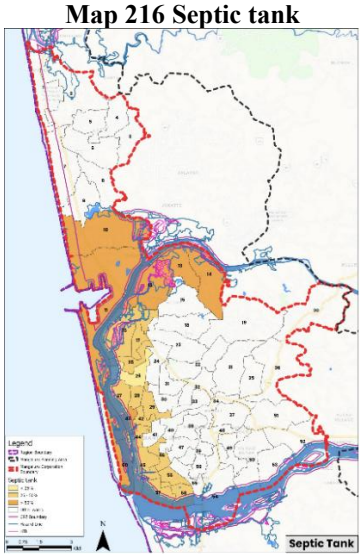
Map 214 Water supply duration



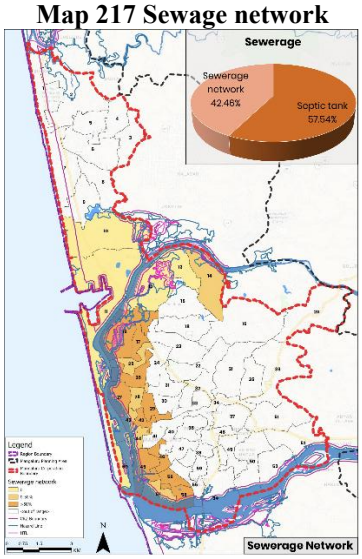
Map 215 Tanker water supply



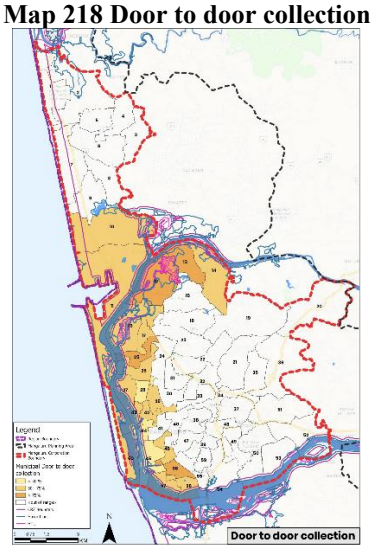
Map 216 Septic tank



Map 217 Sewage network

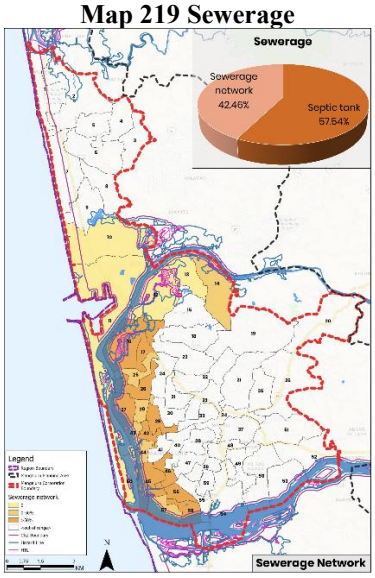


Map 218 Door to door collection

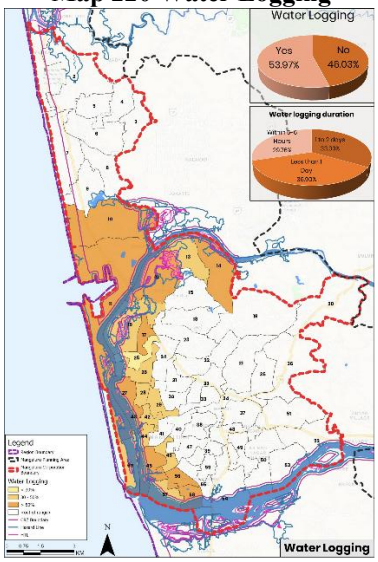


Source 306 Author

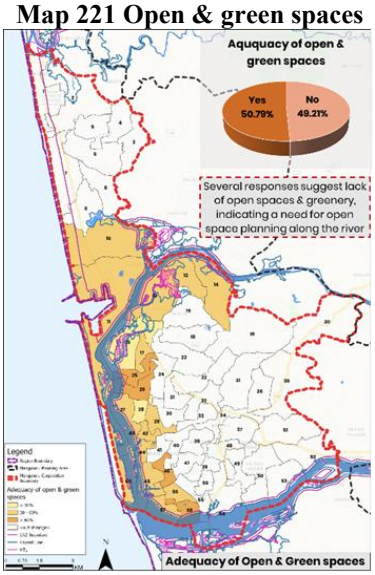
Map 219 Sewerage



Map 220 Water Logging



Map 221 Open & green spaces



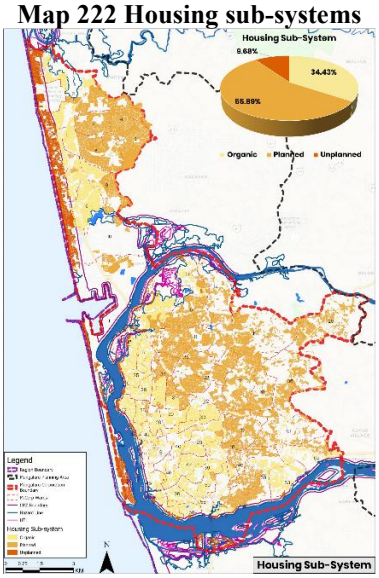
Source 307 Author

5.9 Housing & Solid waste

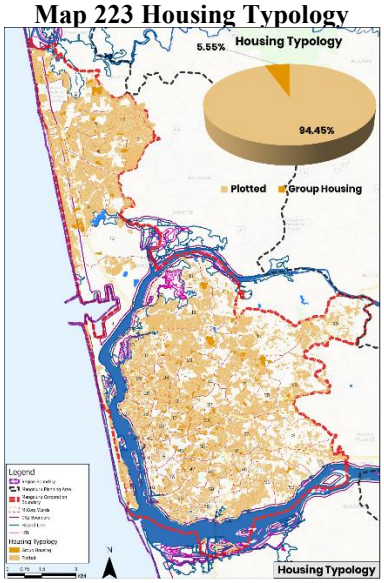
Housing

55.89% **Planned** Housing, indicating a formal urban development trend. A combined 44.11% of housing is organic **(34.43%)** and unplanned **(9.68%),** suggesting mixed development patterns. Slums are mainly located along the Gurupura River and coastal areas, indicating exposure to environmental risks. Wards on the western banks of the Gurupura river have more than **2% Households** living **in temporary housing**, while the wards along the eastern banks of the Gurupura river have **> 15% households** living in **semi-permanent housing.**

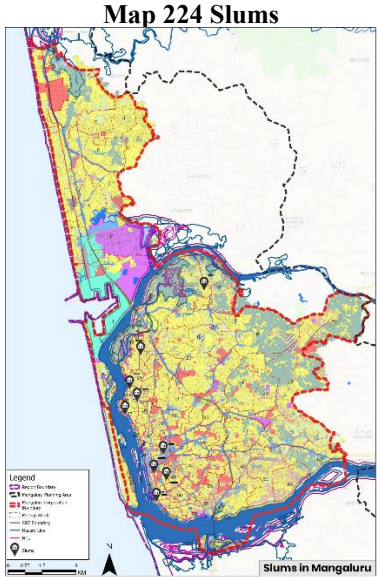
Map 222 Housing sub-systems



Map 223 Housing Typology



Map 224 Slums

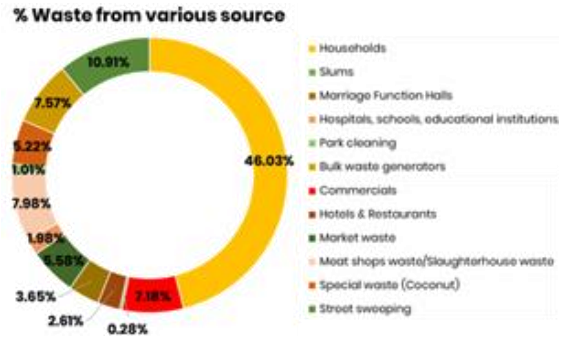


Source 308 Author

Solid Waste

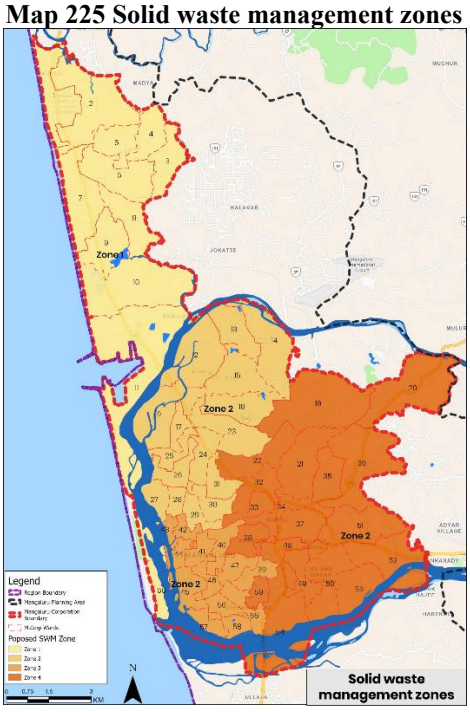
46.03% of the city's waste is generated by **Households**, followed by 10.91% from slums, 7.98% from meat shops, 7.18% from commercial shops

Figure 119 % waste from various sources

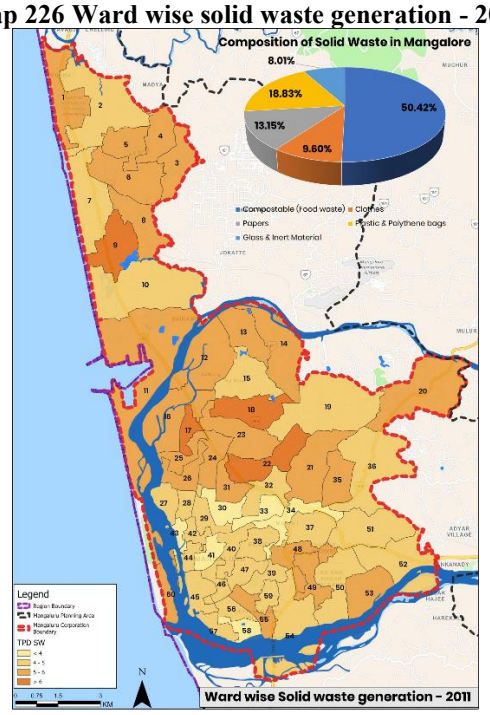


Source 309 Mangaluru Municipal Corporation

Map 225 Solid waste management zones



Map 226 Ward wise solid waste generation - 2011



Source 310 Author

The Current per capita waste generation is **608 grams/day**, Primary Collection is Door-to-door using Jeep tippers, Secondary Collection via compact trucks, tippers, & compactors. Wet waste is collected on a Daily, and Dry waste is collected once every 3 days.

Figure 120 Landfill Location

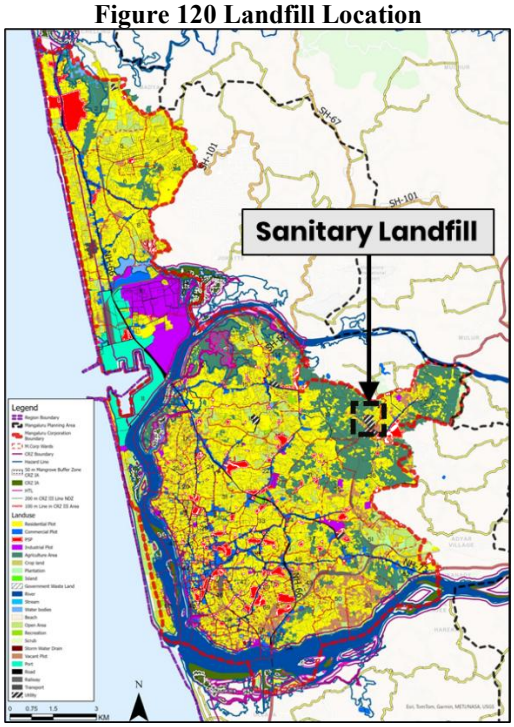


Figure 121 Pachanady Landfill in Mangaluru City



Source 311 Author

The city has a landfill with site area of 77.93 acres established in 2009. The site includes Vermicompost pits, Windrow composting, Sanitary landfill, Leachate collection & treatment facilities.

Issues identified include Poor waste segregation at source, Inefficient collection and manual handling, Sanitary landfill issues: leachate during monsoon, legacy waste, No facility for C&D waste management.

5.10 Physical Infrastructure

Understanding the physical infrastructure within the city, is essential to assess how urban growth and service provisioning interact with the river ecosystem. This helps examines key infrastructure systems—such as **Water supply, sewerage, storm water, and transportation networks** that have a direct or indirect impact on the health and sustainability of the river. The spatial distribution, capacity, and coverage of these systems influence both the environmental performance of the city and its vulnerability to issues like flooding, pollution, and habitat degradation and throws critical insights for integrating urban infrastructure planning with river-sensitive development strategies.

5.10.1 Water Supply

The water supply to Mangaluru city is from Thumbe Dam built across Netravati River and is located 22 km away from the city center. The city receives water for **12 hours per day**, leaving a gap of 12 hours per day

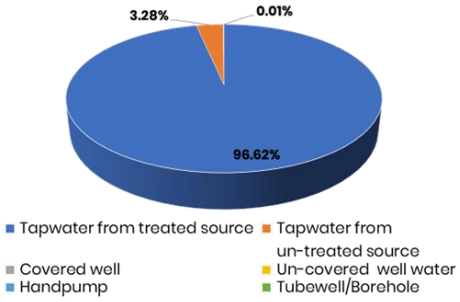
The city has **3 water supply Zones**

1. **Panamboor** –Industrial Area, NITK Surathkal, NMPA, 12 wards in the northern part of the city.
2. **Padil** –26 wards in the Eastern parts of the city
3. **Bendoor** –Includes 22 Wards

Table 79 Storage reservoirs in water supply zones

Sl No	MBR	Pump House	GLSR	OHT
1	Padil	5	6	17
2	Bendoor	4	3	11
3	Panambur	3	1	14
Total		12	10	42

Figure 122 % HH water supply source



Source 312 Mangaluru Municipal Corporation

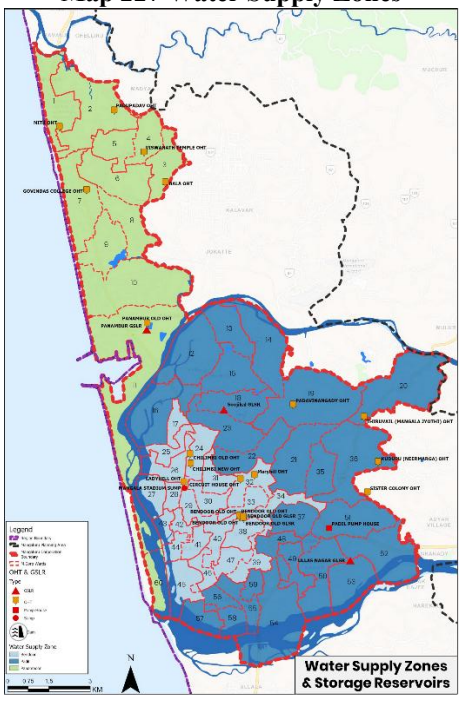
97% Households have access to tap-water from treated source. The city has water surplus & no shortage is observed. **Ground water** allotted for **domestic use** is **7 MLD**. **KIADB Industrial area** has permissions to directly draw **57 MLD** water from Gurupura & Netravati River & additional **38 MLD** treated waste water from STPs in the city

Table 80 Water supply source, Demand, Supply & Gap

	2023	2025	Remark
Population	623136	643852	
Demand			
Domestic (135 LPCD)	84.12	86.92	As per CPHEEO Standard
Non-Domestic	27.78	29.25	Source: MCC (Commercial & Tourism)
Fire demand	2.39	2.60	Source: MCC
Bulk Demand	20.30	20.30	Includes NITK Surathkal, KIADB, Industrial & NMPA
Total demand	**134.59**	**139.07**	
20 % Loss	**26.92**	**27.81**	Non-Revenue water (NRW)
Total demand + 20% Loss	**161.51**	**166.88**	
Source	**Thumbe Dam (MLD)**		
Mangaluru WSS 1st Stage, 1965	10	10	Replaced with new 20MLD WTP under AMRUT (10 MLD to Villages)
Mangaluru WSS 2nd Stage, 1971	81.7	81.7	Discontinued
Mangaluru WSS 3rd Stage, 2012	80	80	
	Adyar Dam (MLD)		
Proposed 24/7 WSS			Designed to supply water upto 2046
Total Water Supply	**171.7**	**171.7**	
Gap	**+ 10.19**	**+ 4.82**	Water surplus

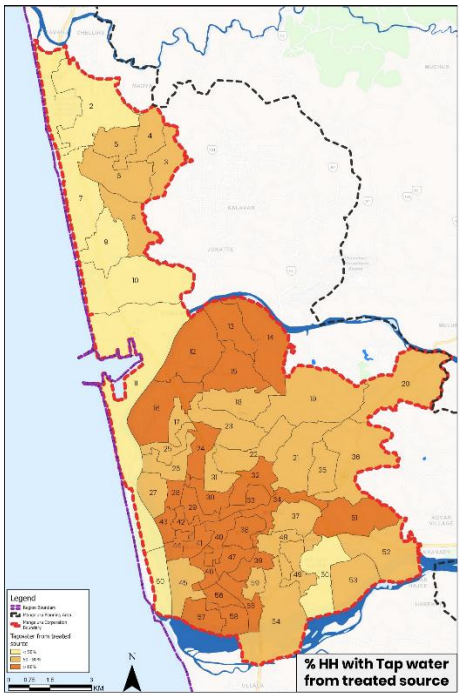
Source 313 Compiled by Author

Map 227 Water Supply Zones



Source 314 Mangaluru Municipal Corporation

Map 228 % HH with tap water from treated sources



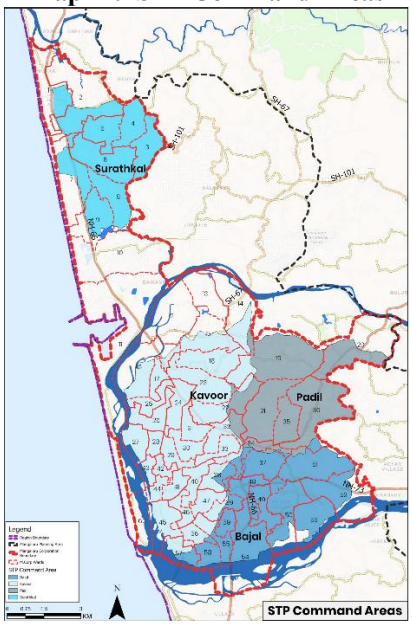
Source 315 Census of India, 2011

5.10.2 Sewerage

The city has 4 STP's that cover 55 wards.

Area Covered under Sewerage network is ~184.85 sq. km, 360 km of sewer lines laid. No Sewerage System in Wards: 10 (Baikampady), 11, 12, 13, 60 (Bengre). Major problems include Choked lines, overflowing manholes, structural failures, final discharge not compliant to CPCB Standards and polluting the Gurupura River. 2 of STP's (Pachanady & Bajal) discharge quality does not subscribe to CPCB standards. Currently, there is a treatment gap of 44.76 MLD.

Map 229 STP Command Areas



Map 230 STP and Wet wells



Source 316 Mangaluru Municipal Corporation

Table 81 Existing treatment capacity and gap

	2025
Population	643852
Total demand + 20% Loss	**166.88**
Waste water generated	133.51
STP	**Existing Capacity (MLD)**
Surathkal STP	16.5
Kavoor	43.5
Pachanady	8.75
Bajal	20
Total	**88.75**
Gap	**-44.76**

Source 317 Mangaluru Municipal Corporation

5.10.3 Stormwater Drainage

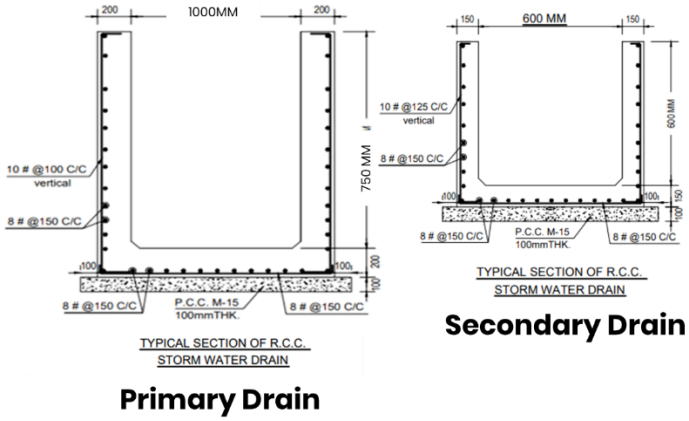
The Mangaluru City lacks in adequate coverage of stormwater drains. The areas adjacent to Gurupura River surrounding the Old Bunder port has stormwater drains.

Table 82 Stormwater drain details

Type of Drain	Width (m)	Depth (m)	Total Length (KM)	Shape	Material	Remarks
Main SWD	1.0	0.75	12	Rectangular	Concrete	Carries runoff from large catchments to rivers or sea (e.g., near Bunder, Kulur)
Secondary SWD	0.6	0.6	3.8	Rectangular	Concrete	Collects runoff from wards or sub-catchments

Source 318 Mangaluru Municipal Corporation

Figure 123 Section of existing stormwater drains



Source 319 Mangaluru Municipal Corporation

To estimate the stormwater flow velocity, assess the drain capacity & demonstrate the pluvial flooding Manning's equation is used.

Manning's Equation: $Q = 1/n \times A \times R^{2/3} \times S^{1/2}$

Q = Discarge (Flow velocity) , n = co-efficient, A = Area, P = Wetted perimeter, R = Hydaulic radius, S = Slope

Design Capacity

Main Storm water drains designed for **50mm/hr**

Secondary drains designed for **30 mm/hr**

Maximum rainfall intensity received is **40mm/hr**

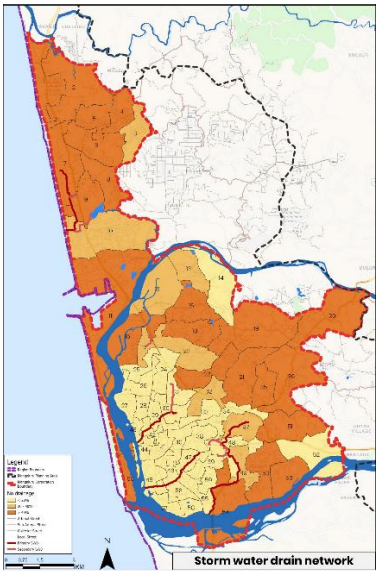
Total Run-off in Mangaluru City limits = **485.179 M.m^3**

Table 83 Calculation of discharge of Stormwater drains

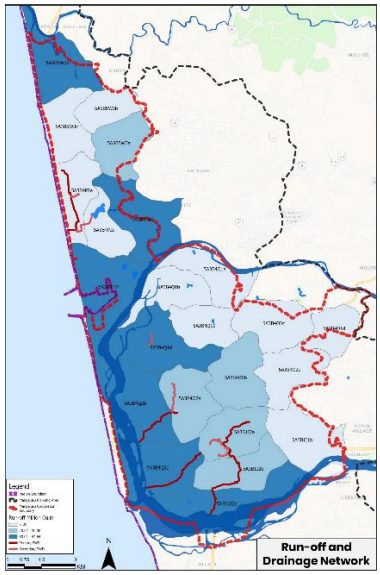
Parameter	Primary Drain	Secondary Drain
Width b (m)	1	0.6
Depth h (m)	0.75	0.6
Area A = b x h	0.75	0.36
Wetted Perimeter P (m)	2.5	1.8
Hydraulic Radius R = A/P (m)	0.30	0.20
$R^{2/3}$	0.45	0.34
$S^{1/2}$ (√0.001)	0.03	0.03
Manning's n	0.013	0.013
Discharge Q (m^3/s)	0.82	0.30
Annual run-off (L x Q x 60 x 60 x 24 x 365) Million Metric Cube	**309**	**36**
% of total run-off	**63.77**	**7.40**

Source 320 Author

Map 231 Stormwater drain connection and network



Map 232 Micro-watershed wise run-off



Map 233 Location of Pluvial flooding areas



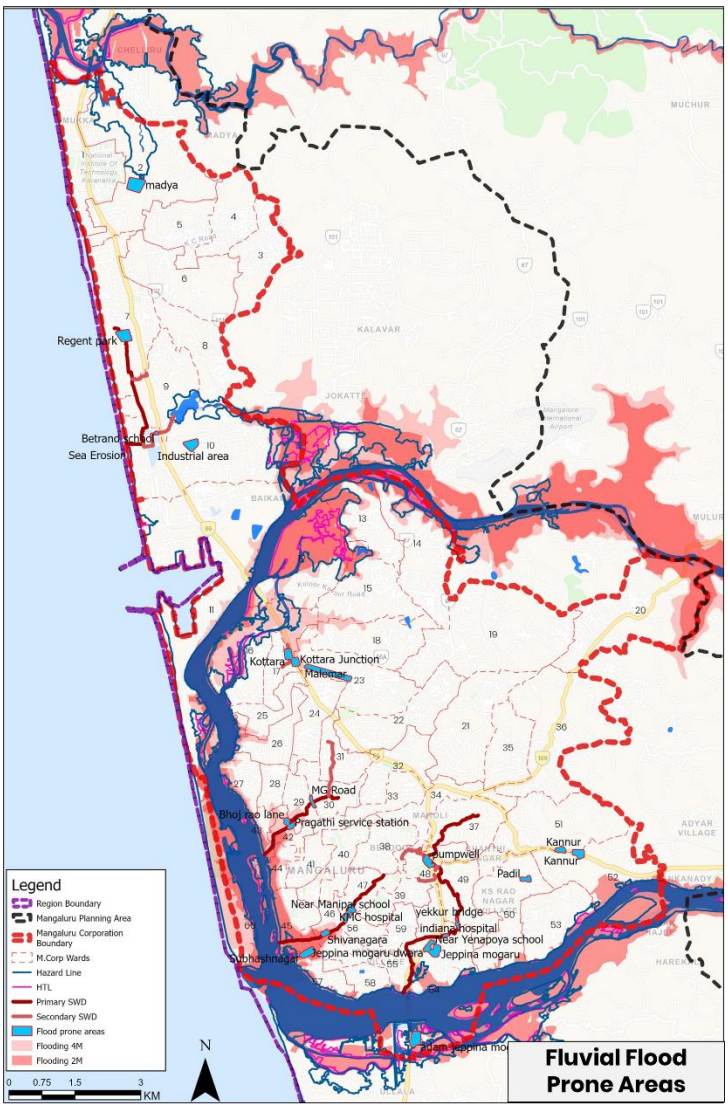
Source 321 Author

The city faces pluvial flooding at several location. SWD Flooding Locations include Malemar (W-17), Kotekara (W-23), Kannur (W – 51 & 52), MG Road (W – 29 & 30), Jeppina Mogaru (W – 54), Near KMC Hospital (W – 46 & 59), Padil (W-50)

Issues:

Solid waste dumping in SWD resulting in Pluvial flooding. In 2022, **3.5 tons** of plastic waste was collected through clean-up of SWD & River banks in the city. Heavy rainfall as well causes flooding. The peripheral wards has **> 40%** households that are not connected to the drains, indicating run-off from roof tops and courtyards are not directed into the SWDs.

Figure 124 Fluvial & Pluvial Flood Prone Areas



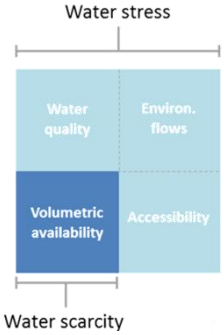
Source 322 Author

Spatial correlations between different types of flooding indicate locations where both **stormwater drainage systems are inadequate** and **riverine systems overflow during high rainfall**.

5.10.4 Water Stress

To assesses water stress in Mangaluru city using an integrated approach that combines definitions from the **Pacific Institute** that distinguishes between **water scarcity** (physical lack), **water stress** (imbalance between supply and demand), and **water risk** (potential socio-economic and environmental impacts) with the **Comprehensive Water Stress Indicator** developed by **Tata Consulting Engineers Ltd. (TCS)** is adopted. The TCS framework accounts for sector-specific stress in **domestic, agricultural, and industrial** water use, while incorporating real-world constraints such as **supply reliability**, **affordability**, and **water quality standards**. Hinged in this methodology, stress indicators are identified for four aspects: **volumetric availability, environmental flow, accessibility, and quality**, at the city level which are then scored based on a set range. The scores are normalized to arrive at the final score. The water stress in the city is calculated for Domestic and industrial sectors.

Figure 125 Physical aspects of water stress



Source 323 Defining Water Scarcity, Water Stress, and Water Risk, Pacific institute

Table 84 Indicators for 4 aspects of water stress and their range for scores

Apect	Indicator	1 (Good)	2 (Moderate)	3 (Poor)
Water quality	Average BOD Levels (mg/l)	1-2 mg/L	3-5 mg/L	>5 mg/L
	Average Turbidity Levels (NTU)	0-5 NTU	6-15 NTU	>15 NTU
	% Wards in STP Command Area	>80%	50-80%	<50%
	% Industries with ETP	>80%	50-80%	<50%
Environmnetal Flow	E-Flow Gurupura (m^3/s)	> 40% of average lean season flow	20 - 30% average lean season flow	< 20% of average lean season flow
	E-Flow Netravati (m^3/s)	> 40% of average lean season flow	20 - 30% average lean season flow	< 20% of average lean season flow
Volumetric Availability	Total Renewable Water Available (Surface+Ground)	>150 LPCD	135 - 150 LPCD	<135 LPCD
	Annual Water Demand	135 - 150 LPCD	150 - 200 LPCD	> 200 LPCD
	Water Stress Index (Demand/Availability)	<0.4	0.4-0.8	>0.8
Accessibility	% HH with access to treated tap water	>90%	70-90%	<70%
	Hours of water supply per day (hours)	>20 hours	12-20 hours	<12 hours
	% of water supplied through Water tankers	<5%	5-15%	>15%
	% Use of recycled / reused water in Industry	<80%	50-80%	<50%

Source 324 Author

Table 85 Water stress for Domestic sector

Aspect	Indicator	Absolute value	Score	Normalized	Average	Remark
Water quality	Average BOD Levels (mg/l)	3.66	2	0.50	0.5	
	Average Turbidity Levels (NTU)	70.10	3	1.00		
	% Industries with ETP	93.33	1	0.00		
Environmnetal Flow	E-Flow Gurupura	351.30	2	0.50	0.5	
	E-Flow Netravati	368.42	2	0.50		
Volumetric Availability	Total Renewable Water Available (Surface + Ground) (MLD)	93.92	2	0.50	0.50	145.87 LPCD
	Annual Water Demand (MLD)	86.92	1	0.00		135 LPCD
	Water Stress Index (Demand/Availability)	**0.93**	3	1.00		
Accessibility	% HH with access to treated tap water	96.62	1	0.00	0.17	
	Hours of water supply per day (hours)	12	2	0.50		
	% of water supplied through Water tankers (1.4 MLD)	1.61	1	0.00		

Source 325 Author

Table 86 Water stress for Industry sector

Aspect	Indicator	Absolute value	Score	Normalized	Average
Water quality	Average BOD Levels (mg/l)	3.66	2	0.50	0.67
	Average Turbidity Levels (NTU)	70.1	3	1.00	
	% Industries with ETP	> 50% & < 80%	2	0.50	
Environmnetal Flow	E-Flow Gurupura	351.3	2	0.50	0.5
	E-Flow Netravati	368.418	2	0.50	
Volumetric Availability	Total Renewable Water Available (Surface+Ground)(MLD)	105	1	0.00	0.67
	Annual Water Demand (MLD)	20.3	3	1.00	
	Water Stress Index (Demand/Availability)	0.19	3	1.00	
Accessibility	Hours of water supply per day (hours)	12	2	0.50	0.75
	% Use of recycled / reused water in Industry	19.70%	3	1.00	

Source 326 Author

Table 87 Water stress range

Average Value	Water Stress
0 – 0.33	Low
0.33 – 0.66	**Moderate**
0.66 – 1.00	High

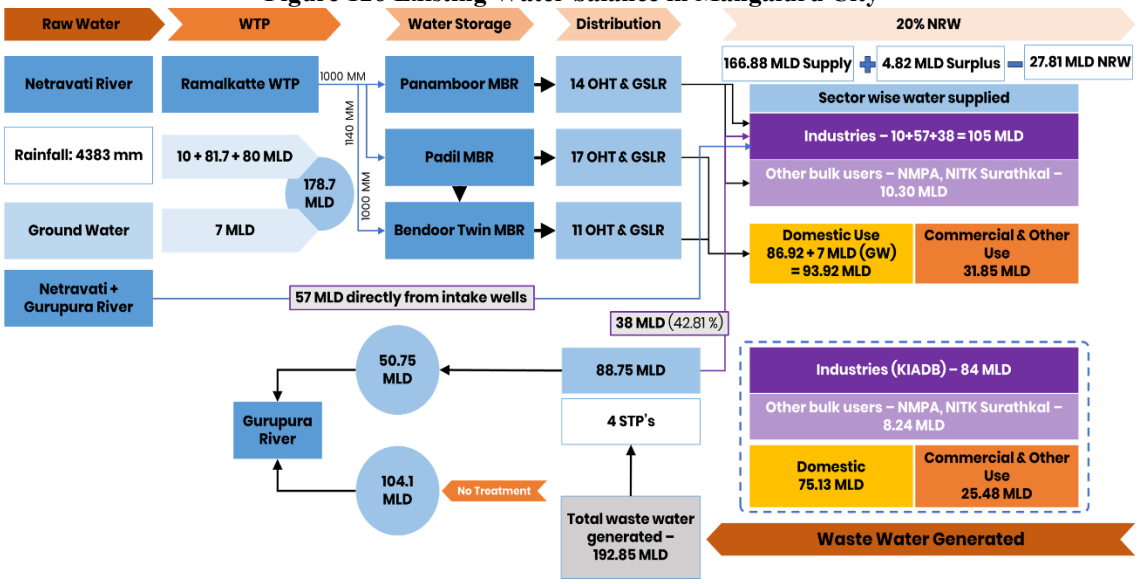
Source 327 Author

The average of the normalized average of each of the four aspects of water stress in domestic & Industrial sector is 0.42 & 0.65 respectively, indicating Moderate water stress in the city of Mangaluru City. Despite moderate water stress, Water stress index in residential sector is 0.93, & values closer to 1 indicated water scarcity.

5.10.5 Water Balance

A Water balance is a tool that helps understand how the water moves through the city, by evaluating and accounting for water source, supply, demand, and return flows, essential specially in the context of a river-dependent city like Mangaluru. This enables identification of gaps in supply & demand, highlights inefficiencies like non-revenue water and captures the amount of untreated waste water re-entering the environment. This helps in developing interventions that promote water use efficiency & promote circular water systems that is beneficial in maintain the ecological health of the river. This serves dual purpose – A diagnostic and strategic tool that supports Integrated Urban River Management.

Figure 126 Existing Water balance in Mangaluru City



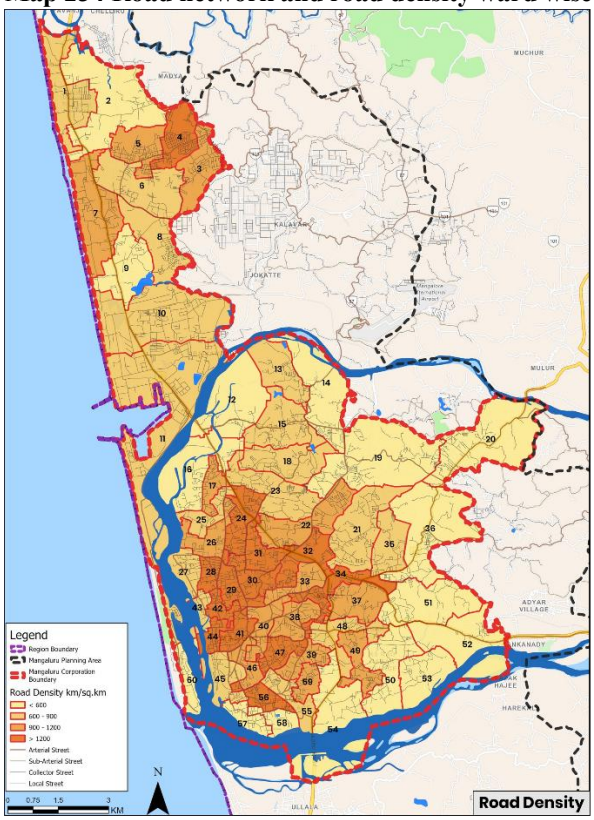
Source 328 Author

The industrial supply reuses 38 MLD treated water from the STP in the city. **46%** of waste water generated is treated while the remaining **54%** is discharged in the river without treatment.

5.10.6Road

The city has a Total Road Length of 974.62 Km. The Road Density as Length of road km / 100 Km^2, therefore Road Density of the city is **735.83 Km/Km^2**

Map 234 Road network and road density ward wise

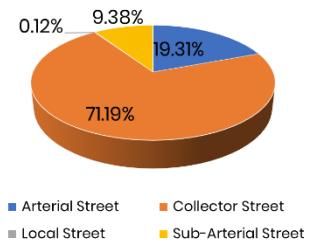


Source 329 Author

To calculate road density ward wise = **(Length of road in km x 100 Km^2)/Ward Area in Km^2**

The **wards in the core of the city** have road density greater than **1200 km/km^2**, while the **peripheral wards** have less than **600 km/km^2** indicating less connectivity compared to the core wards.

Figure 127 % Road Network



Source 330 Author

5.11 Social Infrastructure

After assessing the city's physical infrastructure of the city, it is essential to understand the role of social infrastructure in shaping community resilience and equitable urban development. The focus here would be on the education, healthcare and open spaces and the gaps in such facilities which have an influence on the quality of life, community, and city resilience.

5.11.1 Education & Healthcare

The gap analysis is assessed with reference to URDPFI Guidelines for social infrastructure. Mangalore has adequate higher education and tertiary healthcare facilities, with minor gaps in colleges and nursing home facility, indicating a well-developed urban social infrastructure in these sectors.

Table 88 Gaps in Educational facility

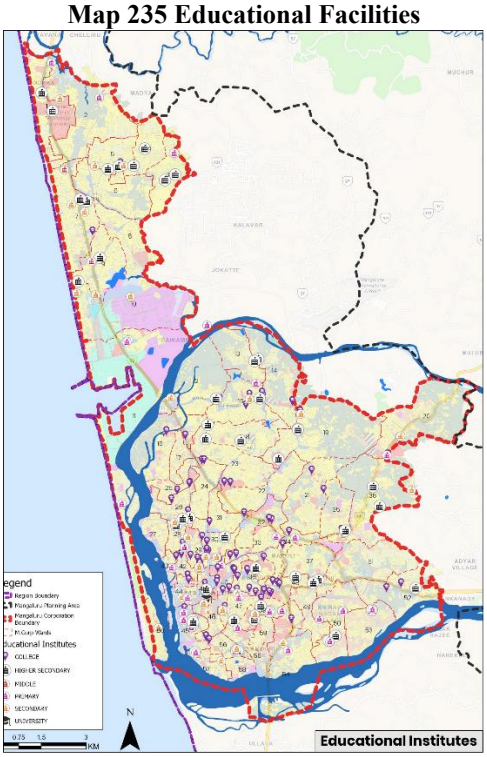
Educational Institute	Population served per unit (URDPFI)	Existing	Required	Gap
Primary school	5000	33	129	96
Secondary School	7500	86	86	0
College	125000	83	5	0
University	-	1-	-	

Table 89 Gaps in Healthcare facilities

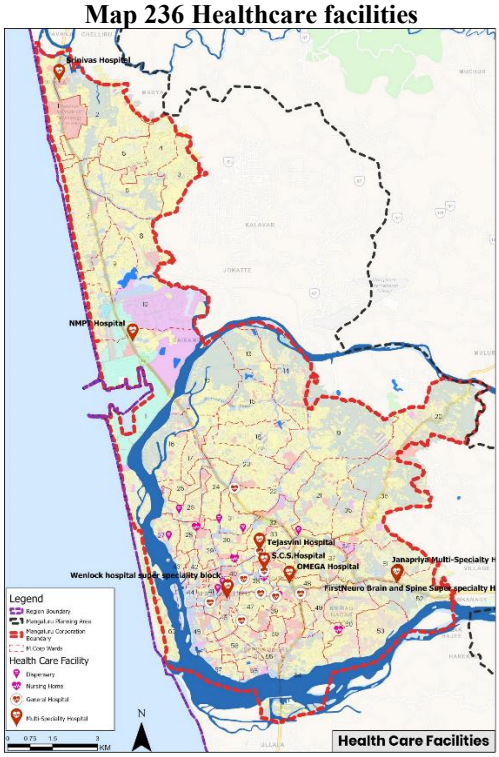
Health care facility	Population served per unit (URDPFI)	Existing	Required	Gap
Dispensary	15,000	8	43	35
Nursing Home	45,000 to 1,00,000	5	6	1
Multi-speciality hospital	1,00,000	10	6	0
General Hospital	2,50,000	10	3	0

Source 331 Author

Map 235 Educational Facilities



Map 236 Healthcare facilities



Source 332 Author

5.11.2 Open Spaces

Open spaces are natural flood buffers and potential recharge zones for a city like Mangaluru. The gaps in open spaces are assessed with respect to URDPFI guidelines which recommends 10 to 12 m^2 of open space per person.

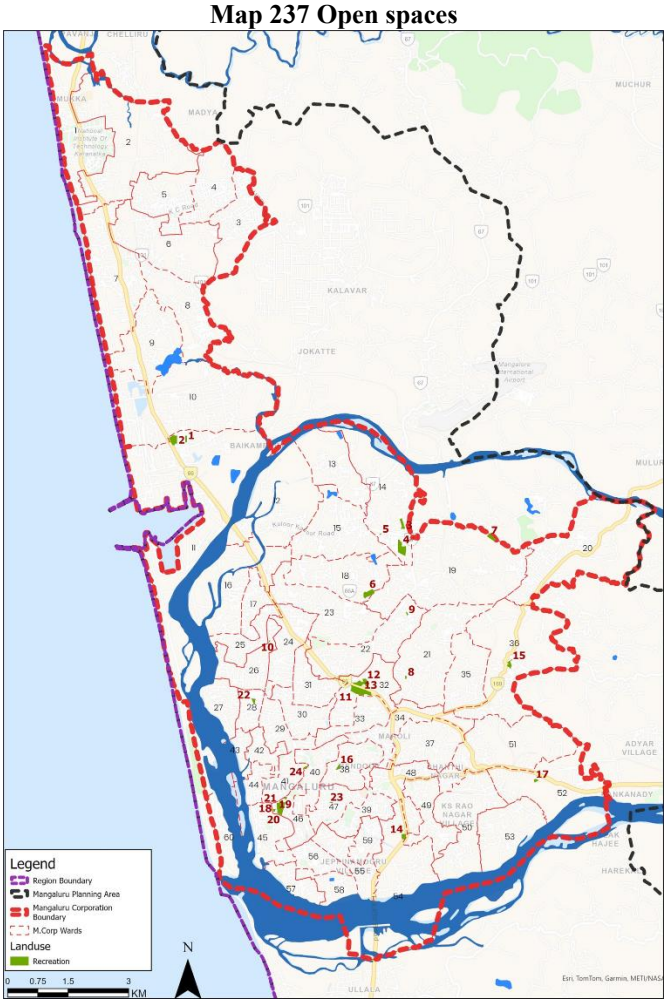
The estimated 2025 population is **6,43,852** Existing area under open space is **17,83,940 m^2 (**including beach). Therefore, Per capita open space is **2.77 m^2** calculated as per URDPFI guidelines. This leaves a gap of 8.23 m^2 per person.

Table 90 Open spaces and gaps

Category	Population Served per unit area	Area Requirement (Ha)	Number of Open Spaces	Existing Area (Ha)	Required Area (Ha)	Gap
Housing Area Park	5000	0.5	6	4.42	64.39	59.97
Neighbourhood Park	15,000	1	9	21.57	42.92	21.35
Community Park	1,00,000	5	2	12.39	79.77	67.38
District Park	5,00,000	25	0	0	32.19	32.19
Sub-City Park	10,00,000	100	0	0	NA	NA

Source 333 Author

Map 237 Open spaces



Source 334 Author

5.12 Identification of critical wards

As part of developing targeted strategies for urban river management, critical wards within Mangaluru city that experience a convergence of environmental stressors, infrastructure gaps and socio-economic vulnerability is identified.

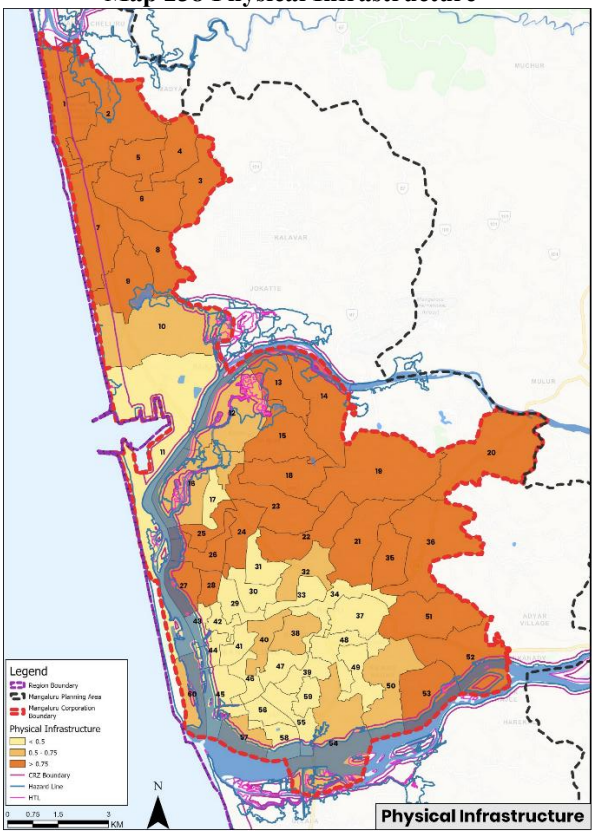
Indicators for **Physical infrastructure, Flood risk, Coastal hazard, water stress & Land use** are considered for identification of critical wards – Absolute values are normalized for each of the 5 parameters and added for the final score. The indicators and their normalized values of some wards are shown in the table below. Entire table is attached in the Annexure.

Table 91 Critical ward identification - Normalized values

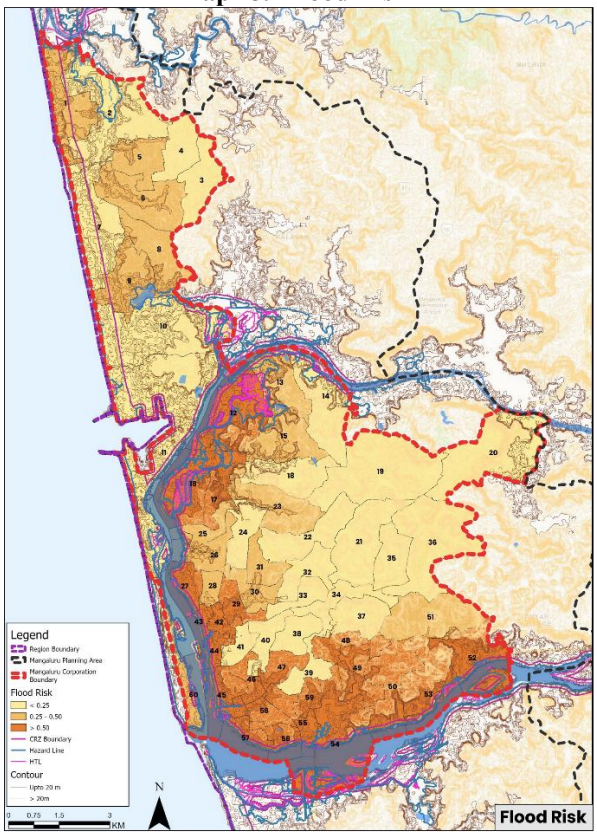
Ward No	Physical Infrastructure			Flood Risk				Coastal Hazard			Water Stress	Land Use			Total
	Solid waste	Storm water drainage	Avg	Pluvial Flooding	Fluvial Flooding	Coastal Flooding	Avg	Sea level rise	Coastal Erosion	Avg	Primary Survey (Use of tanker supply)	Water intensive activities	Water quality	Avg	
1	0.76	1.00	0.88	0.00	0.00	1.00	0.33	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.30
7	0.63	1.00	0.82	0.00	0.00	0.50	0.17	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.07
9	0.89	1.00	0.94	0.00	0.50	0.50	0.33	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.36
10	0.16	1.00	0.58	0.00	0.00	0.50	0.17	0.50	1.00	0.75	0.23	1.00	1.00	1.00	2.73
11	0.00	1.00	0.50	0.00	0.00	0.50	0.17	1.00	1.00	1.00	0.25	1.00	1.00	1.00	2.91
12	0.68	0.50	0.59	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.56	1.00	1.00	1.00	2.82
13	0.69	1.00	0.84	0.00	1.00	0.50	0.50	0.00	0.00	0.00	0.56	1.00	1.00	1.00	2.91
16	0.66	0.50	0.58	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.56	1.00	0.00	0.50	2.31
17	0.86	0.00	0.43	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.71	0.50	0.00	0.25	2.06
27	0.54	1.00	0.77	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.85	0.50	1.00	0.75	3.04

Source 335 Author

Map 238 Physical Infrastructure

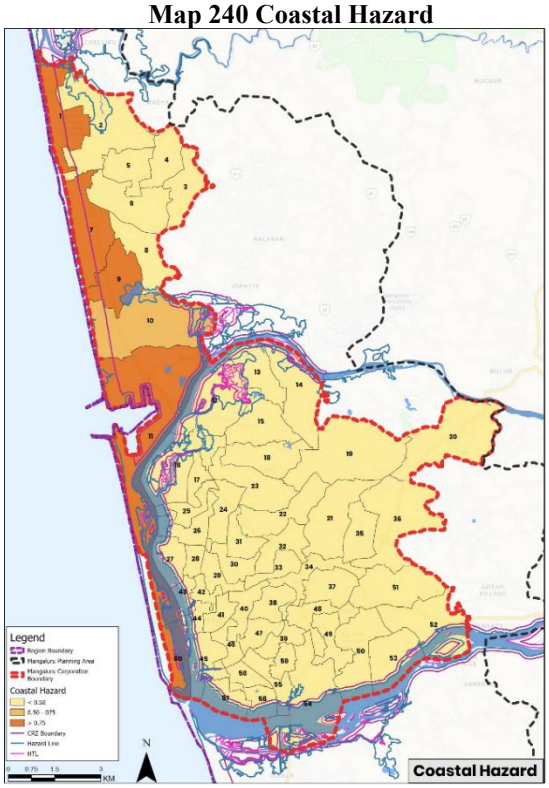


Map 239 Flood Risk

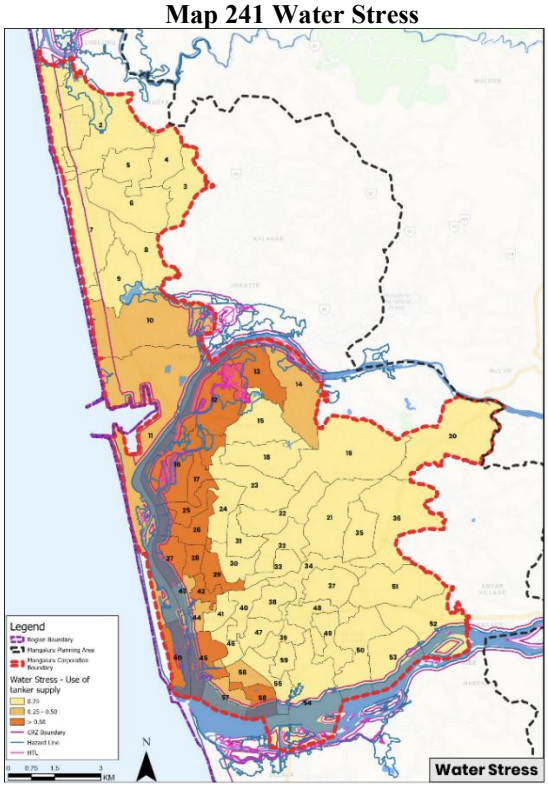


Source 336 Author

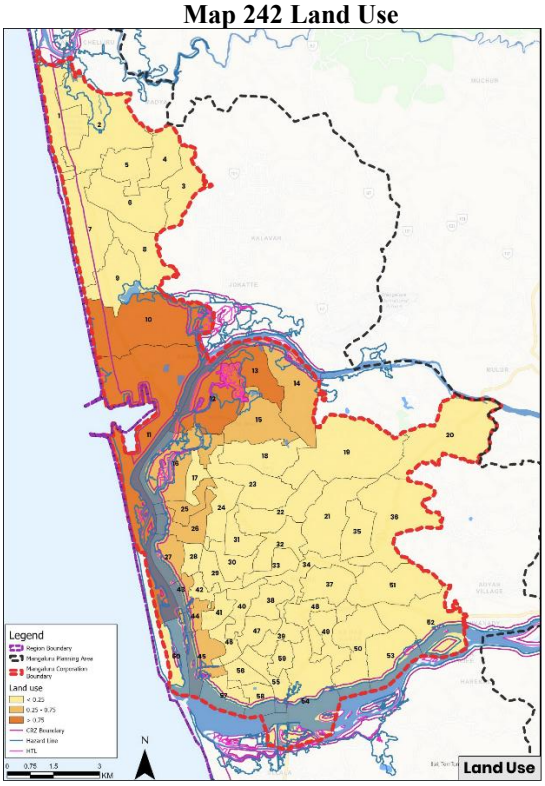
Map 240 Coastal Hazard



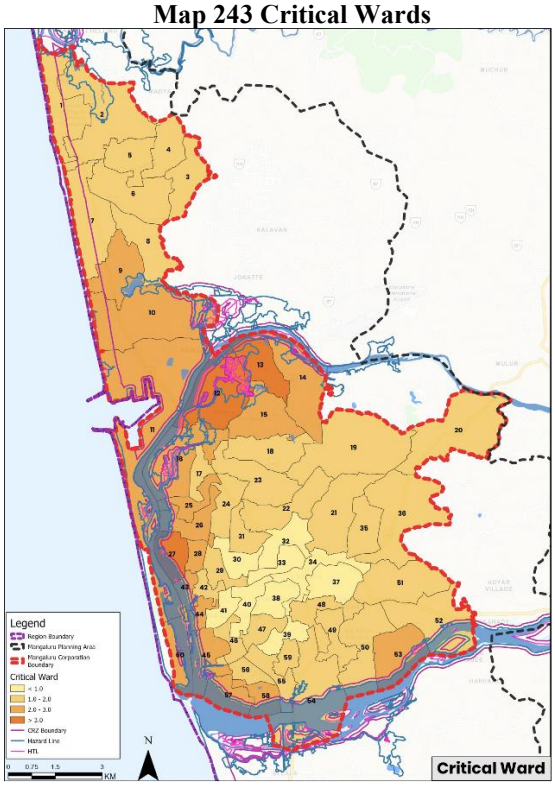
Map 241 Water Stress



Map 242 Land Use



Map 243 Critical Wards



Source 337 Author

- **Ward 11, 12, 13 and 27** are identified as critical wards.
- **Ward 13 and 27** score the highest, and hence chosen for further study

5.13 Critical Ward Analysis

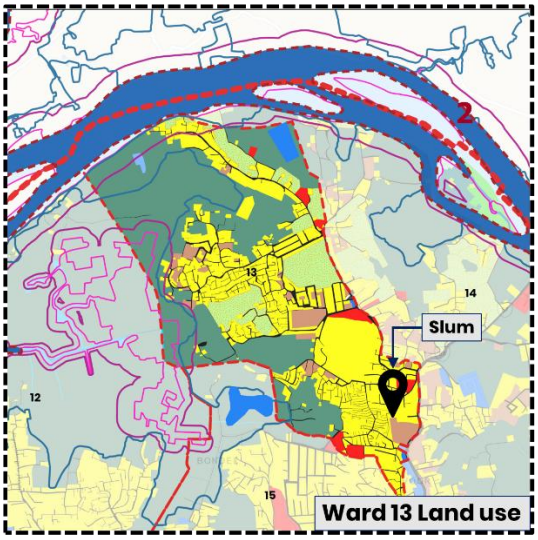
5.13.1 Ward 13

The ward has an area of 2.46 Sq.km. It lies on an average elevation of 35 M. The soil type is Sandy Clay Loam. The ward supports a population of 8615 as per Census 2011 with a population density of 35.16. The total number of Households in the ward is 1988. The work force participation rate (WFPR) is 44%. The total number of Agricultural workers in the ward is 18.

Economic activity: Largely Agricultural, irrigation via Ground water

Socio-economic aspect: **Jyoti Nagar Slum:** current population > **5000.**

Map 244 Land use of ward 13

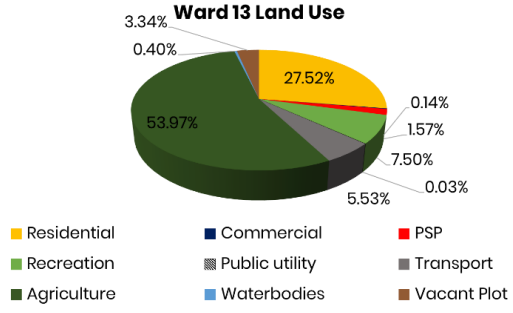


Source 338 Author

Table 92 Land use of ward 13

Ward 13	
Landuse	**Area Sq.Km**
Residential	0.68
Commercial	0.00
PSP	0.04
Recreation	0.18
Public utility	0.00
Transport	0.14
Agriculture	1.33
Waterbodies	0.01
Vacant Plot	0.08
Total	**2.46**

Figure 128 Land use share of ward 13



Source 339 Author

Issues identified in ward 13

1. **Physical infrastructure:** No sewerage network in the ward, Inadequate infrastructure in the slum for water supply, sanitation facilities, sewerage network and storm water drains
2. **Water Quality:** The water quality of **Gurupura River stretch** adjacent to ward 13 has **exceeding levels of BOD (5 mg/l) & COD (42 mg/l)** and falls **in DBU class D**, suitable for propagation or wildlife & fisheries. This is caused by the agricultural run-off, and organic pollution – Inlet of sewage
3. **Water Logging:** Water Logging is a concern as per primary house hold survey conducted – agricultural field inundate during monsoon – crop damage, soil erosion & economic loss.

5.13.2 Ward 27

The ward has an Area of 0.90 Sq.km. It lies on an average elevation of 15 M. The soil type is Sandy Loam. The ward supports a total population of 7077, with a population density of 52.03. The total number of households in the ward is1664 and the work force participation rate (WFPR) is 44.4%

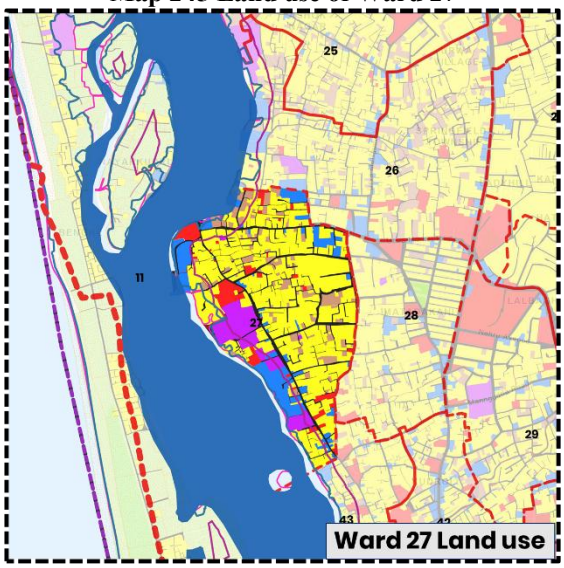


Economic aspect: HUL
Manufacturing unit – **ZLD**
from March 2024



Socio-economic aspect:
Largely residential area,
with MIG housing

Map 245 Land use of Ward 27

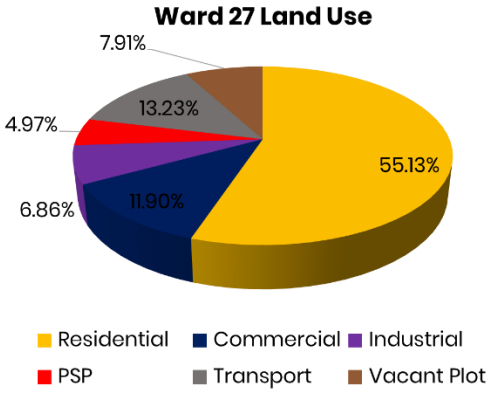


Source 340 Author

Table 93 Land use of Ward 27

Ward 27	
Landuse	**Area SqKm**
Residential	0.49
Commercial	0.10
Industrial	0.06
PSP	0.04
Transport	0.11
Vacant Plot	0.07
Total	**0.90**

Figure 129 Landuse share of ward 27



Source 341 Author

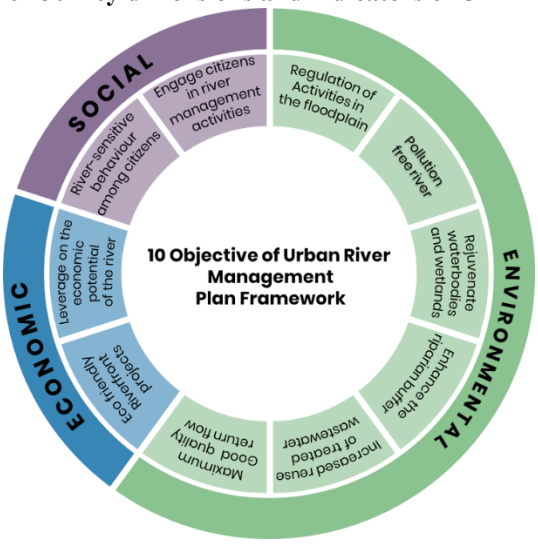
Issues identified in ward 27

1. **Physical infrastructure:** The stormwater network in the ward gets blocked with solid waste leading to fluvial flooding in the ward
2. **Water Quality:** The water quality of **Gurupura River stretch** adjacent to ward 27 has **exceeding levels of BOD (5.1 mg/l), and high Turbidity level** and falls **in DBU class D**, suitable for propagation or wildlife & fisheries. This is caused by the agricultural run-off, and sewerage inlet, industrial effluents from Baikampady industrial are.
3. **Water Logging:** Water Logging due to fluvial & pluvial flooding is a concern in the ward as per primary house hold survey.

5.14 Urban River Resilience Index (URRI)

Urban rivers are important in sustaining ecological integrity, supporting livelihoods, and enhancing the liveability of cities. To address the growing challenges faced by urban rivers, the **National Institute of Urban Affairs (NIUA)**, under the **National Mission for Clean Ganga (NMCG)**, has formulated the **Urban River Management Plan (URMP)** framework. The core of this framework is the **URMP Index**, which assesses urban rivers across **10 key indicators** covering Environmental, Social & Economic dimensions.

Figure 130 Key dimensions and indicators of URM Index



Source 342 Diagram developed by Author based on URMP

To assess and align the Gurupura river's status with the thematic indicators of the URMP, for targeted and structured planning interventions, the URM Index is calculated. Details of the calculation are included in the Annexure.

Table 94 URMP Monitoring indicators and the respective score for Gurupura River

URMP Monitoring Indicators		
No	**Indicator**	**Score**
1	Floodplain Management Score	1
2	Net Dissolved Oxygen Score	5
3	Water Body Revival Score	1
4	Riparian Buffer Score	2
5	Wastewater reuse score	1
6	Return flow score	4
7	Eco-friendly riverfront score	3
8	River economy score	5
9	Citizen sensitization score	1
10	Citizen engagement score	4
URM_{index}		**2.7**

Source 343 Developed by Author based on URMP

Table 95 Status of Gurupura River Management in Mangaluru city with respect to URM Index score

URM_{index}	Interpretation	What it means
<1.5	Poor level of urban river management	The city is incapable of meeting the basic requirements for effective urban river management. The river is neglected and used indiscriminately without proper planning and management. There are serious concerns for all dimensions of urban river management.
1.6-2.5	Elementary level urban river management	Basic actions required to ensure urban river management are evident. However, there are still major gaps and serious concerns with regards to almost all dimensions of urban river management.
2.6-3.5	**Average level of urban river management**	**The city has a satisfactory urban river management system. However, some dimensions of urban river management are still a cause of concern.**
3.6-4.5	High level of urban river management	The city is well-placed with most of the dimensions of urban river management. The dimensions may not be at par with each other, but the overall situation is still nonetheless satisfactory.
4.6-5.0	Ideal level of urban river management	The city is an ideal example of urban river management. There are evidences of exemplary actions against every dimension of urban river management, suggesting that the plans and policies in regards to urban river management are working well.

Source 344 URMP

Gurupura river shows average level of urban river management with a URM index score of 2.7. As per the scores calculated for each indicator, the city of Mangaluru lacks in addressing flood plain management, revival of waterbodies, reuse of waste water and citizen awareness.

While the URMP Index serves as a robust tool for cities across India, it is primarily designed for general urban contexts and does not yet incorporate resilience dimensions, especially those crucial in **coastal and climate-vulnerable settings**. As of now, there is no nationally recognized Urban River Resilience Index (URRI).

Recognising this gap, resilience indicators are identified to expand the existing version of the URMP Index, tailored for **coastal urban rivers** like the **Gurupura River in Mangaluru**. By adding three additional indicators under the domain of resilience the framework is reframed as **Urban River Resilience Index (URRI)**.

1. **CRZ Compliance**,
2. **Mangrove and estuarine habitat health**, and
3. **Urban flood resilience**

The proposed indicators and their desirable features with fixed score and the points earned by Mangaluru City is shown in the tables below.



Table 96 CRZ Compliance Score

Proposed Indicator 11: CRZ Compliance Score			
No	**Desirable feature**	**Fixed Score**	**Points earned**
1	All CRZ-I areas (like mangroves, salt marshes) are strictly protected with no violations	30	30
2	All permitted activities in CRZ-II (urbanized areas) have obtained necessary CRZ clearances	20	0
3	No unauthorized construction in CRZ-III	20	0
4	Presence of updated CRZ maps integrated into local planning documents	15	15
5	Citizen sensitization efforts on CRZ norms (signage, awareness drives)	15	0
Total		**100**	**45**
CRZ Compliance points = 40 - 59		**CRZ Compliance Score = 3**	

Table 97 Range of CRZ Compliance score

Proposed Indicator 11: The CRZ Compliance score is calculated as below:	
If CRZ Compliance points = > 80	CRZ Compliance Score = 5
If CRZ Compliance points = 60 - 79	CRZ Compliance Score = 4
If CRZ Compliance points = 40 - 59	CRZ Compliance Score = 3
If CRZ Compliance points = 20 - 39	CRZ Compliance Score = 2
If CRZ Compliance points < 20	CRZ Compliance Score = 1

Table 98 Mangrove and Estuarian Habitat Health score

Proposed Indicator 12: Mangrove and Estuarine Habitat Health Score			
No	**Desirable feature**	**Fixed Score**	**Points earned**
1	No net loss in mangrove area (year-on-year)	35	0
2	Presence of >75% native species among estuarine vegetation	15	15
3	Visible signs of healthy biodiversity (bird nesting, juvenile fish presence)	15	0
4	No solid waste or oil contamination in estuary	20	0
5	Community initiatives for mangrove conservation	15	0
Total		**100**	**15**
Mangrove and Estuarine Habitat Health Points < 20		**Mangrove and Estuarine Habitat Health Score = 1**	

Table 99 Range of Mangrove and Estuarian Habitat Health score

Proposed Indicator 12: Mangrove and Estuarine Habitat Health score is calculated as below:	
If Mangrove and Estuarine Habitat Health Points > 80	Mangrove and Estuarine Habitat Health = 5
If Mangrove and Estuarine Habitat Health Points 60 - 79	Mangrove and Estuarine Habitat Health = 4
If Mangrove and Estuarine Habitat Health Points 40 - 59	Mangrove and Estuarine Habitat Health = 3
If Mangrove and Estuarine Habitat Health Points 20 - 39	Mangrove and Estuarine Habitat Health = 2
If Mangrove and Estuarine Habitat Health Points < 20	Mangrove and Estuarine Habitat Health = 1

Table 100 Urban Flood Resilience score

Proposed Indicator 13: Urban Flood Resilience score			
No	**Desirable feature**	**Fixed Score**	**Points earned**
1	Flood forecasting system and early warning systems	30	30
2	Flood protection infrastructure (Levees, flood walls, etc)	20	0
3	100% coverage of storm water drains and sewerage	20	0
4	Flood insurance and financial support mechanism for recovery	15	0
5	Mapping of vulnerable population (Low-income communities, elderly, children and people with disabilities)	10	0
Total		**100**	**30**
Urban Flood Resilience points 20 - 39		**Urban Flood Resilience score = 2**	

Table 101 Range of Urban Flood Resilience score

The Urban Flood Resilience score is then calculated as below:	
If Urban Flood Resilience points > 80	Urban Flood Resilience score = 5
If Urban Flood Resilience points 60 - 79	Urban Flood Resilience score = 4
If Urban Flood Resilience points 40 - 59	Urban Flood Resilience score = 3
If Urban Flood Resilience points 20 - 39	Urban Flood Resilience score = 2
If Urban Flood Resilience points < 20	Urban Flood Resilience score = 1

Source 345 Author

Table 102 Score of additional URRI indicators

Proposed indicators for URRI		
No	**Indicator**	**Score**
11	CRZ Compliance Score	3
12	Mangrove and Estuarine Habitat Health Score	1
13	Urban Flood Resilience score	2
$URRI_{index}$ (Along with URM_{index})		**2.5**

Source 346 Author

Each indicator has a value between 1 and 5. An average of all the indicators results in URRI index

$$URR_{index} = (I1 + I2 + I3 + I4 + I5 + I6 + I7 + I8 + I9 + I10 + I11 + I12 + I13) / 13$$

Where I1 to I10 are URM index indicators, and I11 to I13 are the additional URRI indicators proposed.



Table 103 Status of Gurupura River Management in Mangaluru city with respect to URRI score

$URRI_{index}$	Interpretation	What it means
<1.5	Poor resilience of the urban river	The river ecosystem is highly vulnerable to environmental and climate-related stressors. There is minimal or no adaptive infrastructure or planning in place. Communities and biodiversity around the river are at risk.
1.6-2.5	**Low resilience of the urban river**	**Some preliminary efforts toward resilience are evident, but systemic gaps remain. Flood risk, pollution, and ecological degradation persist without long-term mitigation strategies.**
2.6-3.5	Moderate resilience of the urban river	The river shows signs of resilience with functioning infrastructure in some areas. However, inconsistencies exist in governance, ecosystem health, and flood resilience
3.6-4.5	High resilience of the urban river	The river is generally resilient with integrated risk management systems. Ecosystems are protected or restored, and urban systems show readiness for future stressors. However, occasional vulnerabilities remain.
4.6-5.0	Ideal resilience of the urban river	The river and its urban context are fully climate-adaptive and ecologically stable. Nature-based solutions are implemented, stakeholders are engaged, and disaster preparedness and response systems are robust and proactive.

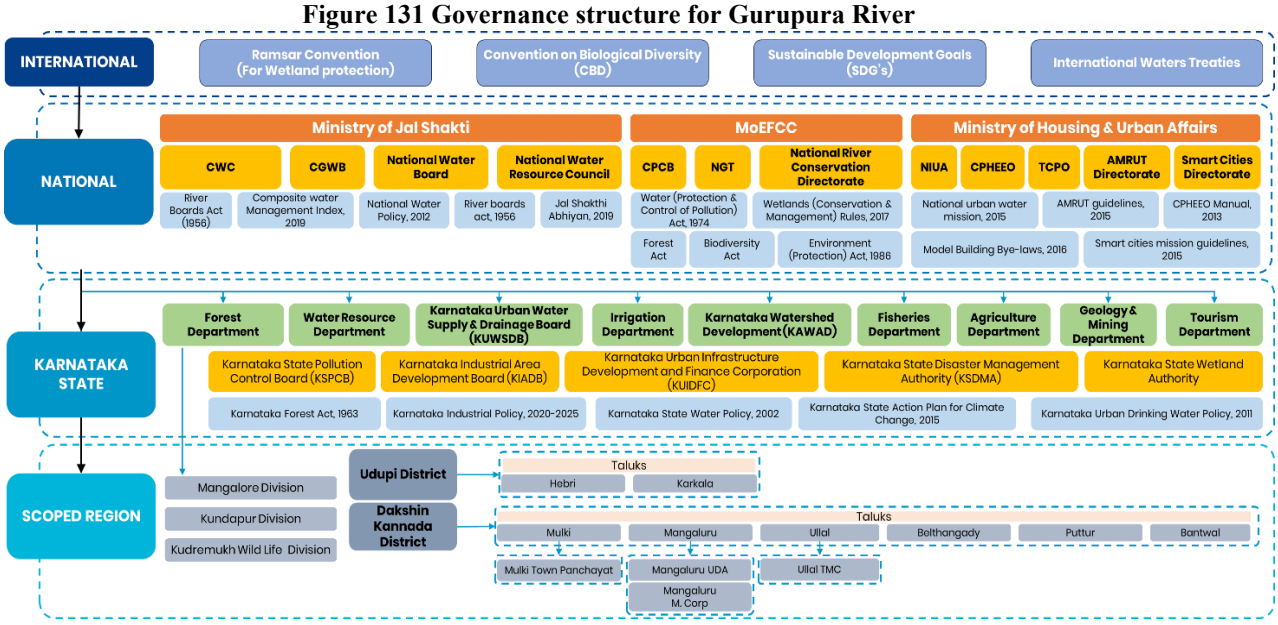
Source 347 Author, Adopter from URM Index scoring range

The URRI score of Mangaluru city is 2.5, which falls in the URRI range of 1.6 – 2.5, indicating low resilience of the urban river. The city needs strategies to mitigate flood, pollution and conserve the mangrove and estuarian ecosystem.

6. Governance

Successful management of the river involves not only technical interventions that are sound but also an effective governance system that can facilitate coordination across scales and sectors of administration. The chapter traces out the institutional complex that rules the Gurupura River, ranging from global environmental agreements like the Ramsar Convention and Convention on Biological Diversity, to ministries, regulatory authorities, and policies at both national and state levels, down to local government institutions in the Dakshin Kannada district. The institutional framework encompasses a broad set of stakeholders such as water resource departments, pollution control boards, urban development authorities, and biodiversity authorities whose mandates frequently overlap spatially along the river corridor but are not integrated.

Figure 131 Governance structure for Gurupura River

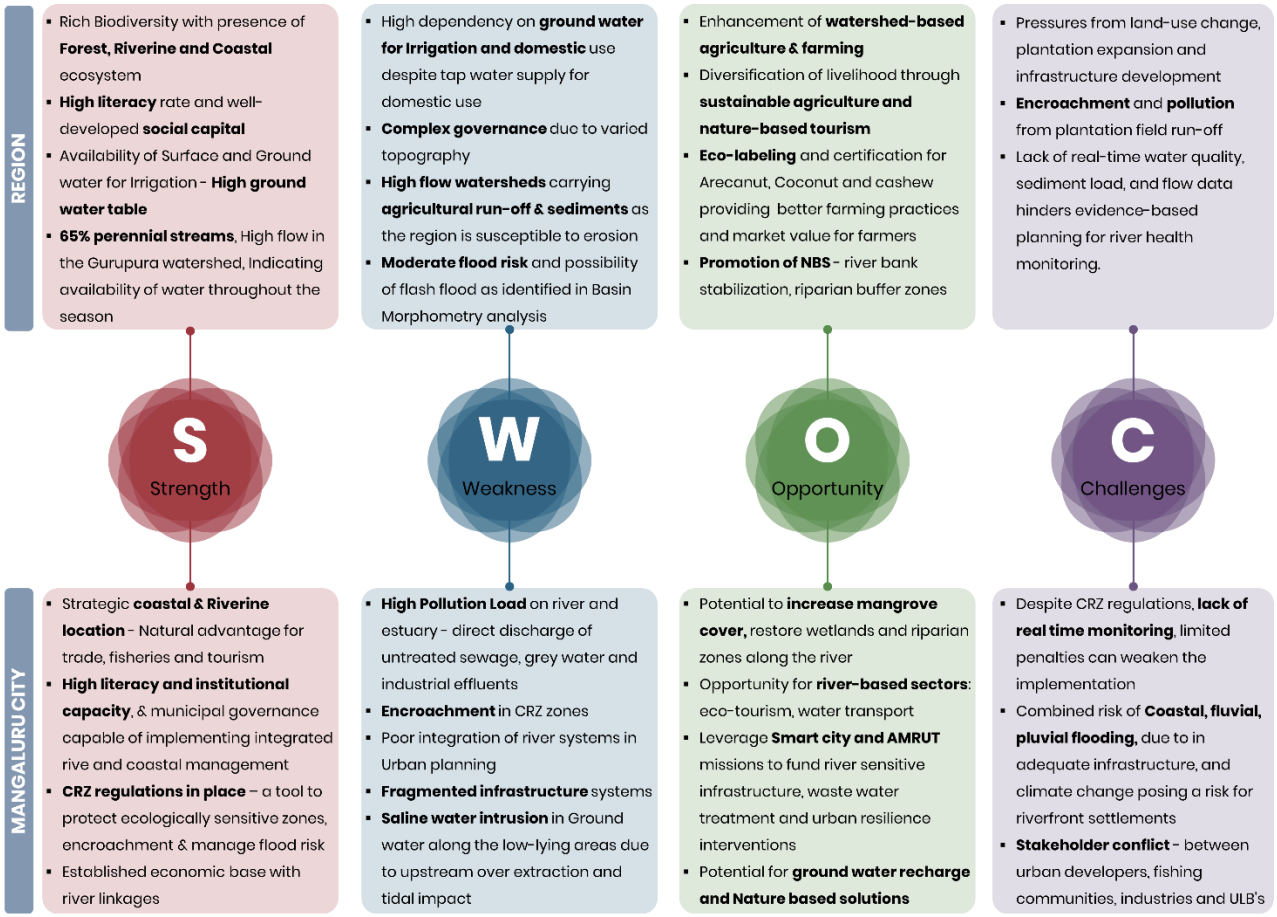


Source 348 Compiled by Author

7. SWOC

SWOC analysis is employed as a strategic tool for synthesizing the multi-scalar findings and locating the planning strategy of the Gurupura River. Through the identification of strengths, weaknesses, opportunities, and challenges at both regional and city scales, the analysis helps in recognizing the key ecological, infrastructural, and institutional processes that shape river well-being and management capability. This two-scale perspective is critical, as it both documents upstream watershed conditions and downstream urban pressures so that intervention priorities can be more clearly comprehended. These results directly inform proposal structuring so that river-sensitive strategies are aligned with ground realities, stakeholder capacities, and prevailing development pressures.

Figure 132 SWOC Analysis for the Region and Mangaluru City



Source 349 Author

8. Proposals

This chapter identifies a framework of environmental planning strategies to restore and responsibly develop the Mangaluru city considering the sensitive Gurupura River and its ecosystem, balancing ecological conditions with urban and regional development needs. Beginning with land suitability analysis which identifies land appropriate for ecological restoration, flood control, and compatible development, followed by population projections, which assist in approximating future land, water, and infrastructure demand, to ensure that the suggested strategies align to long-term growth patterns. Drawing from the multi-scalar baseline and analysis, proposals are framed at three scales: the region, planning area and the city scale A detailed project report (DPR) is prepared for a chosen intervention to illustrate technical feasibility and implementation framework. The chapter is concluded with an implementation framework that includes phasing, governance mechanism, integration with development plans, and a responsibility matrix to facilitate coordinated action among stakeholders.

8.1 Land Suitability

Land suitability analysis assists in the identification of the most suitable areas for specific interventions for development or conservation. here, it is utilized to inform river-sensitive planning by assessing where interventions such as flood buffers, ecological restoration, retrofits, regulations, and low-impact development can be optimally applied. The land suitability is done at Region and Planning Area scale which also encompasses the Mangaluru Municipal Corporation Area.

The analysis is founded on identified elements which are scored in a pair wise comparison matrix on a scale of 1 to 5, and normalized to arrive at a weightage for each layer, based on AHP method. The consistency for the matrix is check which if below 1 indicates consistency in scoring. The matrix was found to be consistent. The calculations are included in the Annexure.

Each layer is given a buffer around the considered feature for defining the suitability under 4 categories – No Development Zone (NDZ), Least suitable, moderately suitable, and highly suitable.

Table 104 Region - Normalized pairwise comparison matrix and weightage for each layer

Pair wise cmparision matrix – Normalised scores									
Parameter	Forest	Rivers	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Weighted average
Forest	0.33	0.39	0.38	0.31	0.32	0.25	0.26	0.21	31
Rivers	0.16	0.19	0.25	0.21	0.16	0.19	0.15	0.17	19
CRZ	0.11	0.10	0.13	0.21	0.16	0.19	0.15	0.17	15
Flood Susceptibility	0.11	0.10	0.06	0.10	0.16	0.13	0.15	0.13	12
Faults & Lineaments	0.08	0.06	0.06	0.05	0.08	0.13	0.10	0.13	9
Slope %	0.08	0.06	0.04	0.05	0.04	0.06	0.10	0.08	7
Major Roads	0.07	0.05	0.04	0.03	0.04	0.03	0.05	0.08	5
Railways	0.07	0.05	0.03	0.03	0.03	0.03	0.03	0.04	4
							Total		100.00

Table 105 Region - Buffers for suitability

Parameter	Suitability			
	NDZ	Least	Moderate	High
Forest	1 KM	5 KM	10 KM	> 10 KM
Rivers	100 m	200 m	500m	> 500m
CRZ	CRZ III NDZ, CRZ IA & 50 m Mangrove buffer, CRZ IB, CRZ IV B	CRZ III A & B	CRZ II	Areas outside CRZ boundary
Flood Susceptibility (FS)	Very high & High FS zones	Moderate FS Zones	Low FS Zone	Very Low FS Zone
Faults & Lineaments	< 100 m	100 - 200 m	200 - 300 m	> 300 m
Slope percentage	> 30 %	20 - 30%	10 - 20%	< 10%
Major Roads	50 m	50 - 150M	150 - 300 M	> 300 M
Railways	50 m	50 - 100 m	100 - 150 m	> 150 m

Table 106 Planning Area - Normalized pairwise comparison matrix and weightage for each layer

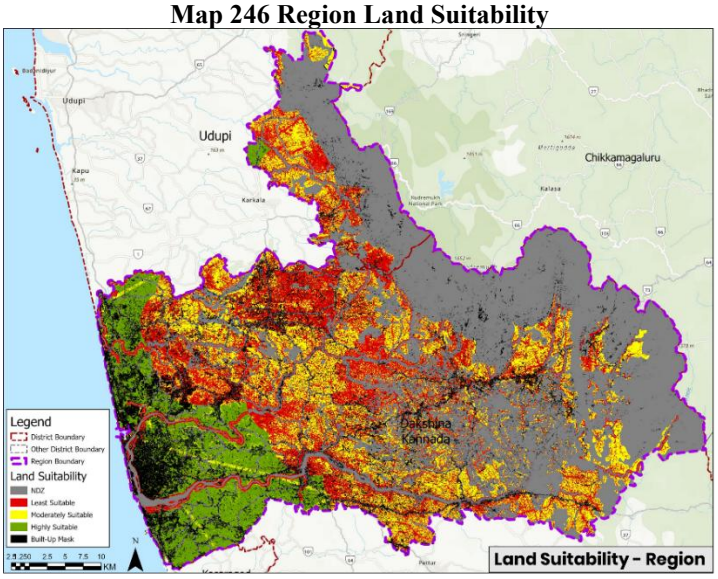
Pair wise comparision matrix – Normalised scores									
Parameters	Rivers	Waterbody	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Weighted average
Rivers	0.27	0.37	0.29	0.31	0.26	0.25	0.22	0.21	28
Waterbody	0.14	0.18	0.29	0.21	0.18	0.19	0.16	0.17	19
CRZ	0.14	0.09	0.14	0.21	0.18	0.19	0.16	0.17	16
Flood Susceptibility	0.14	0.09	0.07	0.10	0.18	0.13	0.16	0.13	12
Faults & Lineaments	0.09	0.09	0.07	0.05	0.09	0.13	0.11	0.13	9
Slope %	0.09	0.06	0.05	0.05	0.04	0.06	0.11	0.08	7
Major Roads	0.07	0.06	0.05	0.03	0.04	0.03	0.05	0.08	5
Railways	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.04	4
								Total	100.00

Table 107 Planning Area - Buffers for suitability

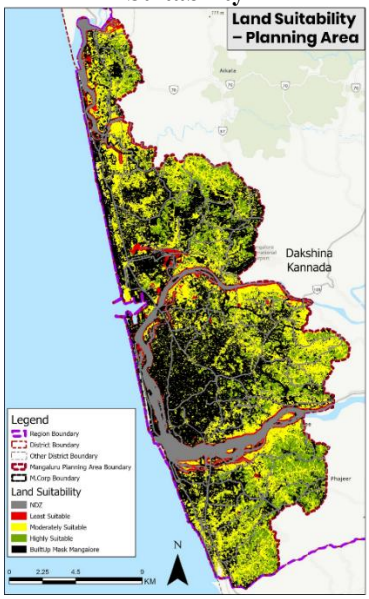
Parameter	Suitability			
	NDZ	Least	Moderate	High
Rivers	100 m	200 m	500m	> 500m
Waterbody	50 m	65 m	95 m	> 95 m
CRZ	CRZ III NDZ, CRZ IA & 50 m Mangrove buffer, CRZ IB, CRZ IV B	CRZ III A & B	CRZ II	Areas outside CRZ boundary
Flood Susceptibility (FS)	Very high & High FS zones	Moderate FS Zones	Low FS Zone	Very Low FS Zone
Faults & Lineaments	< 100 m	100 - 200 m	200 - 300 m	> 300 m
Slope percentage	> 30 %	20 - 30%	10 - 20%	< 10%
Major Roads	50 m	50 - 150M	150 - 300 M	> 300 M
Railways	50 m	50 - 100 m	100 - 150 m	> 150 m

Source 350 Author

Map 246 Region Land Suitability



Map 247 Planning Area Land Suitability



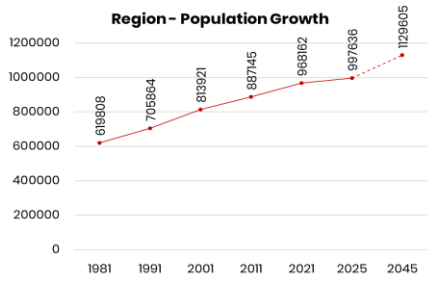
Source 351 Author

8.2 Population Projections

8.2.1 Region

The population in the **region** has grown in a Geometric trend, & projected population for the year **2045** is **11,29,605**

Figure 133 Region population projection

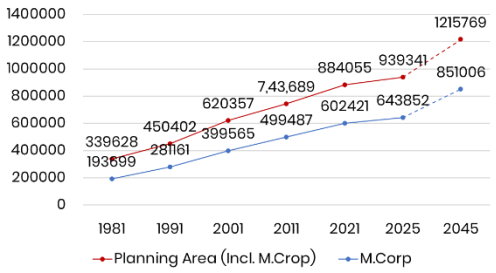


Source 352 Author

8.2.2 Mangaluru Planning Area

The population in the **Planning & Municipal Area** is observed to have a linear growth, therefore, **Arithmetic growth** method is used for Projections.

Figure 134 Mangaluru Planning Area Population Projection



Source 353 Author

8.3 Multi-scalar River Management Framework

In view of being able to adequately address the complexity of river systems as well as urban-rural interaction, it becomes imperative that multiple scales are engaged. The framework presented below shows synoptic strategies across region, planning area, and city scales classified into **policy, planning, and management.** At each scale, the strategy plans scale-specific interventions—ecological zoning and land use integration at the regional level, watershed-based planning and aquifer recharge at the planning area level, and infrastructure development and pollution management measures at the city scale. Integrated together, these activities stimulate a comprehensive river-sensitive approach to development which at the same time assists ecological well-being of river systems while contributing to water security and socio-economic resilience among communities.

Figure 135 Multi-scalar River Management Framework

REGION		
POLICY	**PLANNING**	**MANAGEMENT**
▪ Integrate eco-village guidelines into district rural development schemes. ▪ Mandate buffer zones along the river corridor (zoning restrictions for, agriculture, and construction).	▪ Develop eco-villages with water conservation, regenerative agriculture, & decentralized sanitation. ▪ Delineate & protect river corridor - land use plans & buffer zones.	▪ Implement riverbank vegetation restoration using native species. ▪ Support training for panchayat members on river monitoring and waste management.
PLANNING AREA		
POLICY	**PLANNING**	**MANAGEMENT**
▪ Restrict land use changes in flood-prone zones near the river. ▪ Introduce riverbank buffer guidelines in census towns' development controls.	▪ Prepare a **Watershed Management Plan** for integrated surface water and groundwater coordination. ▪ Development control regulations in flood prone areas.	▪ Map vulnerable areas and implement localized flood mitigation works. ▪ Decentralize greywater treatment and runoff management in towns.
CITY		
POLICY	**PLANNING**	**MANAGEMENT**
▪ Designate Critical Wards for focused interventions: pollution control, infrastructure upgrades, and eviction prevention. ▪ Enforce strict penalties for illegal discharges and encroachments near riverbanks.	▪ Restore mangrove patches and estuary edges to improve river health. ▪ Plan for riverfront open spaces in dense urban stretches with setback areas. ▪ Regulate industrial land use in river-adjacent zones with green buffers and effluent safeguards.	▪ Monitor & penalize industrial effluent discharge from Baikampady. ▪ Upgrade/expand sewerage networks and STPs to stop direct sewage disposal. ▪ Clear stormwater drains blocked by solid waste to reduce pluvial flooding.

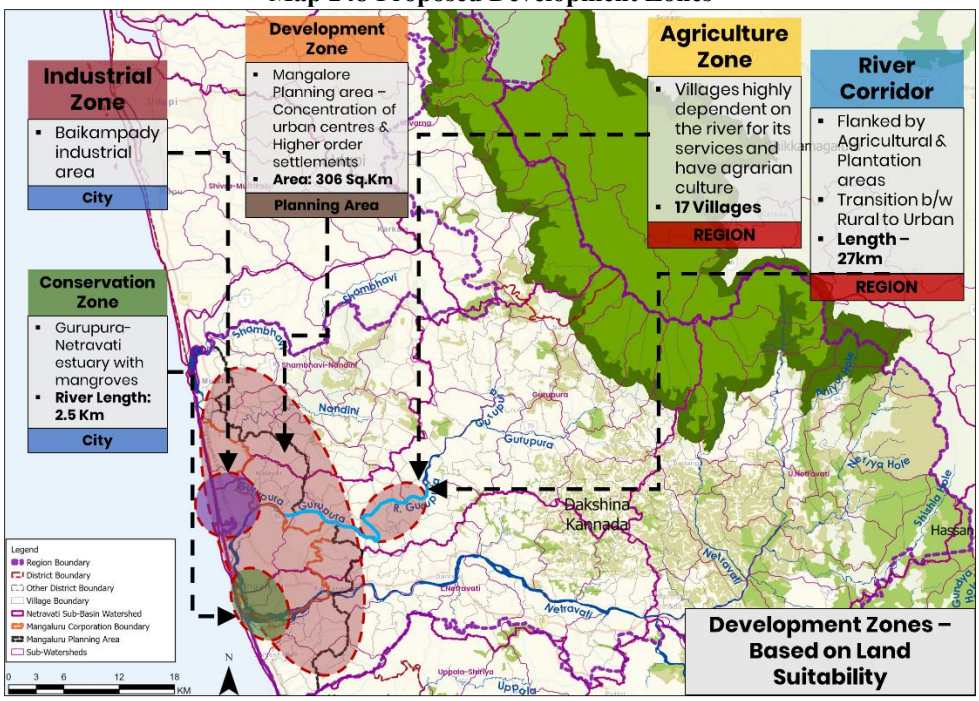
Source 354 Author



8.4 Development Zones

Based on the land suitability in the region and Planning Area, multiple Development zones are identified – which include Agriculture Zone, River corridor at region scale, New Development zone at Planning Area scale, Industrial Zone, and Conservation Zone in the city scale. Each of these are aimed at addressing specific environmental strategies that aligns with restoring the ecological health of Gurupura river.

Map 248 Proposed Development Zones



Source 355 Author

8.5 Region Proposals

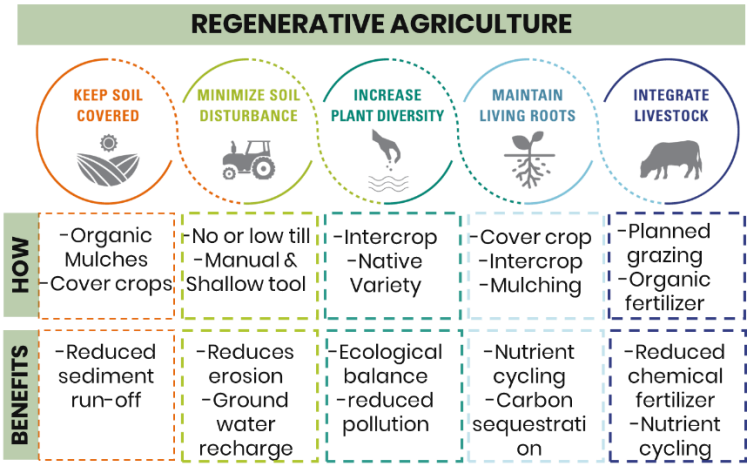
8.5.1 Agriculture zone

The proposals in this zone focuses on improving the agricultural practices and the livelihood of the agrarian society in the region, that ensures sustainable agricultural practices keeping the maintenance of river ecology as the prime focus.

Proposal 1 Regenerative agriculture

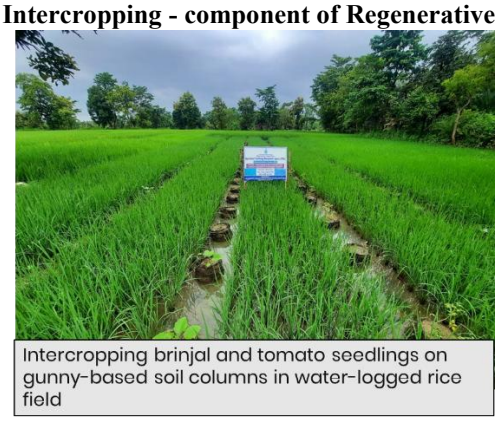
Regenerative agriculture is an integrated farming method that promotes soil health, biodiversity, and ecosystem resilience through methods like maintaining soil cover, reducing disturbance, promoting plant diversity, having living roots, and incorporating livestock. These techniques minimize erosion and runoff, enhance nutrient cycling, facilitate groundwater recharge, and aid in ecological balance and carbon sequestration.

Figure 136 Components of Regenerative Agriculture



Source 356 Compiled by author

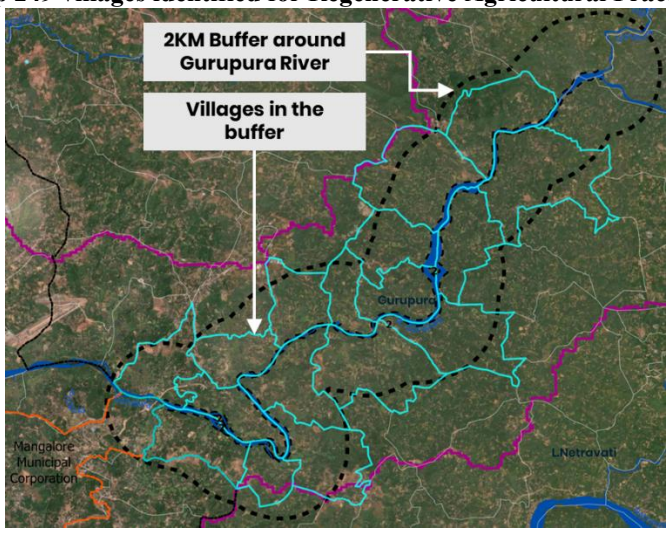
Figure 137 Intercropping - component of Regenerative Agriculture



Source 357 Author

The villages that fall in sub-watersheds within 2km buffer of Gurupura river are identified for promoting Regenerative agriculture.

Map 249 villages identified for Regenerative Agricultural Practices



Source 358 Author

To ensure minimal impact of agricultural practices and its run-oof into Gurupura River, River bank zoning can be adopted that allocated buffer along the river for various uses. Below is a schematic diagram that explains the river bank zoning in the identified villages

Figure 138 River bank zoning in identified villages to enusre minimal impact of agricultural run-off into the river



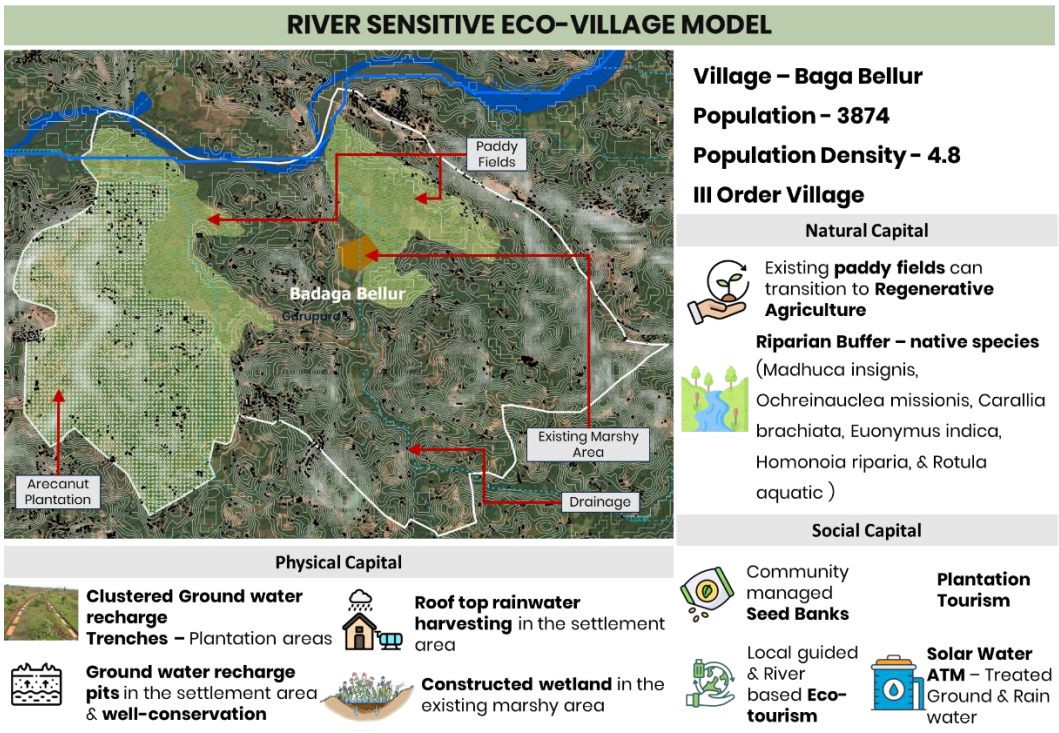
Riparian buffer	Perennial or seasonal cover cropping zones, No till & mulching	Flood inundated or seasonally water-logged
Intermediate Buffer	Intercropping & living root system	Flood prone Transition zone – riparian to agriculture
Agriculture Buffer	Minimal tillage Agro-forestry	Lesser flood risk Suitable for agriculture
Community pasture	Planned grazing & managed manure collection for compost	Shared open land Buffer to high traffic areas

Source 359 Developed by Author

Proposal 2 River Sensitive Eco-Village Model

An eco-village is rural settlement that combines ecological, social, and economic aspects of sustainability through locally derived solutions. It supports community engagement, conservation of the environment, and closed-loop use of resources, thus making villages climate and water-resilient.

Map 250 Conceptual plan for an Eco-Village



Source 360 Author

The river-Sensitive Eco-Village Model proposed for Baga Bellur, a 3rd-order village of 3,874 people, delves into this concept, responding to the Gurupura River's ecological sensitivities.

The interventions proposed align with improvements of livelihood capitals in the village.

Natural Capital:

Natural capital can be developed by converting existing paddy fields to regenerative agriculture and rehabilitating the riparian buffer with native vegetation

Physical Capital:

Enhancing groundwater recharge through clustered ground water recharge trenches in the plantation fields that are developed on the sloping terrain, constructed wetlands as a decentralised mode of waste water treatment, ground water recharge pits and conservation of existing wells in the village and Roof top rainwater harvesting can be investigated to develop the physical capital

Social Capital:

Livelihood diversification through community managed seed banks, plantation tourism, local guided & river based eco-tourism and Development of Solar water ATMs to treat and use ground water and rain water

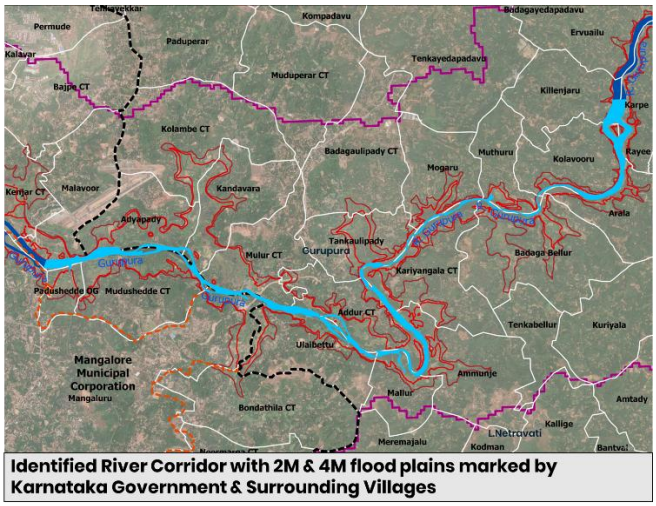
8.5.2 River Corridor

River Corridor Planning Proposal aims to restore and preserve the hydrological and ecological integrity of the Gurupura River by adopting a multi-scalar approach that engages both human and environmental systems along the river's trajectory. Recognizing the corridor as an ecologically active zone defined by floodplains, settlement patterns, and land use, the proposal formulates interventions at three planning scales—macro (at the corridor scale), meso (village/cluster), and micro (parcel/site).

Every scale is designed to fit specific landscape needs and socio-cultural contexts, integrating nature-based approaches such as riparian buffers, indigenous water harvesting techniques, and decentralized water management. The approach considers ecological continuity, raises resilience to flood and climate risks, and repositions the river not just as an environmental asset, but a coherent approach to sustainable development in rural-urban transitions along river banks.

Macro Scale: At **Macro-scale,** the River Corridor considers the 2-meter and 4-meter floodplains as demarcated by the Karnataka Government and village peripheries. This area is proposed as an unbroken ecological buffer ranging from 20 to 100 meters in width, varying according to local slope and land use, to protect hydrology flows and ecological connectivity.

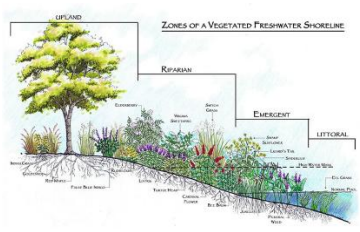
Figure 139 River corridor



Source 361 Author

Native and dense riparian plants like Ochlandra travancorica, Holigarna arnottiana, Homonoia riparia, and Rotula aquatic are given importance for bank stabilization through deep-rooted development, reducing erosion and preserving the natural composition of the riverbanks.

Figure 140 Riparian buffer and commonly found riparian species in the region





Source 362 Compiled by author

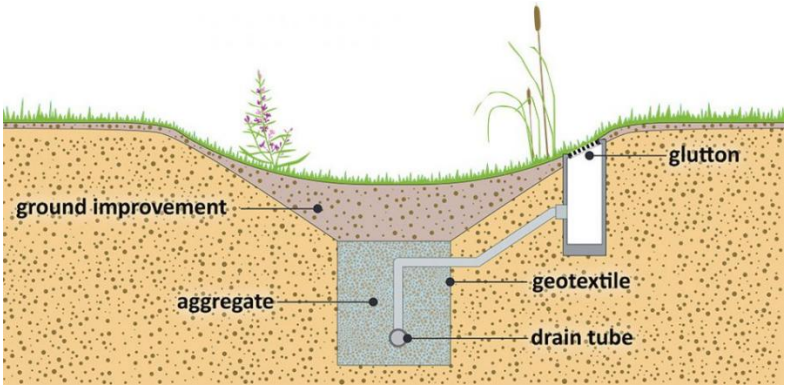
Land use control: Stringent land-use regulation measures are suggested, with the exclusion of new built-up areas in the corridor to negate surface runoff, soil erosion, and habitat fragmentation.

This corridor-scale approach serves as the underlying ecological backbone for any downstream initiatives, providing for the long-term sustainability and ecological integrity of the river system.

At the village or cluster (meso) level, the plan focuses on ecologically friendly planning measures that enhance water quality and rural resilience.

Bio-swales and phytoremediation are implemented at drainage or nala discharge areas to treat greywater by filtering it, thus reducing pollution into the river via village runoff.

Figure 141 Bio-swale



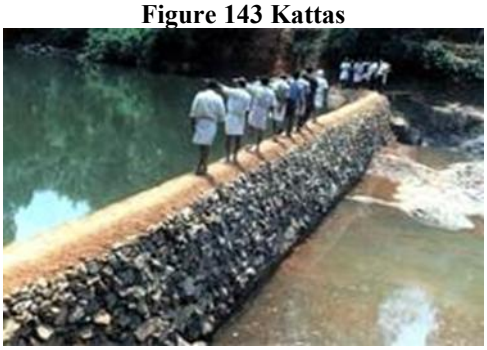
Source 363 urbangreenbluegrids

Development control regulation: To match the regional architectural style and minimize environmental footprint, development control norms require local low-impact materials like laterite blocks and Mangalore tile roofs, discouraging concrete constructions.

Figure 142 Farm ponds



Figure 143 Kattas



Source 364 Compiled by author

In addition, traditional water harvesting methods like farm ponds and kattas are rejuvenated. The farm ponds facilitate irrigation and recharge of groundwater, and the kattas—seasonal mud and stone dykes—arrest post-monsoon flow and biodegrade with the onset of the next monsoon. The combined interventions span traditional knowledge and contemporary resilience planning to increase the ecological and hydrological robustness of the river corridor.

At the parcel or micro site (micro) scale, specific targeted ecological measures are defined to mitigate water and land use issues within the region while simultaneously enhancing adaptive capacity of riparian ecosystems.

Bio-fencing is proposed along defined buffer zones of rivers and wetlands and at the outskirts of villages acts as a natural barrier to encroachment and livestock trespass.

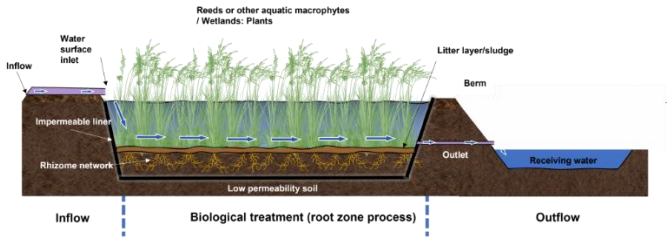
Figure 144 Bio-fencing



Source 365 Author

Constructed wetlands are proposed as decentralized treatment systems to improve water quality and enhance nutrient cycling as part of the region's wastewater treatment strategy.

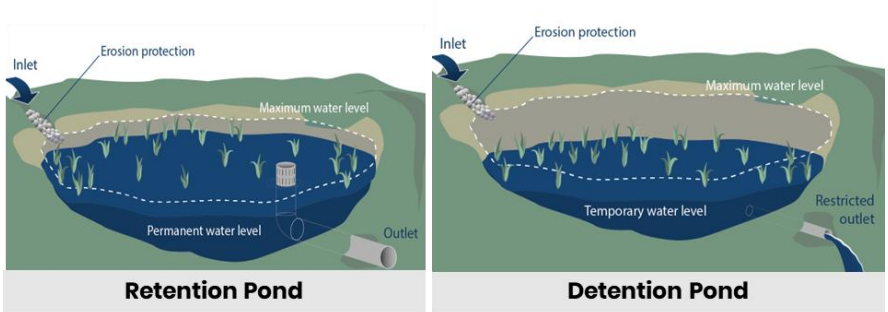
Figure 145 Constructed wetland



Source 366 Compiled by author

Decentralized retention and detention ponds for stormwater are located within plantation areas bordering the riverbank to control rainfall runoff and mitigate flood risks. These systems assist in capturing flash floods and surplus rainfall while recharging groundwater.

Figure 146 Retention & detention ponds

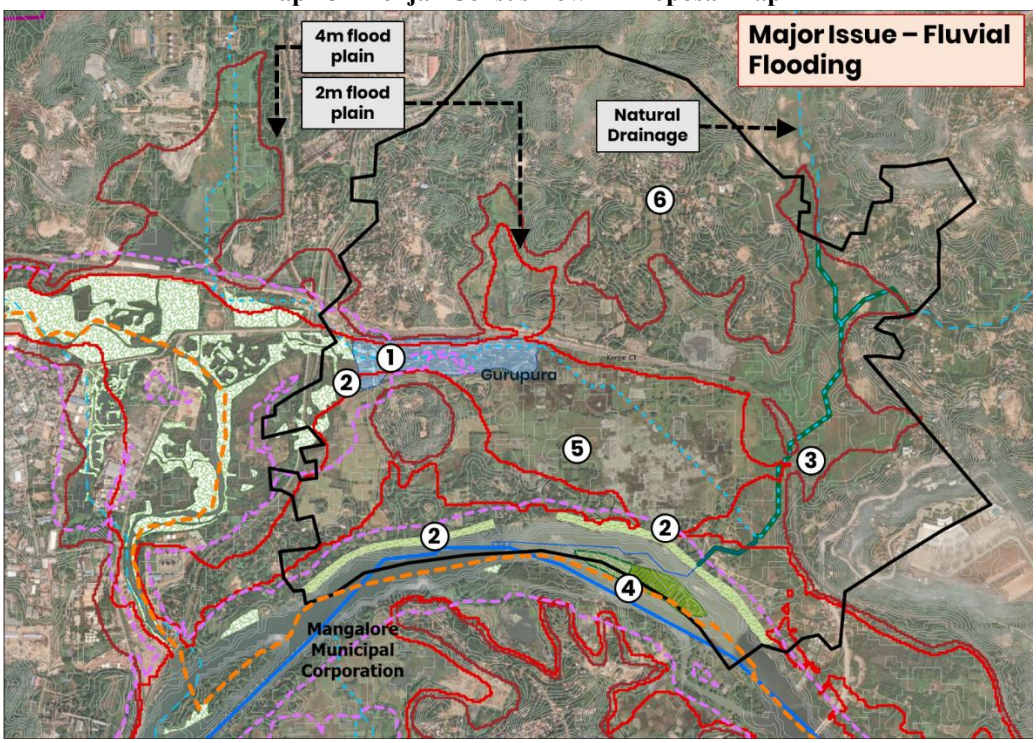


Source 367 Retention & detention facilities, futurelearn

8.6 Planning Area Proposals

The proposal focuses on a census town of a high flood-risk sub-watershed, selected because it is strategically located and regularly faces fluvial flooding. The town has a population of 5,338 individuals in a 6.88 sq.km area and relies heavily on floodplain farming, which, although productive, is increasingly vulnerable because of changing hydrological conditions. The proposal makes provisions for integrated interventions to enhance climate resilience, restore ecological buffers, and strengthen community-based livelihoods. Strategic interventions involve the promotion of tidal fish ponds, mangrove conservation, eco-drainage trails, and tidal wetland parks, drainage and sewerage improvement, early warning systems, and context-specific land use regulation. These interventions are anticipated to balance development with natural processes, safeguarding lives and livelihoods from the vagaries of climate uncertainties.

Map 251 Kenjar Census Town - Proposal map



Source 368 Author

1. Brackish Aquaculture Zone for Livelihood

Tidal fish pond is proposed in low-lying or brackish water zones. These ponds are used for cultivating species such as shrimp, milkfish, and mud crabs, providing an alternative livelihood for local farmers and fishermen. The approach integrates sustainable aquaculture with flood resilience by utilizing areas prone to periodic tidal inundation.

2. Mangrove Flood Buffer

To mitigate flood impact and enhance ecological resilience, this intervention involves **conserving existing mangroves** and **planting native mangrove species** along vulnerable riverbanks and floodplains. Mangroves act as natural barriers by slowing water flow, reducing wave energy, and trapping sediments, and hence, protecting inland areas from erosion and flooding.

Figure 147 Fish ponds



Figure 148 Mangrove belt



Source 369 Compiled by author

3. Eco-Drainage Trails Linking Uplands to River

This includes two complementary strategies:

1. **Bio-swales** are proposed along natural drainage lines to capture and filter runoff, reduce surface flooding, and support groundwater recharge through vegetated infiltration.
2. **Linear Parks** are proposed alongside natural drains, ensuring they remain unobstructed while providing recreational space for the residents. These parks discourage built-up development in sensitive zones.

4. Tidal Wetland Park

A nature-based public space proposal, the Tidal Wetland Park features mangrove plantation and conservation zones integrated with visitor access. It includes bamboo boardwalks, birdwatching towers, and interpretation centers for public awareness. Managed by local communities and SHGs, it promotes eco-tourism while preserving biodiversity.

5. Saline-prone Land Use Regulation

Although the area is not currently salinity-prone, but is located along a tidally influenced waterbody, this proposal is a precautionary measure for future climate risks such as sea-level rise or storm surges. The recommendations include avoiding conventional agriculture in vulnerable low-lying areas, Pilot agro-labs (in collaboration with NIT Surathkal) to demonstrate salt-tolerant crops, multi-variety plantations, and medicinal halophytes that could thrive if salinity issues emerge over time, Shallow Dug Wells & Managed Aquifer Recharge for Irrigation: This groundwater management strategy promotes **shallow dug wells** for localized water storage and **aquifer recharge pits** to enhance groundwater levels. These systems provide **reliable irrigation** during dry periods, making agriculture more climate-resilient without over-extraction.

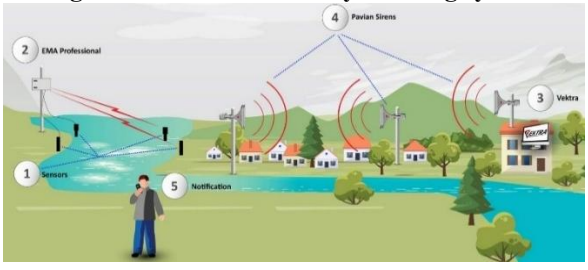
6. Drainage & Sewerage Network

This proposal aims to ensure **100% coverage of the town with modern drainage and sewerage infrastructure**, especially critical in flood-prone zones. Efficient water conveyance systems will prevent waterlogging, improve sanitation, and reduce health hazards during monsoons.

7. Early Warning System

To enhance disaster preparedness, this proposal includes installation of flood sensors and real-time monitoring systems, Dissemination of alerts via SMS, sirens, and digital platforms and flood signage and clearly marked safe evacuation routes to support quick response during extreme events, ensuring community safety.

Figure 149 Schematic early warning system

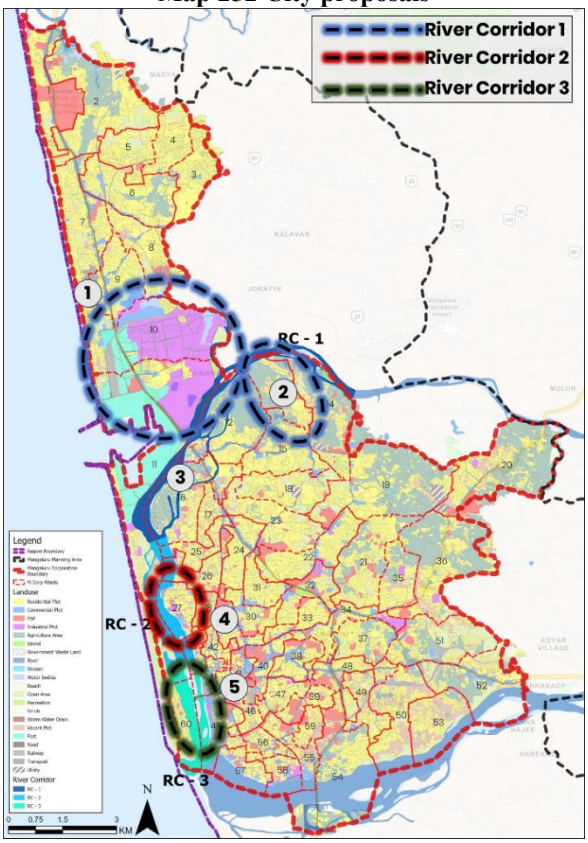


Source 370 Compiled by author

8.7 City Proposals

The city-scale proposals for Mangaluru aim to address the challenges of rapid urbanization, industrial expansion, and increasing climate vulnerabilities across its three river corridors identified – RC 1, RC 2, RC 3

Map 252 City proposals



Source 371 Author

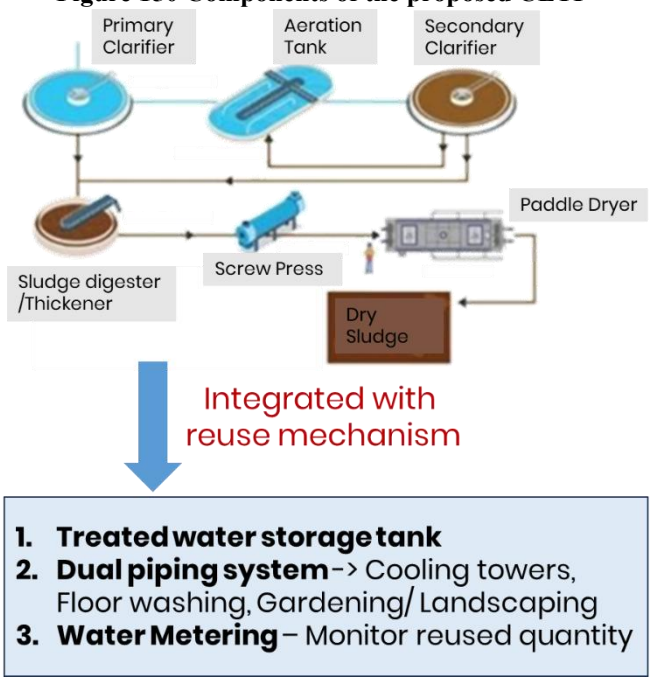
8.7.1 River corridor 1

River corridor 1 is identified as **High Impact Stretch:** Covers the agricultural & industrial belt -> Class D (DBU) indicating high pollution & limited use.

1. Industrial Area proposals

Common effluent treatment park: A 3 MLD CETP is proposed, based on Moving Bed Biofilm Reactor (MBBR) technology with a paddle dryer, to treat effluents from multiple small and medium enterprises (SMEs). Key features include sludge management and energy recovery through the paddle dryer, treated water is reused through a dual piping system for non-potable uses like cooling towers, gardening, floor washing, and flushing, treated water storage tanks and water metering systems ensure efficient reuse and accountability.

Figure 150 Components of the proposed CETP

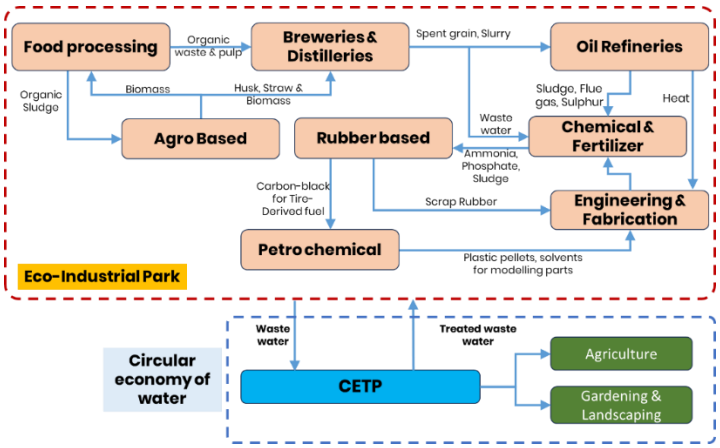


Source 372 Compiled by author

Eco-industrial park

To move towards a circular economy model, the proposal is to convert Baikampady into an Eco-Industrial Park, where industries co-ordinate to optimize resource sharing, waste reuse, and energy efficiency through industrial symbiosis. This means the by-products and waste from one industry (e.g., biomass, sludge, steam) become inputs for another (e.g., agro, chemical, brewery). This reduces waste disposal, lowers costs, and significantly cuts down environmental impact. Treated wastewater can support **urban agriculture, landscaping, and nursery development** in adjacent areas.

Figure 151 Industrial Symbiosis concept applied to some industries in Baikampady



Source 373 Author

Industrial Categorization and zoning restrictions

The establishment of any new industries in Baikampady must adhere to the **Zoning Atlas approach** for environmentally sound industrial siting. KIADB currently permits the operation of **Orange category industries** in the area, future industrial development should be restricted to **Green, White, or blue category industries**. This is essential to prevent the introduction of additional polluting units and to safeguard the **ecologically sensitive Gurupura River ecosystem**.

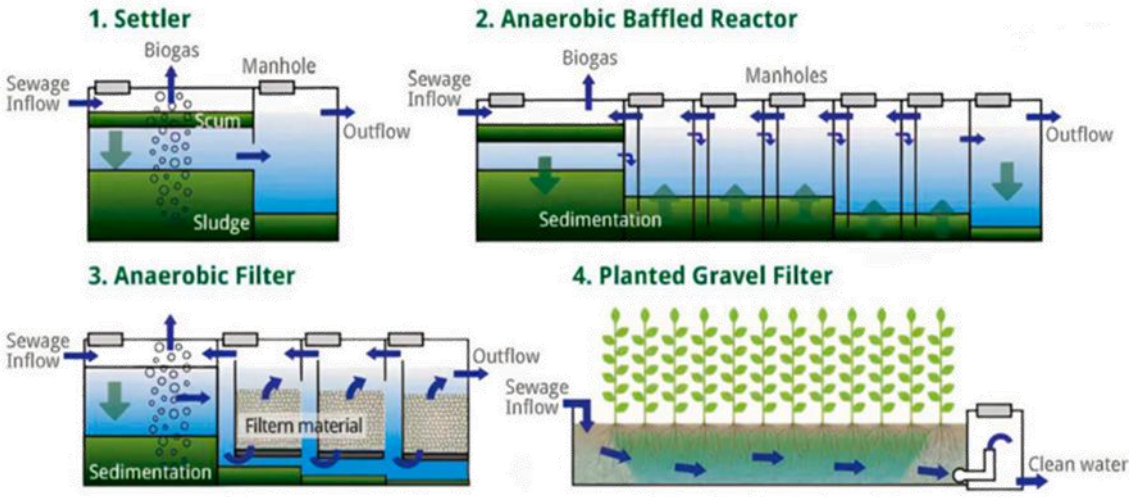
2 Proposals for Ward 13

Ward 13 in Mangaluru has been identified as a critical ward which is a **flood-prone, and low-lying urban pocket**, where poor drainage, informal housing, and a lack of basic infrastructure have compounded the impacts of seasonal flooding and environmental degradation. The proposals aim to build **climate resilience, reduce flood risk, and enhance the quality of life** for its residents through a combination of decentralised infrastructure, slum upgrading, and nature-based solutions.

Decentralized wastewater treatment systems – DEWATS

The ward lacks sewerage network, and hence DEWATS (Decentralised Wastewater Treatment Systems) is proposed with the following components: A treatment capacity of up to 1 MLD, designed using settlers, anaerobic baffled reactors (ABR), planted gravel filters, and polishing ponds, DEWATS operate at low cost and require minimal electricity, making them ideal for community-scale systems. Treated water can be reused for landscaping, flushing, or groundwater recharge, reducing dependency on freshwater and mitigating pollution loads.

Figure 152 Components of DEWATS



Source 374 A review on decentralized wastewater treatment systems in India

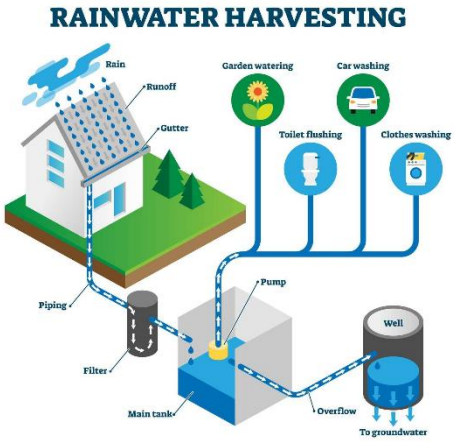
Permeable Paving & Rainwater Harvesting

To manage stormwater and reduce surface flooding in the ward, the recommendations include **Permeable pavements** are proposed for internal roads and pathways to **improve infiltration**, especially in areas with clayey soil and **Rainwater harvesting** will be mandated in **public buildings** and encouraged in private plots to capture excess monsoon water and reduce runoff pressure on drains.

Figure 153 Permeable paving for internal roads



Figure 154 Rain water harvesting for public buildings in the ward



Source 375 Compiled by author

Slum upgradation

A slum improvement strategy is proposed, with upgrades in drainage, sanitation, and housing quality. Provisions for elevated plinth levels, robust flooring, and safe drinking water access will reduce health risks during flood events. Community toilets and greywater reuse systems can be integrated with DEWATS for decentralized sanitation solutions.

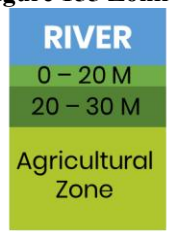
Livelihood support

To ensure community engagement and economic resilience programs to support **nursery development**, **mangrove maintenance**, and **green belt upkeep** is proposed as alternate/additional source of income for the slum dwellers.

3 Zoning strategy for agricultural area

A **buffer-based land-use zoning** is proposed to create **protective ecological belts** within agricultural zones, especially in areas adjoining riverbanks, wetlands, and natural drainage paths. The zones proposed as shown in the image below.

Figure 155 Zoning strategy proposed for agricultural area within Mangaluru city



Phytoremediation buffer	Wetland plants,	Plants that can uptake excess nutrients and tolerate waterlogging.
Intermediate Buffer	Mixed native tree species + understory plants	Recharges soil, adds biodiversity
Agriculture Zone	Regenerative agriculture	Salt tolerant crops, reduced chemical usage

Source 376 Author

This zoning diagram outlines a **three-layered buffer strategy** for managing agricultural lands adjacent to rivers, with the aim of improving **soil and water quality, biodiversity.**

Phytoremediation Buffer (0–20 m from river): This zone is planted with wetland species that can absorb excess nutrients, filter pollutants, and tolerate periodic waterlogging. It acts as the first line of defense, protecting the river from agricultural runoff and stabilizing the riverbank.

Intermediate Buffer (20–30 m from river): Comprising native trees and understory plants, this zone supports biodiversity and improves soil moisture retention. It serves as a transition area that enhances ecological connectivity while reducing the impact of farming on the river ecosystem.

Agriculture Zone (Beyond 30 m)

This is the main cultivation area, where regenerative agricultural practices and salt-tolerant crops are promoted to ensure sustainability and reduced chemical usage. It supports food production while minimizing environmental degradation through soil restoration.

The Soil Type is Clayey indicating poor drainage and low aeration. Suitable plants that can grow in the buffer areas is presented in the table below

Figure 156 Plants for Phytoremediation zone

Plant	Suitability
Vetiver grass	Deep roots adapt to heavy soils
Canna indica	Good for nutrient-rich runoff
Typha angustifolia	Tolerates waterlogging & clayey substrate
Ipomoea carnea	Fast-growing and flood-tolerant
Bamboo species	Grows in compact soil

Source 377 Compiled by Author

The native species that can be planted I the intermediate buffer are as follows:

Native Trees: Terminalia arjuna (Arjun tree), Syzygium cumini (Jamun), Azadirachta indica (Neem), Ficus benghalensis (Banyan)

Shrubs & Grasses: Lemon grass, Vetiver, Lantana camera (controlled), Cassia spp.

8.7.2 River corridor 2

River Corridor 2, which traverses through **Ward 27**, prioritizes nature-based solutions to address urban flooding, restore green cover, and enhance climate resilience at the ward level. The key interventions for the **ward 27** include

1. Rainwater harvesting

Promoting rainwater harvesting systems across **public buildings, schools, and group housing** to reduce surface runoff and enhance groundwater recharge. This also builds local water resilience during dry seasons.

2. Green and Biodiverse Roofs

Incentivizing green roof installations with native and pollinator-friendly plant species on rooftops of residential and commercial buildings. These roofs reduce urban heat island effect, delay runoff, and improve biodiversity within built areas.

Support mechanisms for green and bio-diverse roofs can include Tax rebates for compliant property owners, Inclusion in local building bye-laws (e.g., PMAY housing), Technical assistance from the Urban Local Body (ULB).

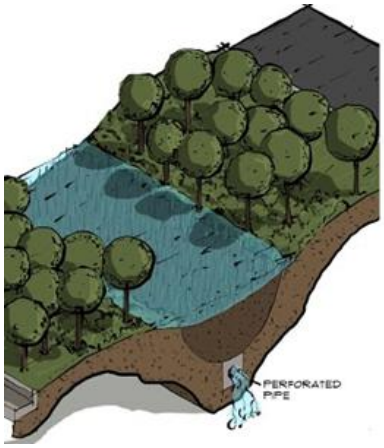
Since most buildings in Mangaluru have sloping roof owing to its heavy rainfall conditions, it is necessary to consider measures necessary for slope angle, new build or a retro fitment to an existing building. Plant species also have to be considered accordingly.



3. Bio-swales along Impervious Surfaces

Constructing **bio-swales** along road medians, sidewalks, and around open spaces to intercept and filter stormwater. These vegetated channels reduce local flooding, slow water flow, and enhance infiltration into subsoil layers.

Figure 157 Bio-swale

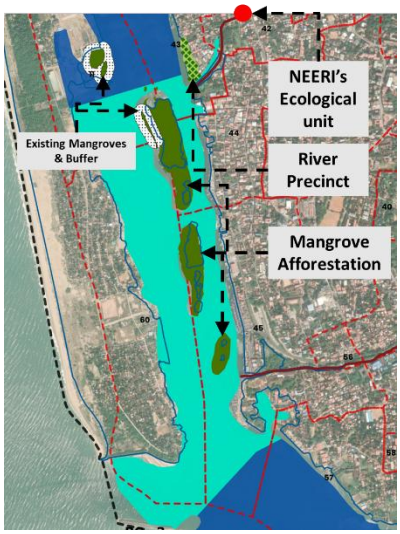


Source 378 Author

8.7.3 River corridor 3

River Corridor 3 lies in the coastal stretch of Mangaluru, where the focus is on ecological restoration and conservation of sensitive riverine and mangrove ecosystems. This corridor experiences frequent fluvial & pluvial flooding and ecological degradation due to urban pressures, necessitating targeted nature-based solutions. The proposed interventions aim to restore the river's ecological balance, conserve mangroves through community participation, and safeguard the corridor's biodiversity and natural drainage functions.

Map 253 Proposals for River corridor 3



Source 379 Author

1 Eco-restoration strategies

The eco-restoration strategy for River Corridor 3 centers on mitigating pluvial flooding and improving water quality through nature-based and engineered ecological solutions. The proposed intervention is NEERI's ecological units that provide in-situ treatment for stormwater drains. These units comprise a series of natural filters—screen and grit traps, phytotraps, biomats, and wetland plants that work together to trap solid waste, allow sedimentation, and promote bacterial growth to break down organic matter. This layered filtration system not only removes physical and chemical pollutants but also controls algal growth and helps maintain ecological balance in the river.

Figure 158 NEERI's ecological unit



Source 380 NEERI

2 Mangrove Conservation and Afforestation

This proposal aims to strengthen the fragile estuarine ecosystem by restoring degraded mangrove areas and promoting sustainable use through active community engagement and regulatory measures.

Conservation Strategies: Focused on reducing ecological stress and protecting existing mangrove habitats through the regulatory actions that include **Removal of artificially created islands** within the river that disrupt natural flow and sedimentation, **Ban on fish net drying** in mangrove zones to prevent vegetation damage, **No plastic zone** to eliminate plastic pollution in sensitive estuarine areas and **Prohibition on motorized boats** in core conservation areas to minimize disturbances to aquatic and avian life.

Afforestation Strategies: Targeting degraded or sparsely vegetated patches using native species and soil improvement measures such as **Soil remediation** techniques to support healthy root growth and microbial activity and **Plantation planning** in consultation with ecological experts and local community knowledge.

Figure 159 Suggested Mangrove species for afforestation



Source 381 Compiled by author

Community-Based Management to Ensure long-term protection and maintenance by involving local institutions:

Active involvement of Local **fishermen communities**, SHGs (Self Help Groups), **ULBs** (Urban Local Bodies) and funding agencies for technical and financial support. **Capacity building** and training programs can be implemented to develop stewardship and monitoring skills, **Volunteering incentives** to encourage long-term community participation.

Mangrove Tourism & Awareness: Balancing conservation with education and livelihood support through eco-tourism infrastructure which includes elevated **boardwalks** for nature walk without disturbing the habitat, **Observation decks** for birdwatching and tidal ecology interpretation, **Signage and displays** to enhance awareness of mangrove functions and species.

Figure 160 Bamboo board walk in a Mangrove Park

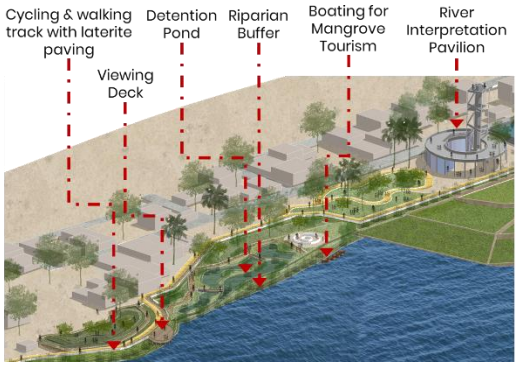


Source 382 Author

3 River Precinct

The River Precinct proposal visualizes the transformation of a 2-hectare area along the riverfront into an ecologically resilient and socially engaging public space. This multifunctional green buffer aims to serve both environmental and recreational purposes while enhancing flood resilience and promoting community awareness of river ecosystems.

Figure 161 River precinct visualization



Source 383 Author

Key Features of the River Precinct:

1. Riparian Buffer with Native Grasses:

Establishment of a green buffer zone planted with **Vetiver Grass**, **Napier Grass**, and **Bermuda Grass**. These species are selected for their deep root systems that stabilize soil, filter runoff, and reduce erosion along the riverbank.

2. Multi-use Public Space:

Integration of **cycling and walking tracks** to promote non-motorized transport and healthy lifestyles. **Viewing decks and open seating areas** are included to encourage people to connect with the river landscape.

3. Stormwater Management Infrastructure:

Incorporation of **detention ponds** and **floating wetland units** to slow down and filter surface runoff before it enters the river. These features support water quality improvement and reduce pluvial flooding risk.

4. Recreational and Educational Tourism:

Provisions for **boating** and **interpretive signage** to support eco-tourism, especially **mangrove tours** and **biodiversity walks**. The space serves as a demonstration site for sustainable riverfront development, integrating **ecological learning** and public engagement.

8.7.4 City wide strategies

The City-Wide Strategies for Mangaluru focus on ensuring water security and climate resilience by addressing future demand, closing service gaps, and enhancing wastewater treatment and reuse. They also integrate nature-based solutions like green buffers, rain gardens, and wetlands to improve groundwater recharge and revival of lakes in the city.

1. Water supply

The gap in water supply for the year 2045 is calculated, which shows adequate supply of water with 5.53 MLD in surplus which is 252.64 LPCD.

Table 108 Water supply gap

	2045	Remark
Population	851006	
Demand		
Domestic (135 LPCD)	114.89	CPHEEO Standard
Non-Domestic	36.01	Source: MCC
Fire demand	3.36	Source: MCC
Bulk Demand	20.30	Source: MCC
Total demand	**174.56**	
20 % Loss	**34.91**	NRW
Total demand + 20% Loss	**209.47**	
Source	**Thumbe Dam (MLD)**	
Mangaluru WSS 1st Stage, 1965	10	
Mangaluru WSS 3rd Stage, 2012	80	
Source	**Adyar Dam (MLD)**	
Proposed 24/7 WSS	125	Up to 2046
Total Water Supply	**215**	
Gap	**+ 5.53**	Water surplus

Source 384 Author

However, the proposal here is to bring down the non-revenue water from 20% to 10%. The strategies for which include conducting Water Audit & Leak Detection, Infrastructure upgrades by replace aging or leaking pipelines, introduce pressure management systems, Institutional Measures such as building capacity in the ULB for NRW management, incentivize leak reporting, ensure metering & billing compliance.

2. Waste water treatment

80% of water supply considered for waste water generation quantity and the treatment gap is calculated for the year 2045.

Table 109 Waste water treatment gap

	2045
Waste water generated	167.57
STP	
Surathkal STP	16.5
Kavoor	43.5
Pachanady	8.75
Bajal	20
Total	**88.75**
Gap	**-44.76**

Source 385 Author

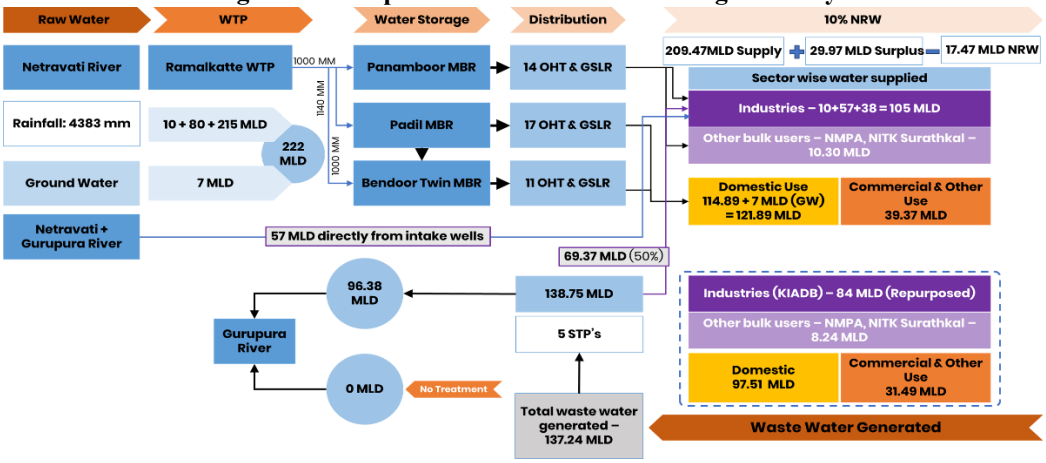
Intervention Strategies

100% Sewerage network coverage in all wards and a **50 MLD STP** to be proposed to address the treatment gap (buffer **capacity of ~5 MLD**, accommodating **peak flows** in Monsoon)

3. Water balance

The proposed water balance captures the reduction in NRW and the addressed waste water treatment gap, bringing down the discharge of untreated waste water into the Gurupura River to Zero. The water balance also suggests repurposing of 50% treated water of STP for industrial use hence reducing the quantity of treated waste water as well, into Gurupura river.

Figure 162 Proposed water balance for Mangaluru city



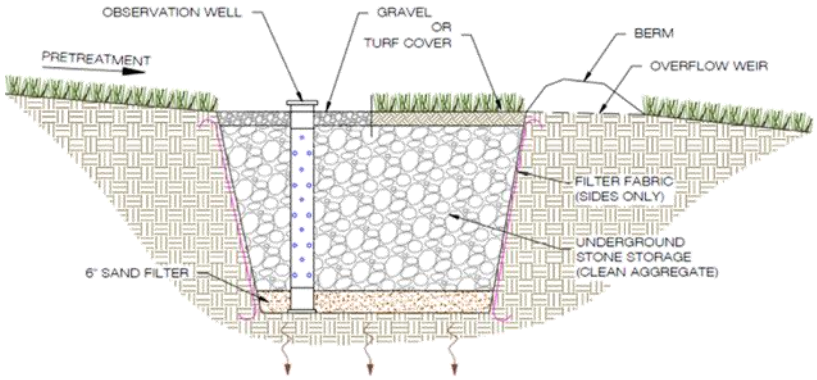
Source 386 Author

4. Ground water recharge strategies

Shallow trenches, typically 1–2 meters deep and 0.5–1 meter wide, are proposed which are simple yet effective structures for stormwater management and groundwater recharge. Filled with layers of coarse sand, gravel, and pebbles, these trenches facilitate the infiltration of rainwater while filtering out sediments and pollutants.

These are to be strategically placed along the edges of parks and sidewalks, they help reduce surface runoff, prevent waterlogging, and support the replenishment of aquifers. Integrating them into urban landscapes enhances climate resilience, improves soil moisture, and contributes to sustainable water management in built environments.

Figure 163 Section of ground water recharge trench



Source 387 Compiled by Author

5. Revival of water bodies

A 50-meter buffer is to be maintained around all the lakes and ponds in the city to ensure sustenance of the lakes that play a vital role in the city's hydrology. Rain gardens can be developed in these buffers to soak excess run-off and allow infiltration. **Constructed wetland** to be developed for inflow channels draining into lakes

Figure 164 Rain Garden section

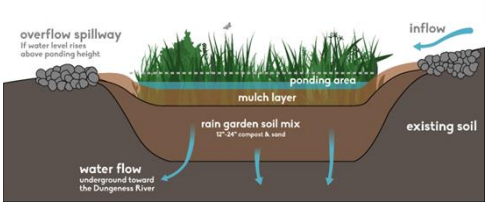
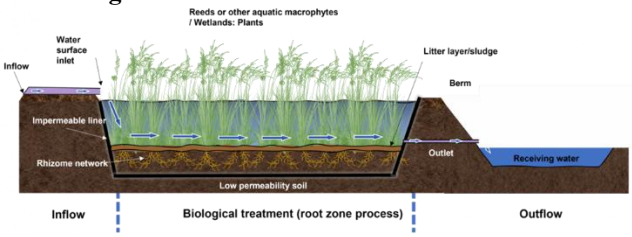


Figure 165 Section f constructed wetland

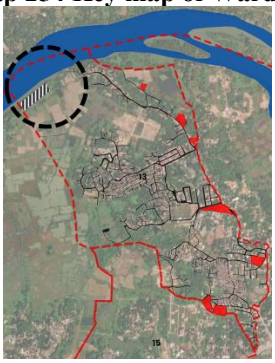


Source 388 Compiled by author

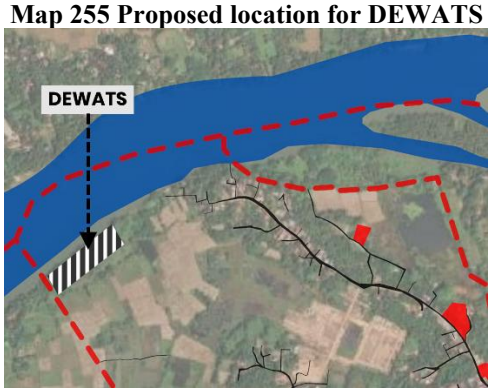
8.8 Detail Project Report (DPR) for DEWATS

The Detailed Project Report (DPR) outlines the proposal for establishing a Decentralized Wastewater Treatment System (DEWATS) with a treatment capacity of 1 Million Liters per Day (1 MLD) in Ward 13 of Mangalore city. Situated on a 0.7-hectare plot along the Gurupura River, the project is designed to serve a population of approximately 8,615, including a slum area currently lacking access to basic sanitation facilities. The DEWATS approach focuses on sustainable, low-energy, and low-maintenance wastewater management using natural treatment processes. By employing a series of biological and physical treatment modules, the system aims to improve local sanitation, enhance public health, and support urban water resilience while offering environmental and social co-benefits.

Map 254 Key map of Ward 13

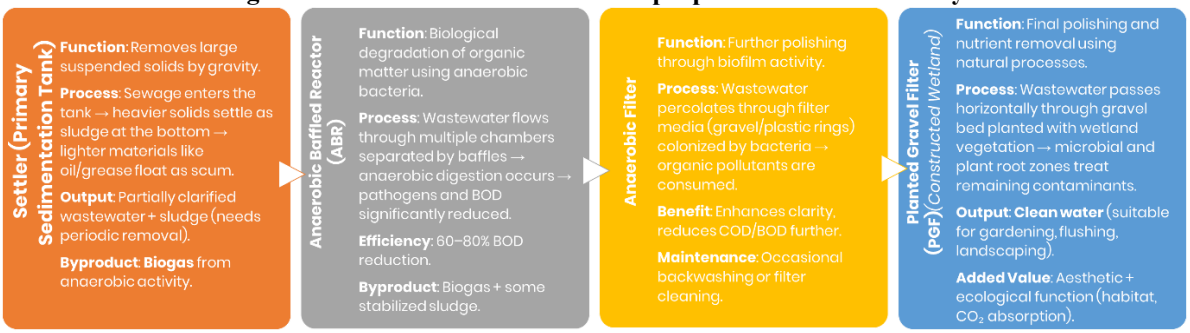


Map 255 Proposed location for DEWATS



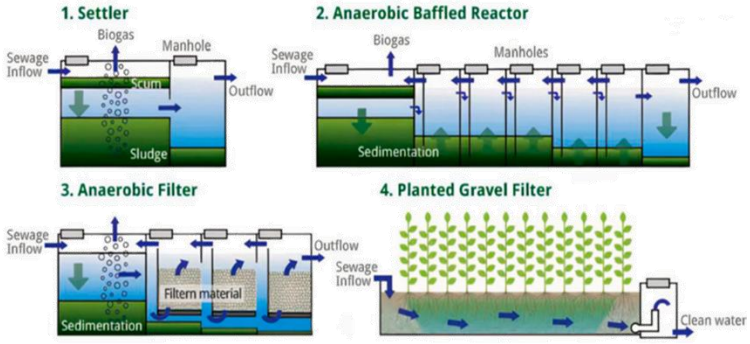
Source 389 Author

Figure 166 Treatment modules of the proposed DEWATS facility



Source 390 Author

Figure 167 Components of DEWATS



Source 391 A review on decentralized wastewater treatment systems in India

The financial components and revenue mechanisms are also investigated.

Table 110 Total project cost

S. No	Component	Unit Cost	Estimated Cost (INR)
1	**Land Development & Site Preparation**	₹17–20/sq.m (for 7,000 sq.m)	₹12,00,000
2	**Settler Tank (Primary)**	₹1.8 lakh per 100 KLD	₹18,00,000
3	**Anaerobic Baffled Reactor (ABR)**	₹2.5 lakh per 100 KLD	₹25,00,000
4	**Anaerobic Filter**	₹2 lakh per 100 KLD	₹20,00,000
5	**Planted Gravel Filter (PGF)**	₹400–500/sq.m (6,000 sq.m area)	₹30,00,000
6	**Plumbing, Pumps, Piping**	₹10/litre/day capacity	₹10,00,000
7	**Instrumentation, Valves, Flow Meters**	₹4/litre/day capacity (shared)	₹4,00,000
8	**Plantation for PGF (wetland plants)**	₹50–75/plant (6000 plants approx.)	₹3,00,000
9	**Boundary Wall + Landscaping**	₹1100–1300 per Rm	₹8,00,000
10	**Misc. Civil Works (manholes, footpaths)**	Lumpsum	₹5,00,000
11	**Contingency (5%)**	5% of project cost	₹6,75,000
	Total		₹1,41,75,000

Source 392 Author

Table 111 Funding and Subsidies

Funding Source	%	Amount (INR)
AMRUT 2.0	50%	₹70,87,500
SBM 2.0	30%	₹42,52,500
KUIDFC (State Fund)	10%	₹14,17,500
ULB (Net Cost)	**10%**	**₹14,17,500**
Total	100%	₹1,41,75,000

Source 393 Author

Table 112 Annual O & M costs

Item	Description	Cost (INR/Year)
Labour	3 operators (round-the-clock)	₹6,00,000
Electricity	Pumps, lighting	₹1,20,000
Sludge Management	Dewatering/desludging every 6 months	₹1,00,000
Maintenance	Spare parts, chemicals	₹80,000
Monitoring & Testing	BOD/COD, turbidity, Fecal coliform	₹60,000
Total O&M/Year		**₹9,60,000** (~₹10 lakh/year)**

Source 394 Author

Table 113 Revenue Mechanisms

Stream	Description	Potential Income
Treated Water Sale	₹15/KL for construction/gardening use	₹4.5–5 lakh/year
CSR-Based O&M Support	Tie-ups with local industries	₹5–10 lakh/year
Carbon Credits / ESG Branding	Offset via emissions reductions	Long-term value
Green Certification & SDG Score	Improves city-level environment index	Non-monetary value

Source 395 Author

Table 114 Impact summary

Parameter	Before Project	After DEWATS
Wastewater Treated	~0 KLD	1,000 KLD
Households Benefitted	0	5,000–7,000
Surface Water Contamination	High	Reduced
Flood Risk	Medium	Lowered via infiltration
Operational Energy	High (if STP)	Low (gravity/biogas)
Community Engagement	Limited	Participatory O&M

Source 396 Author

The suggested species that can be planted in the planted gravel filter is presented in the table below.

Table 115 Species for Planted gravel filter module

Botanical Name	Common Name	Function
Phragmites karka	Common Reed	Fast-growing, excellent root aeration
Typha latifolia	Cattail	Strong root system, removes nutrients like nitrogen & phosphorus
Cyperus papyrus	Papyrus	Effective in sediment stabilization and aesthetics
Canna indica	Indian Shot	Beautiful, absorbs heavy metals
Colocasia esculenta	Taro/Arbi	Broad leaves, water-loving
Vetiveria zizanioides	Vetiver Grass	Sludge stabilizer, deep roots prevent clogging
Scirpus spp.	Bulrush	Tolerant to polluted water, pathogen reduction

Source 397 Compiled by Author

The timeline for the completion of the project is estimated to be 1 year. The Gantt chart for the phasing of the project is presented below.

Table 116 Project timeline - Gantt chart

Activity	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12
Land Acquisition & Clearances												
Detailed Project Report (DPR)												
Funding Approvals & Tendering												
Site Development & Excavation												
Civil Works - Settler & ABR												
Civil Works - Anaerobic Filter & PGF Bed												
Plumbing, Electrical & Instrumentation												
PGF Plantation & Landscaping												
Commissioning & Testing												
Staff Training & Handing Over												

Source 398 Author

8.9 Phasing & Governance

The implementation of the proposed interventions requires a phased and well-coordinated governance strategy. The framework outlines short-, medium-, and long-term actions across regional, planning, and city scales to ensure systematic development and effective outcomes. The proposals are structured across four timelines—1 year, 2–5 years, 5–10 years, and beyond 10 years—enabling gradual scale-up, continuous monitoring, and adaptive management. Each proposal aligns with relevant national acts, policies, and schemes, and is supported by dedicated funding streams from both public and private sources.

The approach emphasizes participatory planning, integration with existing master plans, and convergence with ongoing missions such as AMRUT 2.0, RURBAN, MGNREGA, and CAMPA, fostering synergy across sectors and stakeholders for inclusive and resilient urban development.

Table 117 Phasing & Governance

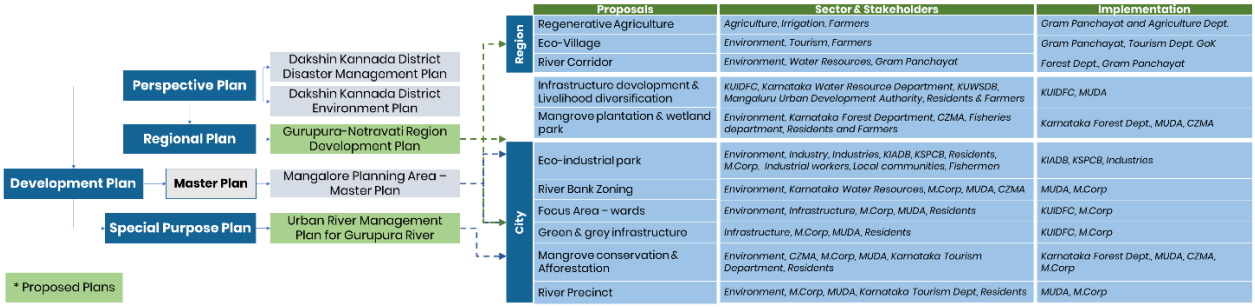
	Proposals	1 Year	2 - 5 Year	5 - 10 Year	> 10 Year	Acts/Policies/Schemes	Funds
Region	Regenerative Agriculture	Framers outreach & training	Pilot projects, scale-up in target villages	Region wide transition to regenerative model		Soil health cards, Parampoaragat Krishi Vikas Yojana (PKVY)	ICAR, MoA&FW, PM-KISAN, NABARD's AgriSURE, SKDRDP
			Implementation on agriculture fields across Gurupura River Basin				
	Eco-Village	Village identification, workshops with farmers	Implementation & monitoring progress	Capacity building for livelihood diversification & transition to eco-village	Scaling up with multiple eco-villages in Gurupura Watershed	RURBAN Mission, Jal Sakthi Abhiyan, MGNREGA	RURBAN, CSR, International climate adaptation grants
	River Corridor	Demarcating riparian buffer and integrating in Regional Plan, Training for Traditional Water Harvesting techniques.	Riparian zone plantation by Community, Implementation of sustainable solutions	Monitoring & removal of invasive species		National River Conservation Plan, CAMPA	RURBAN, CSR, CAMPA, Panchayat funds
Planning Area	Infrastructure development & Livelihood diversification	Natural drain mapping, workshops for aquaculture, Pilot agro lab	Implementing soft infrastructure, testing salt tolerant crops, MAR & shallow dug wells for irrigation	Development of physical infrastructure	100% Sewer network coverage	Atal Bhujal Yojana, Jal Shakti Abhiyan, AMRUT 2.0	MoWR, SDRF, ULB funds, CSR
	Mangrove plantation & Wetland park	Awareness & training for mangrove afforestation, selection of species	Implementation & Monitoring of progress	Maintenance & monitoring		CRZ Notification 2019, NMCG, Wetland guidelines 2020	MoEFCC, NMCG, State Fisheries department, CAMPA
City	Eco-Industrial Park	Integrating Eco-Industrial park into City Master Plan & site plans of proposed industries	Implementing & monitoring progress	Achieve 40% Target	Achieve 80% Target	NGT Guidelines, CPCB ETP norms, AMRUT 2.0	KIADB, AMRUT, Industries (PPP)
	River Bank Zoning	Integrating into master plan, Implementation	Achieve 40% Target	Achieve 80% Target		NMCG, CRZ, RRZ, Water Act, 1974	NMCG, AMRUT 2.0, Smart cities mission, Forest Department
			Implementing & monitoring progress				
	Focus area – wards (13 & 27)	Awareness & workshops for residents	Implementation & Monitoring program	Maintenance & monitoring		NUSP, Swachh Bharat Mission (SBM), Building bye-laws	SBM, ULB, Development bank fundings, CSR
	Green & Grey infrastructure	Augmentation & Implementation	Implementing & monitoring progress	Achieve 40% Target	Achieve 80% Target	SBM, AMRUT 2.0, Smart Cities Mission, URDPFI	AMRUT 2.0, ULB, KUIDFC
	Mangrove Conservation & Afforestation	Awareness & training for mangrove afforestation, selection of species	Implementation & Monitoring of progress	Achieve 40% Target	Achieve 80% Target	CRZ Notification 2019, NMCG, Wetland guidelines 2020	MoEFCC, NMCG, State Fisheries department, CAMPA
				Maintenance & monitoring			
	River Precinct	Integration in local area plan	Implementation & achievement – 100%			URMP, CRZ, Waterfront development guidelines - MoHUA	NMCG, AMRUT 2.0, Smart cities mission, ULB, CSR

Source 399 Author

8.10 Development plan integration

To ensure long-term impact and coordination, the proposals are integrated into existing and proposed development plans at multiple levels—regional, planning area, and city. This includes alignment with key documents like the **Master Plan for Mangalore**, the **Gurupura-Netravati Region Development Plan**, and the **Urban River Management Plan** for the Gurupura River. Each proposal connects with relevant departments and stakeholders, such as the Gram Panchayat, Mangalore City Corporation, KUIDFC, MUDA, and environmental agencies. By embedding these initiatives into formal planning processes, the approach promotes better implementation, resource allocation, and inter-agency coordination, while also encouraging active participation from local communities.

Figure 168 Development plan integration



	Proposals	Sector & Stakeholders	Implementation
Region	Regenerative Agriculture	*Agriculture, Irrigation, Farmers*	*Gram Panchayat and Agriculture Dept.*
	Eco-Village	*Environment, Tourism, Farmers*	*Gram Panchayat, Tourism Dept. GoK*
	River Corridor	*Environment, Water Resources, Gram Panchayat*	*Forest Dept., Gram Panchayat*
City	Infrastructure development & Livelihood diversification	*KUIDFC, Karnataka Water Resource Department, KUWSDB, Mangaluru Urban Development Authority, Residents & Farmers*	*KUIDFC, MUDA*
	Mangrove plantation & wetland park	*Environment, Karnataka Forest Department, CZMA, Fisheries department, Residents and Farmers*	*Karnataka Forest Dept., MUDA, CZMA*
	Eco-industrial park	*Environment, Industry, Industries, KIADB, KSPCB, Residents, M.Corp, Industrial workers, Local communities, Fishermen*	*KIADB, KSPCB, Industries*
	River Bank Zoning	*Environment, Karnataka Water Resources, M.Corp, MUDA, CZMA*	*MUDA, M.Corp*
	Focus Area – wards	*Environment, Infrastructure, M.Corp, MUDA, Residents*	*KUIDFC, M.Corp*
	Green & grey infrastructure	*Infrastructure, M.Corp, MUDA, Residents*	*KUIDFC, M.Corp*
	Mangrove conservation & Afforestation	*Environment, CZMA, M.Corp, MUDA, Karnataka Tourism Department, Residents*	*Karnataka Forest Dept., MUDA, CZMA, M.Corp*
	River Precinct	*Environment, M.Corp, MUDA, Karnataka Tourism Dept, Residents*	*MUDA, M.Corp*

Source 400 Author

Conclusion

The research presented in this thesis highlights the urgent need for ecologically sensitive planning approaches in managing urban rivers within dynamic coastal ecosystems. Using the Gurupura River as a case study, the study bridges ecological and spatial dimensions to demonstrate how urbanization, land use patterns, and watershed degradation have collectively undermined the river's health and its role in sustaining both biodiversity and human settlements.

By integrating environmental and human parameters, the study delineates priority areas that reflect the river's ecological value and the pressures it faces. It emphasizes that planning must extend beyond administrative boundaries to account for the river basin as a connected ecological unit. The assessment of riverine health across different scales - from region, planning area to the city scale - enabled the formulation of strategies tailored to varied landscape conditions.

The thesis ultimately proposes a planning framework that emphasizes ecological restoration, water security, and community well-being, promoting a symbiotic relationship between the river and its dependent settlements. In doing so, it contributes toward reimagining urban rivers not as fragmented natural features but as central structuring systems in sustainable and resilient urban futures.

Overall, this thesis demonstrates the importance of environmentally-informed planning in safeguarding urban rivers, especially in ecologically fragile and hydrologically dynamic regions like coastal Karnataka. The Gurupura River case exemplifies how landscape-based planning, when aligned with institutional frameworks and local participation, can drive more sustainable, inclusive, and river-sensitive urban futures.

Summary

This thesis explores environmental planning strategies for urban rivers through an in-depth case study of the Gurupura River in the coastal city of Mangaluru. As rapid urbanization, industrial growth, and ecological neglect strain urban water systems across India, this research addresses the specific planning gaps and ecological vulnerabilities faced by west-flowing rivers (WFRs), which requires its due recognition in national river management efforts. The Gurupura River, which transitions from rural agricultural landscapes to heavily urbanized and industrial zones within Mangaluru, exemplifies the need for context-sensitive, multi-scalar planning interventions.

Situated within a rapidly urbanizing and ecologically sensitive region, the Gurupura River supports a complex web of stakeholders—from farmers in the hinterlands to industries, fishermen and municipal authorities in the core urban area. Despite its historical and economic importance, the river suffers from serious environmental challenges: pollution from critically polluted areas like Baikampady Industrial Estate, unchecked urban runoff, loss of mangroves, and recurring flood events. National frameworks such as the Urban River Management Plan (URMP) and global alliances like the River Cities Alliance have advanced strategies for river-sensitive planning, but their scope has largely bypassed coastal and west-flowing urban rivers like Gurupura. This thesis aims to address this gap.

The study roots itself in an extensive literature review and theoretical understanding of river ecology, spatial planning, watershed management, and climate resilience. It draws from global and national frameworks including Integrated Water Resource Management (IWRM), Water Sensitive Urban Design and Planning (WSUDP), and the ClimateSmart Cities framework. These perspectives are incorporated into a conceptual model that interlinks spatial planning, interaction within the rural and urban waterscape and watershed management.

A regional-scale assessment of the Gurupura River forms the environmental foundation of the study. Using GIS-based analysis, ecosystem service dependency analysis, the thesis maps biophysical layers like slope, vegetation health, and ground water and surface water bodies, alongside anthropogenic factors such as land use changes, and village-level livelihood patterns. Notably, the study highlights rural areas with high dependency on forest and water-based ecosystem services but low resilience, indicating the need for focused planning to ensure ecological and economic stability.



Further shifting the focus to Mangaluru Planning Area, understanding of unique environmental resources not common to the region is gained and a flood risk assessment of 12 sub-watersheds identified as critical sub-watersheds helps identify zones where urban expansion collides with high flood risk and fragile ecosystems. The analysis of the existing master plan for Mangaluru planning area 2021 is conducted to identify the discrepancies in the spatial planning which overlooks the ecological aspects of the river and its immediate context while encouraging development. These findings strengthen the need for integrating flood data and ecosystem sensitivity into urban planning and development strategies

At the city scale, the thesis investigated the state of infrastructure and the gaps, environmental resources (through Mangrove ecosystem service dependency) within the city and further identifies two critical wards within the Mangaluru Municipal Corporation. Using a ward-wise evaluation of sewerage coverage, stormwater drainage, sanitation, mangrove cover, and informal settlements, and land use it plots the locations where unregulated waste discharge, high-population density, and poor infrastructure directly impact the health of the Gurupura River. These urban pressures are accompanied by limited public access to the river and degradation of riparian buffers, emphasizing the need for decentralized infrastructure solution, and habitat restoration

This thesis also investigates the institutional framework governing the Gurupura River, from international conventions (e.g., Ramsar) to local governance bodies. It shows overlapping mandates among departments like pollution control boards, water resource departments, and urban authorities, resulting in fragmented governance. It calls for integrated, multi-stakeholder governance with clear responsibility matrices for effective river management

SWOC analysis is done to bring together results at various levels. It brings out the cultural and natural resource base of the region with deficiency in governance and infrastructural facets. It further explores the myriad opportunities and potential areas for development, such as ecotourism, mangrove restoration, climate-resilient agriculture while focusing on integration with national programs such as AMRUT, Smart Cities, and Namami Gange. The challenges include land use conflicts, unplanned development, industrial effluents, and increasing climatic hazards of urban flooding and sea level rise.

Following the multi-scalar analysis and its findings, the thesis proposes environmental planning strategies across scales: the region, planning area, and city levels. Using a land suitability analysis that is based on AHP, development zones are identified which include: agricultural zone, river corridor development, and regulated urban development which further includes industrial zone and conservation zone.

Regional interventions include an eco-village prototype, explores concepts of regenerative agriculture, and afforestation in the riparian buffer. At the planning area level, measures such as Managed Aquifer Recharge (MAR), flood buffer zoning, and improved waste management in peri-urban census towns are suggested. City-level interventions focus on augmentation of infrastructure and reducing the service gaps, wastewater management, mangrove protection, and ecologically sensitive riverfront development.

To effectively implement and understand the financial component of the proposed interventions, a detailed pilot project (DPR) for an adopted proposal (DEWATS) is developed. This includes the governance framework which provides details of institutional roles, details for installation of the intervention, timeline for implementation and completion, monitoring criteria, and possible revenue schemes to benefit from. This also ensures the suggested interventions do not just remain as theoretical approaches but are practically implementable.

To sum up, this thesis re-positions the Gurupura River from a passive environmental resource coursing through the city to a dynamic socio-ecological system in urgent need of inclusive, participatory, and context-sensitive planning. Grounding its plans in the local setting but adhering to national and international best practices, this thesis provides a model that can be replicated for the sustainable management of urban rivers, particularly in coastal cities that are bedevilled by the interlinked problems of environmental degradation and urbanization.

Recommendations

This chapter consolidates the key insights from the thesis and translates them into actionable recommendations. This includes a concise summary of each chapter, followed by specific planning and policy recommendations, and concludes with a suggested way forward for integrated river management in coastal urban regions.

Chapter-wise summary

Chapter 1 – Introduction

Recognized the significance of urban rivers and emphasized the lack of proper concern for west-flowing rivers like Gurupura in national planning activities. It laid down the task of developing spatial and environmental planning strategies and established the objectives, scope, limitations, and methodology.

Chapter 2 – Literature Study

Understanding the theoretical concepts and planning tools like IWRM, WSUDP, URMP, and climate resilience models. This is used to construct a conceptual framework that connects spatial planning, Rural and Urban waterscape, and Watershed management with themes and sub-themes under relevant planning scales.

Chapter 3 – Regional Study

Gives an overview of the contextual setting of the study area with respect to its connectivity, physiographic region, forest classifications, biogeographic, climate, and agro-ecological zones. This chapter also includes the scoping of the region for detailed study

Chapter 4 – Mangaluru Planning Area

Dedicated to flood risk, zoning, and spatial vulnerability within the Mangaluru Planning Area. It recognized incompatibilities between ecological risk zones and suggested urban land uses, particularly in sub-watershed coded 5A3B4Q, for which planning realignments must be implemented with high priority.

Chapter 5 – Mangaluru City

Assessed city-level pressures including infrastructure gaps, pollution hotspots, and socio-economic pressures. Wards 13 & 27 are identified as priority wards due to untreated sewage, solid waste, and mangrove destruction, which required immediate and targeted interventions.

Chapter 6 – Governance

Captures the existing governance structure from international conventions to local governing bodies that can be used to guide the implementation of the proposed interventions, overall management for Gurupura river across scales, identify gaps and overlaps in the roles and responsibilities across departments and planning scales, and ensure monitoring and timely implementation of the development proposals and strategies.

Chapter 7 – SWOC

Consolidates the findings of all the analysis across scales into internal factors that includes Strengths (cultural and environmental value) and weakness (governance loopholes, pollution) and external factors that includes Opportunities (national missions, local stewardship) and Threats (urban sprawl, climate risks) to develop informed proposal and strategies, both spatial and management.

Chapter 8 – Proposals

Includes spatially focused planning interventions and management strategies at regional, planning area, and city levels, such as eco-village masterplans, flood plain zones, and mangrove restoration. Provides an understanding of the financial component through a DPR of selected project and incorporates the Phasing and governance for the proposed intervention along with Development Plan integration.

Chapter 9 – Conclusion

Emphasizes the river as a dynamic socio-economic and ecological system best positioned at the centre of city planning. Stresses on the necessity of spatial, participatory, and institutional integration.

Key Recommendations

1. Integrate River Health into Urban Planning

Include ecologically meaningful indicators like flood vulnerability, groundwater recharge, NDVI, and ecosystem reliance in master plans, zoning regulations, and infrastructure plans.

2. Prioritize Nature-Based Solutions (NbS)

Installing green buffers, mangrove reforestation, permeable pavement, bio-swales, rain gardens detention and retention ponds, aquifer recharge systems, and afforestation in rural and urban zones along the river can greatly enhance climate resilience.

3. Implement Decentralized Infrastructure

Invest in decentralized wastewater treatment, solid waste management systems, and stormwater drainage in identified critical wards that lack infrastructure coverage to reduce pollutant load on the river.

4. Strengthen River Corridor Regulations

Identify river corridors as ecologically sensitive areas. Define regulatory policies that restrict and regulate industrial and construction uses within these corridors along with increasing public access and ecological recovery.

5. Create a River Management Cell

Establish a cross-institutional river management cell for the Gurupura River under the Urban Development Authority, which has representatives from important departments, local bodies, and civil society.

6. Empower Local Governance

Enhance the role of Gram Panchayats and ward level committees in overseeing pollution sources, managing wetland ecosystems, and executing environmentally sustainable practices in river management at the community level.

7. Promote Livelihood Linkages with Conservation

Implement eco-village planning and regenerative agriculture designs that connect local livelihood wellbeing to river health and which are locally owned.

8. Align with National Missions and SDGs

Leverage the support of finance and policy through missions such as AMRUT, Smart Cities, Namami Gange, and Jal Shakti Abhiyan, aligning all the plans with SDGs 6, 11, 13, and 15.

Way Forward

The suggested strategies in this thesis are site-specific and adaptable, offering a model that is scalable for the management of west-flowing urban rivers in India. Following this, The initial use of the DPR, proposed in Chapter 8, can start in coordination with the local government agencies for real-time evaluation.

Encouragement of policy advocacy is needed to integrate west-flowing rivers into the central planning frameworks of national river and urban planning. Other researches need to concentrate on hydrological modelling, valuation of ecosystem services, and community-based monitoring systems to fill present data and governance gaps. Stewardship and community participation in river health can be promoted through capacity building through training workshops, student participation, and citizen science platforms.

In summary, the Gurupura River presents a challenge and a chance to reinvent the city-river nexus through interconnected, integrated, and nature-oriented planning measures. The effectiveness of this approach will depend on collaboration, commitment, and continuous innovation.

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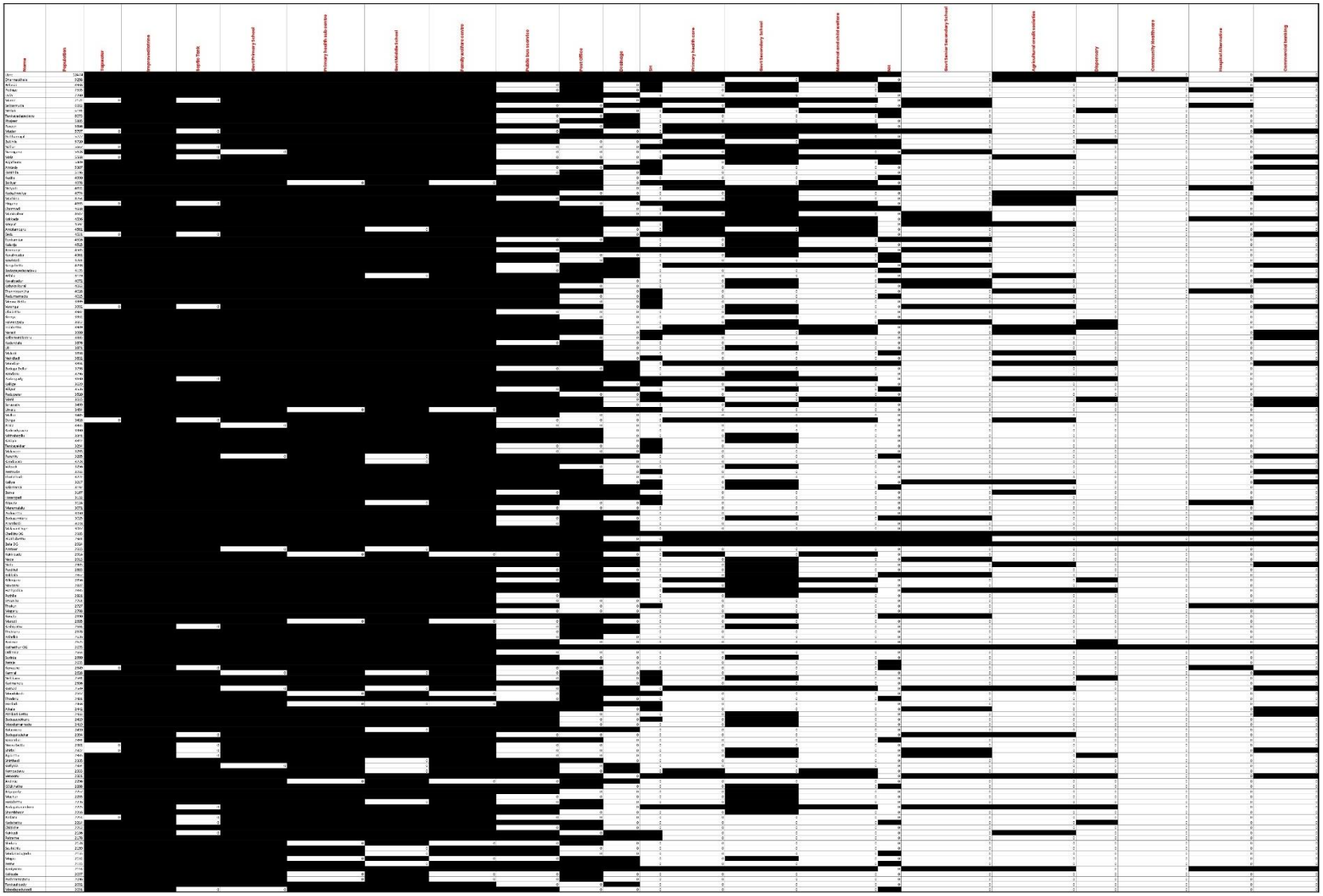
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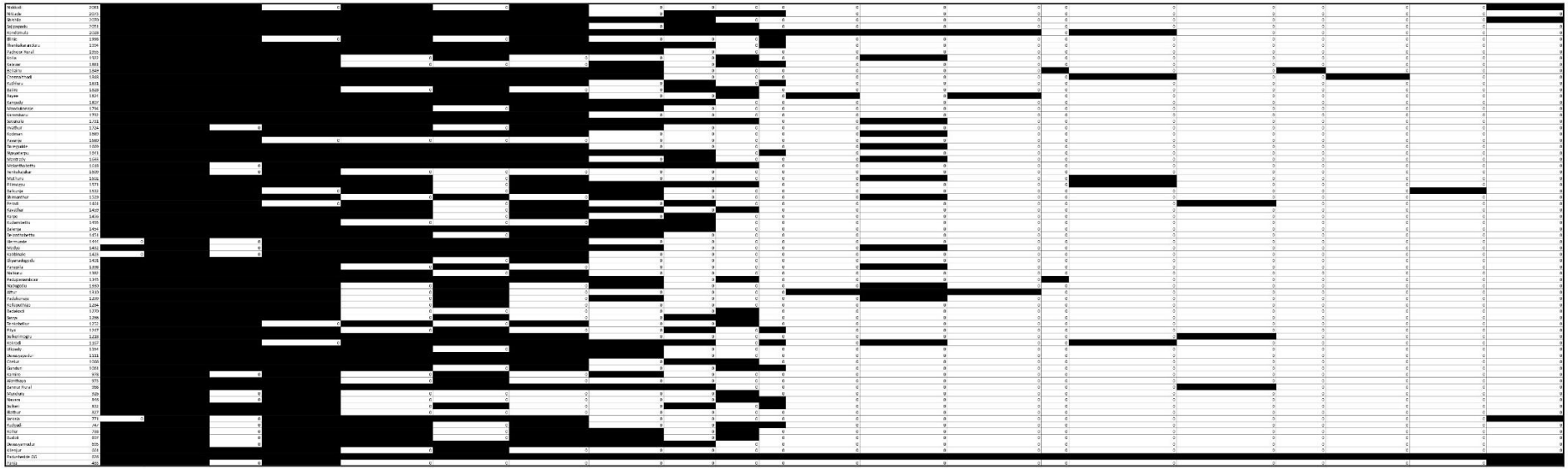


Annexure

Annexure 1 (for section 3.4.2): Scalogram



Annexure 1 (for section 3.4.2): Scalogram



Name	Population	Tapwater	Improved latrine	Septic Tank	Govt Primary School	Primary health sub centre	Govt Middle School	Family welfare centre	Public bus sservice	Post Office	Drainage	SH	Primary health care	Govt Secondary School	Maternal and child welfare	NH	Govt Senior Secondary School	Agricultural credit societies	Dispensary	Community Healthcare	Hospital Alternative	Commercial banking

Annexure 2 (for section 3.4.3): Forest Ecosystem Service Dependency (Score)

Name	3x for core area(2km buffer) 2x for buffer area (2-5 & 5-7km buffer)	2x for villages with more than average population	Provisioning					Regulating				Supporting				Cultural					Dependency
	Forest Buffer	Population 2011	Water	Source of food	Timber, Fibre, & fuel	Medicines	Average	Air quality	Micro-climate	Ground water rejuvenation	Average	Nutrient cycling & soil formaiton	Habitat for spcies	Employment Genertion	Average	Cultural & Religious importance	Recreation & tourism	Aesthetic value	Research & knowledge building	Average	
Kabbinale	2	1407	9	9	9	9	9	9	9	9	9.00	6	9	6	7.00	3	9	9	9	7.5	8.13
Varanga	2	4011	18	18	18	18	18	18	18	18	18.00	12	18	12	14.00	6	18	18	18	15	16.25
Andaru	2	2358	9	9	9	9	9	9	9	9	9.00	6	9	9	8.00	3	9	9	9	7.5	8.38
Shirlal	2	2251	9	9	9	9	9	9	9	9	9.00	6	9	6	7.00	3	9	9	9	7.5	8.13
Kervashe	2	3018	9	9	9	9	9	9	9	9	9.00	6	9	6	7.00	3	9	9	9	7.5	8.13
Mala	2	5998	18	18	18	18	18	18	18	18	18.00	12	18	18	16.00	6	18	18	18	15	16.75
Eedu	2	5176	18	18	18	18	18	18	18	18	18.00	18	18	18	18.00	6	18	18	18	15	17.25
Nooralbettu	2	2367	9	9	9	9	9	9	9	9	9.00	6	9	6	7.00	3	9	9	9	7.5	8.13
Kuthluru	2	1859	9	9	9	9	9	9	9	9	9.00	9	9	6	8.00	3	9	9	9	7.5	8.38
Navara	2	912	9	9	9	9	9	9	9	9	9.00	6	9	3	6.00	3	9	9	9	7.5	7.88
Sulkeri	2	829	9	9	9	9	9	9	9	9	9.00	9	9	3	7.00	3	9	9	9	7.5	8.13
Naravi	2	3950	18	18	18	18	18	18	18	18	18.00	12	18	12	14.00	6	18	18	18	15	16.25
Sulkerimogru	2	1196	9	9	9	9	9	9	9	9	9.00	9	9	3	7.00	3	9	9	9	7.5	8.13
Shirlalu	2	2336	9	9	9	9	9	9	9	9	9.00	9	9	6	8.00	3	9	9	9	7.5	8.38
Charmadi	2	5169	18	18	18	18	18	18	18	18	18.00	18	18	12	16.00	6	18	18	18	15	16.75
Mithabagilu	2	4002	18	18	18	18	18	18	18	18	18.00	18	18	18	18.00	6	18	18	18	15	17.25
Savanalu	2	1823	9	9	9	9	9	9	9	9	9.00	9	9	3	7.00	3	9	9	9	7.5	8.13
Laila	2	7804	18	18	18	18	18	18	18	18	18.00	18	18	12	16.00	6	18	18	18	15	16.75
Nada	2	3466	18	18	18	18	18	18	18	18	18.00	18	18	12	16.00	6	18	18	18	15	16.75
Malavanthige	2	3022	9	9	9	9	9	9	9	9	9.00	9	9	9	9.00	3	9	9	9	7.5	8.63
Indabettu	2	4295	9	9	9	9	9	9	9	9	9.00	9	9	9	9.00	3	9	9	9	7.5	8.63
Navooru	2	3163	9	9	9	9	9	9	9	9	9.00	9	9	9	9.00	3	9	9	9	7.5	8.63
Nellikaru	5	3030	4	4	4	4	4	4	4	4	4.00	2	4	4	3.33	2	4	2	2	2.5	3.46
Pilya	5	1276	4	4	4	4	4	4	4	4	4.00	4	4	2	3.33	2	4	2	2	2.5	3.46
Kudyadi	5	701	4	4	4	4	4	4	4	4	4.00	4	4	2	3.33	2	4	2	2	2.5	3.46
Kokradi	5	1395	4	4	4	4	4	4	4	4	4.00	2	4	2	2.67	2	4	2	2	2.5	3.29
Savya	5	1403	4	4	4	4	4	4	4	4	4.00	2	4	4	3.33	2	4	2	2	2.5	3.46
Thenkakaranduru	5	2345	4	4	4	4	4	4	4	4	4.00	4	4	2	3.33	2	4	2	2	2.5	3.46
Badagakaranduru	5	2300	4	4	4	4	4	4	4	4	4.00	4	4	2	3.33	2	4	2	2	2.5	3.46
Karambaru	5	1940	4	4	4	4	4	4	4	4	4.00	6	4	4	4.67	2	4	2	2	2.5	3.79
Melanthabettu	5	1930	4	4	4	4	4	4	4	4	4.00	2	4	2	2.67	2	4	2	2	2.5	3.29
Beltangadi	5	7746	8	8	8	8	8	8	8	8	8.00	8	8	4	6.67	4	8	4	4	5	6.92
Kadirudyavara	5	3421	8	8	8	8	8	8	8	8	8.00	12	8	12	10.67	4	8	4	4	5	7.92
Munduru	5	948	4	4	4	4	4	4	4	4	4.00	2	4	4	3.33	2	4	2	2	2.5	3.46
Kanyady	5	1926	4	4	4	4	4	4	4	4	4.00	4	4	2	3.33	2	4	2	2	2.5	3.46
Marne	5	7766	8	8	8	8	8	8	8	8	8.00	12	8	4	8.00	4	8	4	4	5	7.25
Jarkala	5	896	4	4	4	4	4	4	4	4	4.00	4	4	2	3.33	2	4	2	2	2.5	3.46
Mudar	5	6088	8	8	8	8	8	8	8	8	8.00	8	8	12	9.33	4	8	4	4	5	7.58
Nallur	5	5829	8	8	8	8	8	8	8	8	8.00	4	8	12	8.00	4	8	4	4	5	7.25
Panapila	7	1625	4	2	2	2	2.5	2	2	4	2.67	2	4	2	2.67	2	2	2	2	2	2.46
Mantrady	7	1744	4	2	2	2	2.5	2	2	4	2.67	4	4	4	4.00	2	2	2	2	2	2.79
Kuvettu CT	7	7041	8	4	4	4	5	4	4	8	5.33	4	8	8	6.67	12	4	4	8	7	6.00
Andinje	7	2175	4	2	2	2	2.5	2	2	4	2.67	4	4	2	3.33	2	2	2	2	2	2.63
Peradi	7	1506	4	2	2	2	2.5	2	2	4	2.67	2	4	2	2.67	2	2	2	2	2	2.46
Marodi	7	2582	4	2	2	2	2.5	2	2	4	2.67	4	4	6	4.67	2	2	2	2	2	2.96
Nalkuru	7	1344	4	2	2	2	2.5	2	2	4	2.67	4	4	2	3.33	2	2	2	2	2	2.63
Balenja	7	1456	4	2	2	2	2.5	2	2	4	2.67	4	4	2	3.33	2	2	2	2	2	2.63
Padangady	7	4045	8	4	4	4	5	4	4	8	5.33	8	8	4	6.67	4	4	4	4	4	5.25
Ujire	7	13429	8	4	4	4	5	4	4	8	5.33	4	8	12	8.00	4	4	4	4	4	5.58
Mundaje	7	4259	8	4	4	4	5	4	4	8	5.33	8	8	8	8.00	4	4	4	4	4	5.58
Hermunde	7	1463	4	2	2	2	2.5	2	2	4	2.67	4	4	4	4.00	2	2	2	2	2	2.79
Durga	7	3383	8	4	4	4	5	4	4	8	5.33	8	8	4	6.67	4	4	4	4	4	5.25
Valpadi	10	3520	4	2	2	2	2.5	2	2	4	2.67	2	2	4	2.67	2	2	2	2	2	2.46
Shirthadi	10	2655	2	1	1	1	1.25	1	1	2	1.33	2	1	2	1.67	1	1	1	1	1	1.31
Daregudde	10	1804	2	1	1	1	1.25	1	1	2	1.33	1	1	2	1.33	1	1	1	1	1	1.23
Sonandur	10	2439	2	1	1	1	1.25	1	1	2	1.33	2	1	1	1.33	1	1	1	1	1	1.23
Odilnala	10	2860	2	1	1	1	1.25	1	1	2	1.33	1	1	1	1.00	1	1	1	1	1	1.15
Kashipatna	10	2673	2	1	1	1	1.25	1	1	2	1.33	1	1	2	1.33	1	1	1	1	1	1.23
Nittade	10	2116	2	1	1	1	1.25	1	1	2	1.33	2	1	2	1.67	1	1	1	1	1	1.31
Karimanelu	10	2463	2	1	1	1	1.25	1	1	2	1.33	2	1	2	1.67	1	1	1	1	1	1.31
Moodukodi	10	2557	2	1	1	1	1.25	1	1	2	1.33	2	1	2	1.67	1	1	1	1	1	1.31
Gardadi	10	2700	2	1	1	1	1.25	1	1	2	1.33	2	1	3	2.00	1	1	1	1	1	1.40
Koyyur	10	5130	4	2	2	2	2.5	2	2	4	2.67	4	2	6	4.00	2	2	2	2	2	2.79
Nyayatarpu	10	1915	2	1	1	1	1.25	1	1	2	1.33	1	1	1	1.00	1	1	1	1	1	1.15
Kaliya	10	3792	4	2	2	2	2.5	2	2	4	2.67	4	2	6	4.00	2	2	2	2	2	2.79
Thotathadi	10	3591	4	2	2	2	2.5	2	2	4	2.67	2	2	6	3.33	2	2	2	2	2	2.63
Chibidre	10	2372	2	1	1	1	1.25	1	1	2	1.33	2	1	2	1.67	1	1	1	1	1	1.31
Kalamanja	10	3709	4	2	2	2	2.5	2	2	4	2.67	4	2	4	3.33	2	2	2	2	2	2.63
Hirgana	10	5019	4	2	2	2	2.5	2	2	4	2.67	4	2	6	4.00	2	2	2	2	2	2.79



Annexure 2 (for section 3.4.3): Forest Ecosystem Service Dependency (Normalised score)

Name	3x for core area(2km buffer) 2x for buffer area (2-5 & 5-7km buffer)	2x for villages with more than average population	Provisioning					Regulating				Supporting				Cultural					Dependency
	Forest Buffer	Population 2011	Water	Source of f	Timber, Fibre, & fuel	Medicines	Average	Air quality	Micro-climate	Ground water rejuvenation	Average	Nutrient cycling & soil formaiton	Habitat for spcies	Employment Genertion	Average	Cultural & Religious importance	Recreation & tourism	Aesthetic value	Research & knowledge building	Average	
Kabbinale	2	1407	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.28	0.44	0.28	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Varanga	2	4011	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.61	0.94	0.61	**0.72**	0.42	0.94	0.94	0.94	**0.81**	0.98
Andaru	2	2358	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.28	0.44	0.44	**0.39**	0.17	0.44	0.44	0.44	**0.38**	0.46
Shirlal	2	2251	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.28	0.44	0.28	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Kervashe	2	3018	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.28	0.44	0.28	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Mala	2	5998	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.61	0.94	0.94	**0.83**	0.42	0.94	0.94	0.94	**0.81**	1.01
Eedu	2	5176	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.94	0.94	0.94	**0.94**	0.42	0.94	0.94	0.94	**0.81**	1.03
Nooralbettu	2	2367	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.28	0.44	0.28	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Kuthluru	2	1859	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.28	**0.39**	0.17	0.44	0.44	0.44	**0.38**	0.46
Navara	2	912	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.28	0.44	0.11	**0.28**	0.17	0.44	0.44	0.44	**0.38**	0.43
Sulkeri	2	829	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.11	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Naravi	2	3950	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.61	0.94	0.61	**0.72**	0.42	0.94	0.94	0.94	**0.81**	0.98
Sulkerimogru	2	1196	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.11	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Shirlalu	2	2336	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.28	**0.39**	0.17	0.44	0.44	0.44	**0.38**	0.46
Charmadi	2	5169	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.94	0.94	0.61	**0.83**	0.42	0.94	0.94	0.94	**0.81**	1.01
Mithabagilu	2	4002	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.94	0.94	0.94	**0.94**	0.42	0.94	0.94	0.94	**0.81**	1.03
Savanalu	2	1823	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.11	**0.33**	0.17	0.44	0.44	0.44	**0.38**	0.45
Laila	2	7804	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.94	0.94	0.61	**0.83**	0.42	0.94	0.94	0.94	**0.81**	1.01
Nada	2	3466	1.78	0.94	0.94	0.94	**1.15**	0.94	0.94	1.78	**1.22**	0.94	0.94	0.61	**0.83**	0.42	0.94	0.94	0.94	**0.81**	1.01
Malavanthige	2	3022	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.44	**0.44**	0.17	0.44	0.44	0.44	**0.38**	0.48
Indabettu	2	4295	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.44	**0.44**	0.17	0.44	0.44	0.44	**0.38**	0.48
Navooru	2	3163	0.78	0.44	0.44	0.44	**0.53**	0.44	0.44	0.78	**0.56**	0.44	0.44	0.44	**0.44**	0.17	0.44	0.44	0.44	**0.38**	0.48
Nellikaru	5	3030	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.06	0.17	0.17	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Pilya	5	1276	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.17	0.17	0.06	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Kudyadi	5	701	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.17	0.17	0.06	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Kokradi	5	1395	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.06	0.17	0.06	**0.09**	0.08	0.17	0.06	0.06	**0.09**	0.14
Savya	5	1403	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.06	0.17	0.17	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Thenkakaranduru	5	2345	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.17	0.17	0.06	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Badagakaranduru	5	2300	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.17	0.17	0.06	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Karambaru	5	1940	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.28	0.17	0.17	**0.20**	0.08	0.17	0.06	0.06	**0.09**	0.16
Melanthabettu	5	1930	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.06	0.17	0.06	**0.09**	0.08	0.17	0.06	0.06	**0.09**	0.14
Beltangadi	5	7746	0.67	0.39	0.39	0.39	**0.46**	0.39	0.39	0.67	**0.48**	0.39	0.39	0.17	**0.31**	0.25	0.39	0.17	0.17	**0.24**	0.37
Kadirudyavara	5	3421	0.67	0.39	0.39	0.39	**0.46**	0.39	0.39	0.67	**0.48**	0.61	0.39	0.61	**0.54**	0.25	0.39	0.17	0.17	**0.24**	0.43
Munduru	5	948	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.06	0.17	0.17	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Kanyady	5	1926	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.17	0.17	0.06	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Marne	5	7766	0.67	0.39	0.39	0.39	**0.46**	0.39	0.39	0.67	**0.48**	0.61	0.39	0.17	**0.39**	0.25	0.39	0.17	0.17	**0.24**	0.39
Jarkala	5	896	0.22	0.17	0.17	0.17	**0.18**	0.17	0.17	0.22	**0.19**	0.17	0.17	0.06	**0.13**	0.08	0.17	0.06	0.06	**0.09**	0.15
Mudar	5	6088	0.67	0.39	0.39	0.39	**0.46**	0.39	0.39	0.67	**0.48**	0.39	0.39	0.61	**0.46**	0.25	0.39	0.17	0.17	**0.24**	0.41
Nallur	5	5829	0.67	0.39	0.39	0.39	**0.46**	0.39	0.39	0.67	**0.48**	0.17	0.39	0.61	**0.39**	0.25	0.39	0.17	0.17	**0.24**	0.39
Panapila	7	1625	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.06	0.17	0.06	**0.09**	0.08	0.06	0.06	0.06	**0.06**	0.09
Mantrady	7	1744	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.17	0.17	**0.17**	0.08	0.06	0.06	0.06	**0.06**	0.11
Kuvettu CT	7	7041	0.67	0.17	0.17	0.17	**0.29**	0.17	0.17	0.67	**0.33**	0.17	0.39	0.39	**0.31**	0.92	0.17	0.17	0.39	**0.41**	0.34
Andinje	7	2175	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.17	0.06	**0.13**	0.08	0.06	0.06	0.06	**0.06**	0.10
Peradi	7	1506	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.06	0.17	0.06	**0.09**	0.08	0.06	0.06	0.06	**0.06**	0.09
Marodi	7	2582	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.17	0.28	**0.20**	0.08	0.06	0.06	0.06	**0.06**	0.12
Nalkuru	7	1344	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.17	0.06	**0.13**	0.08	0.06	0.06	0.06	**0.06**	0.10
Balenja	7	1456	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.17	0.06	**0.13**	0.08	0.06	0.06	0.06	**0.06**	0.10
Padangady	7	4045	0.67	0.17	0.17	0.17	**0.29**	0.17	0.17	0.67	**0.33**	0.39	0.39	0.17	**0.31**	0.25	0.17	0.17	0.17	**0.19**	0.28
Ujire	7	13429	0.67	0.17	0.17	0.17	**0.29**	0.17	0.17	0.67	**0.33**	0.17	0.39	0.61	**0.39**	0.25	0.17	0.17	0.17	**0.19**	0.30
Mundaje	7	4259	0.67	0.17	0.17	0.17	**0.29**	0.17	0.17	0.67	**0.33**	0.39	0.39	0.39	**0.39**	0.25	0.17	0.17	0.17	**0.19**	0.30
Hermunde	7	1463	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.17	0.17	**0.17**	0.08	0.06	0.06	0.06	**0.06**	0.11
Durga	7	3383	0.67	0.17	0.17	0.17	**0.29**	0.17	0.17	0.67	**0.33**	0.39	0.39	0.17	**0.31**	0.25	0.17	0.17	0.17	**0.19**	0.28
Valpadi	10	3520	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.06	0.06	0.17	**0.09**	0.08	0.06	0.06	0.06	**0.06**	0.09
Shirthadi	10	2655	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.06	**0.04**	0.00	0.00	0.00	0.00	**0.00**	0.01
Daregudde	10	1804	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.00	0.00	0.06	**0.02**	0.00	0.00	0.00	0.00	**0.00**	0.00
Sonandur	10	2439	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.00	**0.02**	0.00	0.00	0.00	0.00	**0.00**	0.00
Odilnala	10	2860	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**	0.00
Kashipatna	10	2673	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.00	0.00	0.06	**0.02**	0.00	0.00	0.00	0.00	**0.00**	0.00
Nittade	10	2116	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.06	**0.04**	0.00	0.00	0.00	0.00	**0.00**	0.01
Karimanelu	10	2463	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.06	**0.04**	0.00	0.00	0.00	0.00	**0.00**	0.01
Moodukodi	10	2557	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.06	**0.04**	0.00	0.00	0.00	0.00	**0.00**	0.01
Gardadi	10	2700	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.11	**0.06**	0.00	0.00	0.00	0.00	**0.00**	0.01
Koyyur	10	5130	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.06	0.28	**0.17**	0.08	0.06	0.06	0.06	**0.06**	0.11
Nyayatarpu	10	1915	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**	0.00
Kaliya	10	3792	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.06	0.28	**0.17**	0.08	0.06	0.06	0.06	**0.06**	0.11
Thotathadi	10	3591	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.06	0.06	0.28	**0.13**	0.08	0.06	0.06	0.06	**0.06**	0.10
Chibidre	10	2372	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	**0.00**	0.06	0.00	0.06	**0.04**	0.00	0.00	0.00	0.00	**0.00**	0.01
Kalamanja	10	3709	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.06	0.17	**0.13**	0.08	0.06	0.06	0.06	**0.06**	0.10
Hirgana	10	5019	0.22	0.06	0.06	0.06	**0.10**	0.06	0.06	0.22	**0.11**	0.17	0.06	0.28	**0.17**	0.08	0.06	0.06	0.06	**0.06**	0.11



Annexure 2 (for section 3.4.3): River Ecosystem Service Dependency (Score)

Name	3x for core area(2km buffer) 2x for buffer area (2-5km buffer)	2x for villages with more than average population	Provisioning				Regulating					Supporting				Cultural Value					Dependency
	Micro watershed Buffer	Population 20	Fresh water	Fishing	Irrigation	Average	Water quality regulation	Carbon sequestration	Micro Climate Regulation	Ground water regulation	Average	Nutriet cycling & formation of soil	Habitat for species	Employment generation	Average	Cultural & Religious importance	Tourism and recreation Value	Aesthetic Value	Educational & Research Value	Average	
Addur CT	2	5426	18	6	12	**12.0**	18	18	18	18	**18**	12	6	12	**10.00**	12	12	18	18	**15**	13.8
Ammunje	2	5193	6	6	12	**8.0**	18	18	18	18	**18**	12	12	12	**12.00**	12	12	18	18	**15**	13.3
Arala	2	3827	3	3	6	**4.0**	9	9	9	9	**9**	6	6	6	**6.00**	6	6	9	9	**7.5**	6.6
Badagaulipady CT	2	7062	18	6	6	**10.0**	18	18	18	18	**18**	12	6	6	**8.00**	12	12	18	18	**15**	12.8
Ervuailu	2	2931	3	3	9	**5.0**	9	9	9	9	**9**	6	3	9	**6.00**	6	6	9	9	**7.5**	6.9
Hosangadi	2	3366	3	3	9	**5.0**	9	9	9	9	**9**	6	6	9	**7.00**	6	6	9	9	**7.5**	7.1
Kariyangala CT	2	4698	18	6	18	**14.0**	18	18	18	18	**18**	12	6	18	**12.00**	18	18	18	18	**18**	15.5
Kolavooru	2	2491	6	3	9	**6.0**	9	9	9	9	**9**	6	3	9	**6.00**	6	6	9	9	**7.5**	7.1
Mallur	2	3601	6	3	3	**4.0**	9	9	9	9	**9**	6	3	3	**4.00**	6	6	9	9	**7.5**	6.1
Mogaru	2	2797	3	3	3	**3.0**	9	9	9	9	**9**	6	3	3	**4.00**	6	6	9	9	**7.5**	5.9
Mulur CT	2	5445	18	6	6	**10.0**	18	18	18	18	**18**	12	6	6	**8.00**	12	12	18	18	**15**	12.8
Muthuru	2	1875	3	3	6	**4.0**	9	9	9	9	**9**	6	3	6	**5.00**	6	6	9	9	**7.5**	6.4
Puchhamoguru	2	2108	3	3	3	**3.0**	9	9	9	9	**9**	6	3	3	**4.00**	6	6	9	9	**7.5**	5.9
Rayee	2	2012	6	3	6	**5.0**	9	9	9	9	**9**	6	3	6	**5.00**	6	6	9	9	**7.5**	6.6
Sangabettu	2	4400	6	6	12	**8.0**	18	18	18	18	**18**	12	12	12	**12.00**	12	12	18	18	**15**	13.3
Tankaulipady	2	2188	6	3	3	**4.0**	9	9	9	9	**9**	6	3	3	**4.00**	6	6	9	9	**7.5**	6.1
Ulaibettu	2	4162	12	6	6	**8.0**	18	18	18	18	**18**	12	6	6	**8.00**	12	12	18	18	**15**	12.3
Adyapady	5	2089	4	2	4	**3.3**	6	4	4	6	**5**	2	2	4	**2.67**	2	2	2	4	**2.5**	3.4
Arambodi	5	3442	2	2	4	**2.7**	6	4	4	6	**5**	2	6	4	**4.00**	2	2	2	4	**2.5**	3.5
Badaga Bellur	5	3874	4	2	6	**4.0**	6	4	4	6	**5**	2	4	6	**4.00**	2	2	2	4	**2.5**	3.9
Badakodi	5	1337	2	2	2	**2.0**	6	4	4	6	**5**	2	6	2	**3.33**	2	2	2	4	**2.5**	3.2
Bondathila CT	5	5858	12	4	8	**8.0**	12	8	8	12	**10**	4	4	8	**5.33**	4	4	4	8	**5**	7.1
Hosabettu	5	2260	2	2	2	**2.0**	6	4	4	6	**5**	2	6	2	**3.33**	2	2	2	4	**2.5**	3.2
Kandavara	5	3347	4	2	4	**3.3**	6	4	4	6	**5**	2	2	4	**2.67**	2	2	2	4	**2.5**	3.4
Karpe	5	1542	2	2	6	**3.3**	6	4	4	6	**5**	2	4	6	**4.00**	2	2	2	4	**2.5**	3.7
Killenjaru	5	3225	2	2	6	**3.3**	6	4	4	6	**5**	2	2	6	**3.33**	2	2	2	4	**2.5**	3.5
Koila	5	2083	2	2	4	**2.7**	6	4	4	6	**5**	2	4	4	**3.33**	2	2	2	4	**2.5**	3.4
Kukkipady	5	3116	2	2	6	**3.3**	6	4	4	6	**5**	2	4	6	**4.00**	2	2	2	4	**2.5**	3.7
Kuriyala	5	2248	2	2	6	**3.3**	6	4	4	6	**5**	2	4	6	**4.00**	2	2	2	4	**2.5**	3.7
Mudushedde CT	5	8155	12	4	4	**6.7**	12	8	8	12	**10**	4	4	4	**4.00**	4	4	4	8	**5**	6.4
Neermarga CT	5	5503	12	4	8	**8.0**	12	8	8	12	**10**	4	4	8	**5.33**	4	4	4	8	**5**	7.1
Padukonaje	5	1313	2	2	2	**2.0**	6	4	4	6	**5**	2	6	2	**3.33**	2	2	2	4	**2.5**	3.2
Tenkabellur	5	1230	2	2	2	**2.0**	6	4	4	6	**5**	2	2	2	**2.00**	2	2	2	4	**2.5**	2.9
Tenkayedapadavu	5	6228	4	4	8	**5.3**	12	8	8	12	**10**	4	12	8	**8.00**	4	4	4	8	**5**	7.1
Eliyanadugodu	7	1406	1	1	2	**1.3**	3	1	1	3	**2**	1	2	2	**1.67**	1	1	1	1	**1**	1.5
Gunduri	7	1175	1	1	2	**1.3**	3	1	1	3	**2**	1	3	2	**2.00**	1	1	1	1	**1**	1.6
Kolambe CT	7	5592	6	2	6	**4.7**	6	2	2	6	**4**	2	2	6	**3.33**	2	2	2	2	**2**	3.5
Malavoor	7	3468	2	1	1	**1.3**	3	1	1	3	**2**	1	1	1	**1.00**	1	1	1	1	**1**	1.3
Moodukonaje	7	1929	1	1	2	**1.3**	3	1	1	3	**2**	1	1	2	**1.33**	1	1	1	1	**1**	1.4
Mudbidri	7	29431	6	2	4	**4.0**	6	2	2	6	**4**	2	2	4	**2.67**	6	6	2	2	**4**	3.7
Venooru	7	2317	3	1	2	**2.0**	3	2	2	3	**2.5**	2	1	2	**1.67**	3	3	2	2	**2.5**	2.2



Annexure 2 (for section 3.4.3): River Ecosystem Service Dependency (Normalised Score)

Name	3x for core area(2km buffer) 2x for buffer area (2-5km buffer)	2x for villages with more than average population	Provisioning				Regulating					Supporting				Cultural Value					Dependency
	MWS Buffer	CeT_Pop2011	Fresh water	Fishing	Irrigation	Average	Water quality regulation	Carbon sequestration	Micro Climate Regulation	Ground water regulation	Average	Nutriet cycling & formation of soil	Habitat for species	Employment generation	Average	Cultural & Religious importance	Tourism and recreation Value	Aesthetic Value	Educational & Research Value	Average	
Addur CT	2	5426	1.0	1.0	0.6	**0.9**	1.0	1.0	1.0	1.0	**1.00**	1.0	0.5	0.6	**0.70**	0.6	0.6	1.0	1.0	**0.82**	0.9
Ammunje	2	5193	0.3	1.0	0.6	**0.6**	1.0	1.0	1.0	1.0	**1.00**	1.0	1.0	0.6	**0.88**	0.6	0.6	1.0	1.0	**0.82**	0.8
Arala	2	3827	0.1	0.4	0.3	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.5	0.3	**0.40**	0.3	0.3	0.5	0.5	**0.38**	0.4
Badagaulipady CT	2	7062	1.0	1.0	0.3	**0.8**	1.0	1.0	1.0	1.0	**1.00**	1.0	0.5	0.3	**0.58**	0.6	0.6	1.0	1.0	**0.82**	0.8
Ervuailu	2	2931	0.1	0.4	0.5	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.5	**0.37**	0.3	0.3	0.5	0.5	**0.38**	0.4
Hosangadi	2	3366	0.1	0.4	0.5	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.5	0.5	**0.46**	0.3	0.3	0.5	0.5	**0.38**	0.4
Kariyangala CT	2	4698	1.0	1.0	1.0	**1.0**	1.0	1.0	1.0	1.0	**1.00**	1.0	0.5	1.0	**0.82**	1.0	1.0	1.0	1.0	**1.00**	1.0
Kolavooru	2	2491	0.3	0.4	0.5	**0.4**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.5	**0.37**	0.3	0.3	0.5	0.5	**0.38**	0.4
Mallur	2	3601	0.3	0.4	0.1	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.1	**0.25**	0.3	0.3	0.5	0.5	**0.38**	0.3
Mogaru	2	2797	0.1	0.4	0.1	**0.2**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.1	**0.25**	0.3	0.3	0.5	0.5	**0.38**	0.3
Mulur CT	2	5445	1.0	1.0	0.3	**0.8**	1.0	1.0	1.0	1.0	**1.00**	1.0	0.5	0.3	**0.58**	0.6	0.6	1.0	1.0	**0.82**	0.8
Muthuru	2	1875	0.1	0.4	0.3	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.3	**0.31**	0.3	0.3	0.5	0.5	**0.38**	0.3
Puchhamoguru	2	2108	0.1	0.4	0.1	**0.2**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.1	**0.25**	0.3	0.3	0.5	0.5	**0.38**	0.3
Rayee	2	2012	0.3	0.4	0.3	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.3	**0.31**	0.3	0.3	0.5	0.5	**0.38**	0.4
Sangabettu	2	4400	0.3	1.0	0.6	**0.6**	1.0	1.0	1.0	1.0	**1.00**	1.0	1.0	0.6	**0.88**	0.6	0.6	1.0	1.0	**0.82**	0.8
Tankaulipady	2	2188	0.3	0.4	0.1	**0.3**	0.4	0.5	0.5	0.4	**0.44**	0.5	0.2	0.1	**0.25**	0.3	0.3	0.5	0.5	**0.38**	0.3
Ulaibettu	2	4162	0.6	1.0	0.3	**0.6**	1.0	1.0	1.0	1.0	**1.00**	1.0	0.5	0.3	**0.58**	0.6	0.6	1.0	1.0	**0.82**	0.8
Adyapady	5	2089	0.2	0.2	0.2	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.1	0.2	**0.12**	0.1	0.1	0.1	0.2	**0.09**	0.1
Arambodi	5	3442	0.1	0.2	0.2	**0.1**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.5	0.2	**0.24**	0.1	0.1	0.1	0.2	**0.09**	0.2
Badaga Bellur	5	3874	0.2	0.2	0.3	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.3	0.3	**0.22**	0.1	0.1	0.1	0.2	**0.09**	0.2
Badakodi	5	1337	0.1	0.2	0.1	**0.1**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.5	0.1	**0.20**	0.1	0.1	0.1	0.2	**0.09**	0.1
Bondathila CT	5	5858	0.6	0.6	0.4	**0.6**	0.6	0.4	0.4	0.6	**0.51**	0.3	0.3	0.4	**0.32**	0.2	0.2	0.2	0.4	**0.24**	0.4
Hosabettu	5	2260	0.1	0.2	0.1	**0.1**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.5	0.1	**0.20**	0.1	0.1	0.1	0.2	**0.09**	0.1
Kandavara	5	3347	0.2	0.2	0.2	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.1	0.2	**0.12**	0.1	0.1	0.1	0.2	**0.09**	0.1
Karpe	5	1542	0.1	0.2	0.3	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.3	0.3	**0.22**	0.1	0.1	0.1	0.2	**0.09**	0.2
Killenjaru	5	3225	0.1	0.2	0.3	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.1	0.3	**0.16**	0.1	0.1	0.1	0.2	**0.09**	0.2
Koila	5	2083	0.1	0.2	0.2	**0.1**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.3	0.2	**0.18**	0.1	0.1	0.1	0.2	**0.09**	0.2
Kukkipady	5	3116	0.1	0.2	0.3	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.3	0.3	**0.22**	0.1	0.1	0.1	0.2	**0.09**	0.2
Kuriyala	5	2248	0.1	0.2	0.3	**0.2**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.3	0.3	**0.22**	0.1	0.1	0.1	0.2	**0.09**	0.2
Mudushedde CT	5	8155	0.6	0.6	0.2	**0.5**	0.6	0.4	0.4	0.6	**0.51**	0.3	0.3	0.2	**0.24**	0.2	0.2	0.2	0.4	**0.24**	0.4
Neermarga CT	5	5503	0.6	0.6	0.4	**0.6**	0.6	0.4	0.4	0.6	**0.51**	0.3	0.3	0.4	**0.32**	0.2	0.2	0.2	0.4	**0.24**	0.4
Padukonaje	5	1313	0.1	0.2	0.1	**0.1**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.5	0.1	**0.20**	0.1	0.1	0.1	0.2	**0.09**	0.1
Tenkabellur	5	1230	0.1	0.2	0.1	**0.1**	0.2	0.2	0.2	0.2	**0.19**	0.1	0.1	0.1	**0.08**	0.1	0.1	0.1	0.2	**0.09**	0.1
Tenkayedapadavu	5	6228	0.2	0.6	0.4	**0.4**	0.6	0.4	0.4	0.6	**0.51**	0.3	1.0	0.4	**0.56**	0.2	0.2	0.2	0.4	**0.24**	0.4
Eliyanadugodu	7	1406	0.0	0.0	0.1	**0.0**	0.0	0.0	0.0	0.0	**0.00**	0.0	0.1	0.1	**0.05**	0.0	0.0	0.0	0.00	**0.00**	0.0
Gunduri	7	1175	0.0	0.0	0.1	**0.0**	0.0	0.0	0.0	0.0	**0.00**	0.0	0.2	0.1	**0.08**	0.0	0.0	0.0	0.00	**0.00**	0.0
Kolambe CT	7	5592	0.3	0.2	0.3	**0.3**	0.2	0.1	0.1	0.2	**0.13**	0.1	0.1	0.3	**0.16**	0.1	0.1	0.1	0.06	**0.06**	0.2
Malavoor	7	3468	0.1	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	**0.00**	0.0	0.0	0.0	**0.00**	0.0	0.0	0.0	0.00	**0.00**	0.0
Moodukonaje	7	1929	0.0	0.0	0.1	**0.0**	0.0	0.0	0.0	0.0	**0.00**	0.0	0.0	0.1	**0.02**	0.0	0.0	0.0	0.00	**0.00**	0.0
Mudbidri	7	29431	0.3	0.2	0.2	**0.2**	0.2	0.1	0.1	0.2	**0.13**	0.1	0.1	0.2	**0.12**	0.3	0.3	0.1	0.06	**0.18**	0.2
Venooru	7	2317	0.1	0.0	0.1	**0.1**	0.0	0.1	0.1	0.0	**0.03**	0.1	0.0	0.1	**0.05**	0.1	0.1	0.1	0.06	**0.09**	0.1



Annexure 2 (for section 3.4.3): Forest Livelihood Service Dependency

Name	Forest Buffer	Natural Capital							Physical Capital																	
		Forest Area		Barren Land		Presence of water		Natural Capital	% HH with permanent House		Tap Water %		Septic Tank %		Drainage %		Improved Latrine %		Access to Road		Education		Healthcare		Wells & Tubewells		Physcial capital
		Value	Normalized score	Value	Normalized score	Value	Normalized score		Value	Normalized score	Value	Normalized score	Value	Normalized score	Value	Normalized score	Value	Normalized score	Value	Normalized score	Value	Normalized score	Value	Normalized score	Value	Normalized score	
Andaru	2	68.45	0.01	121.72	0.17	26.73	0.16	**0.12**	86	0.97	1	0.00	81.6	0.85	0.2	0.00	82	0.41	0.00	0.00	2.00	0.50	2.00	0.40	0.00	0.00	**0.35**
Charmadi	2	4222.7	0.76	74.28	0.10	86.20	0.53	**0.46**	28.50	0.28	18.7	0.19	46.2	0.48	25.3	0.25	90.6	0.73	0.00	0.00	3.00	0.75	4.00	0.80	290.00	0.98	**0.49**
Eedu	2	1636.63	0.29	78.21	0.11	6.63	0.04	**0.15**	37.70	0.39	15.8	0.16	90.1	0.94	20	0.20	90.4	0.72	1.00	1.00	3.00	0.75	4.00	0.80	139.44	0.47	**0.60**
Indabettu	2	204.22	0.04	231.62	0.33	0.00	0.00	**0.12**	47.8	0.51	25.8	0.26	13	0.14	45.3	0.45	88.9	0.66	0.00	0.00	3.00	0.75	5.00	1.00	200.61	0.68	**0.49**
Kabbinale	2	1803.59	0.32	40.30	0.06	0.00	0.00	**0.13**	32.80	0.33	0.7	0.00	87.2	0.91	52.1	0.52	87.2	0.60	0.00	0.00	2.00	0.50	2.00	0.40	122.57	0.41	**0.41**
Kervashe	2	2551	0.46	75.94	0.11	18.77	0.11	**0.23**	59.3	0.65	5.5	0.05	78.6	0.82	26.5	0.27	78.7	0.29	1.00	1.00	2.00	0.50	3.00	0.60	126.75	0.43	**0.51**
Kuthluru	2	2145	0.39	148.00	0.21	0.00	0.00	**0.20**	28.80	0.28	41.2	0.42	42	0.44	75.3	0.76	98	1.00	1.00	1.00	2.00	0.50	2.00	0.40	75.50	0.25	**0.56**
Laila	2	694.76	0.12	66.35	0.09	0.00	0.00	**0.07**	60.60	0.66	16	0.16	0	0.00	58.5	0.59	96.8	0.96	0.00	0.00	2.00	0.50	2.00	0.40	296.40	1.00	**0.47**
Mala	2	2456.77	0.44	55.11	0.08	0.00	0.00	**0.17**	54.6	0.59	4.7	0.04	87.4	0.91	17	0.17	94.6	0.87	1.00	1.00	3.00	0.75	4.00	0.80	122.14	0.41	**0.62**
Malavanthige	2	5560.85	1.00	14.57	0.02	20.05	0.12	**0.38**	18.00	0.15	41.1	0.42	89.9	0.94	18.2	0.18	71	0.00	0.00	0.00	2.00	0.50	2.00	0.40	185.25	0.63	**0.36**
Mithabagilu	2	3.6	0.00	224.66	0.32	43.00	0.26	**0.19**	17.10	0.14	62.8	0.65	41.5	0.43	33.4	0.33	88.8	0.66	0.00	0.00	3.00	0.75	2.00	0.40	62.00	0.21	**0.40**
Nada	2	829.42	0.15	84.79	0.12	14.14	0.09	**0.12**	39.60	0.41	33.6	0.35	60.9	0.63	92.7	0.93	93	0.81	0.00	0.00	4.00	1.00	2.00	0.40	146.50	0.49	**0.56**
Naravi	2	1709	0.31	139.4	0.20	0.00	0.00	**0.17**	47.90	0.51	23.4	0.24	0	0.00	39.2	0.39	92.5	0.80	1.00	1.00	2.00	0.50	4.00	0.80	91.40	0.31	**0.51**
Navara	2	298	0.05	19	0.03	0.00	0.00	**0.03**	20.10	0.18	32.5	0.33	96.1	1.00	60.4	0.61	88.4	0.64	1.00	1.00	1.00	0.25	0.00	0.00	32.50	0.11	**0.46**
Navooru	2	5341.35	0.96	10.1	0.01	50.80	0.31	**0.43**	22.80	0.21	56.6	0.59	80.7	0.84	1.9	0.02	86.2	0.56	0.00	0.00	3.00	0.75	2.00	0.40	104.50	0.35	**0.41**
Nooralbettu	2	1355.63	0.24	31.02	0.04	0.00	0.00	**0.10**	32.9	0.33	16.5	0.17	82.7	0.86	1.1	0.01	88.4	0.64	1.00	1.00	2.00	0.50	2.00	0.40	114.55	0.39	**0.48**
Savanalu	2	1669.8	0.30	29.46	0.04	0.00	0.00	**0.11**	16.00	0.13	26.1	0.27	84.4	0.88	1.1	0.01	89.9	0.70	0.00	0.00	3.00	0.75	2.00	0.40	67.50	0.23	**0.37**
Shirlal	2	1057.12	0.19	188.29	0.27	0.00	0.00	**0.15**	73.5	0.82	7.3	0.07	84.1	0.88	27.1	0.27	84	0.48	0.00	0.00	4.00	1.00	2.00	0.40	71.47	0.24	**0.46**
Shirlalu	2	1856.62	0.33	59.01	0.08	0.00	0.00	**0.14**	51.90	0.56	7.3	0.07	1.3	0.01	64.5	0.65	93.9	0.85	0.00	0.00	2.00	0.50	0.00	0.00	221.10	0.75	**0.38**
Sulkeri	2	0	0.00	169.07	0.24	0.00	0.00	**0.08**	42.60	0.45	29.5	0.30	1.1	0.01	98.4	0.99	93.7	0.84	1.00	1.00	2.00	0.50	0.00	0.00	69.80	0.24	**0.48**
Sulkerimogru	2	1344	0.24	0.4	0.00	0.00	0.00	**0.08**	42.20	0.44	3.6	0.03	88.1	0.92	98.2	0.99	84.7	0.51	0.00	0.00	2.00	0.50	2.00	0.40	152.02	0.51	**0.48**
Varanga	2	99.55	0.02	8.22	0.01	4.86	0.03	**0.02**	81.8	0.92	6.7	0.06	83	0.86	23.3	0.23	84.1	0.49	1.00	1.00	4.00	1.00	2.00	0.40	57.60	0.19	**0.57**
Badagakaranduru	5	108.58	0.02	10.66	0.01	0.00	0.00	**0.01**	50.60	0.54	23.2	0.24	0	0.00	99.2	1.00	93.6	0.84	1.00	1.00	4.00	1.00	5.00	1.00	55.50	0.19	**0.64**
Beltangadi	5	12	0.00	104.00	0.15	0.00	0.00	**0.05**	57.60	0.63	94	0.98	91	0.95	93	0.94	94.3	0.86	1.00	1.00	4.00	1.00	5.00	1.00	10.00	0.03	**0.82**
Jarkala	5	91.46	0.02	33.09	0.05	0.00	0.00	**0.02**	88.60	1.00	13.2	0.13	95.2	0.99	36.1	0.36	95.2	0.90	0.00	0.00	2.00	0.50	2.00	0.40	56.28	0.19	**0.50**
Kadirudyavara	5	404.6	0.07	122.83	0.17	163.90	1.00	**0.42**	35.90	0.37	13.9	0.14	10.2	0.11	67.9	0.68	78.7	0.29	0.00	0.00	2.00	0.50	2.00	0.40	86.80	0.29	**0.31**
Kanyady	5	234.41	0.04	61.18	0.09	0.00	0.00	**0.04**	14.00	0.10	11.5	0.11	0.2	0.00	65.4	0.66	92.5	0.80	0.00	0.00	2.00	0.50	2.00	0.40	80.59	0.27	**0.32**
Karambaru	5	54.12	0.01	7.28	0.01	0.00	0.00	**0.01**	81.30	0.91	48.4	0.50	60.3	0.63	91	0.92	90.3	0.71	0.00	0.00	2.00	0.50	2.00	0.40	137.80	0.46	**0.56**
Kokradi	5	18.06	0.00	25.00	0.03	0.00	0.00	**0.01**	55.50	0.60	66	0.69	89.4	0.93	96	0.97	92.1	0.78	1.00	1.00	3.00	0.75	2.00	0.40	216.10	0.73	**0.76**
Kudyadi	5	97	0.02	11.50	0.02	0.00	0.00	**0.01**	35.50	0.36	34.7	0.36	93.2	0.97	78.3	0.79	95.5	0.91	1.00	1.00	1.00	0.25	2.00	0.40	58.60	0.20	**0.58**
Marne	5	870.28	0.16	82.19	0.12	2.96	0.02	**0.10**	67	0.74	21.1	0.21	86.8	0.90	49.4	0.50	87.6	0.61	1.00	1.00	4.00	1.00	4.00	0.80	179.26	0.60	**0.71**
Melanthabettu	5	92.2	0.02	15	0.02	0.00	0.00	**0.01**	36.00	0.37	33.9	0.35	55.2	0.57	86.5	0.87	89.6	0.69	0.00	0.00	2.00	0.50	2.00	0.40	79.20	0.27	**0.45**
Mudar	5	73.65	0.01	167.2	0.24	7.55	0.05	**0.10**	80.4	0.90	13.7	0.14	90	0.94	15.4	0.15	89.6	0.69	1.00	1.00	4.00	1.00	4.00	0.80	192.40	0.65	**0.70**
Munduru	5	165.6	0.03	5.8	0.01	0.00	0.00	**0.01**	44.90	0.47	52.9	0.55	0.6	0.01	23.3	0.23	89.9	0.70	0.00	0.00	1.00	0.25	0.00	0.00	80.65	0.27	**0.28**
Nallur	5	419.65	0.08	93.73	0.13	0.00	0.00	**0.07**	61.1	0.67	10.9	0.11	88	0.92	0.3	0.00	90.6	0.73	1.00	1.00	3.00	0.75	4.00	0.80	22.66	0.08	**0.56**
Nellikaru	5	154.9	0.03	93.11	0.13	0.00	0.00	**0.05**	36.40	0.37	25.5	0.26	15	0.16	41.2	0.41	82.4	0.42	1.00	1.00	3.00	0.75	3.00	0.60	60.00	0.20	**0.46**
Pilya	5	144	0.03	10.65	0.01	0.00	0.00	**0.01**	50.90	0.55	49.8	0.52	86	0.89	46	0.46	88.3	0.64	1.00	1.00	2.00	0.50	0.00	0.00	35.60	0.12	**0.52**
Savya	5	61.2	0.01	55.3	0.08	0.00	0.00	**0.03**	9.50	0.05	13.3	0.13	0.4	0.00	93.7	0.94	86.1	0.56	0.00	0.00	2.00	0.50	0.00	0.00	129.30	0.44	**0.29**
Thenkakaranduru	5	234	0.04	75.3	0.11	0.00	0.00	**0.05**	49.90	0.53	30.8	0.32	0.2	0.00	91.8	0.92	91.7	0.77	1.00	1.00	2.00	0.50	2.00	0.40	34.00	0.11	**0.51**
Andinje	7	137.24	0.02	25.40	0.04	0.00	0.00	**0.02**	29.30	0.29	14.3	0.14	25.9	0.27	95.6	0.96	92	0.78	0.00	0.00	2.00	0.50	0.00	0.00	184.70	0.62	**0.40**
Balenja	7	15.7	0.00	118.20	0.17	11.00	0.07	**0.08**	56.20	0.61	29.1	0.30	1.6	0.02	52.3	0.53	95.8	0.92	0.00	0.00	2.00	0.50	2.00	0.40	34.00	0.11	**0.38**
Durga	7	777	0.14	55.06	0.08	0.00	0.00	**0.07**	40.10	0.42	16.4	0.16	78.5	0.82	37.7	0.38	80.4	0.35	0.00	0.00	3.00	0.75	4.00	0.80	214.21	0.72	**0.49**
Hermunde	7	194.2	0.03	81.58	0.12	5.52	0.03	**0.06**	66.20	0.73	9.3	0.09	85.1	0.89	39.4	0.40	85.8	0.55	0.00	0.00	2.00	0.50	2.00	0.40	0.76	0.00	**0.39**
Kuvettu CT	7	10	0.00	18.00	0.02	12.00	0.07	**0.03**	58.80	0.64	96	1.00	93	0.97	91	0.92	92.3	0.79	1.00	1.00	4.00	1.00	5.00	1.00	8.00	0.03	**0.82**
Mantrady	7	44.75	0.01	80.06	0.11	0.00	0.00	**0.04**	80.30	0.90	4.7	0.04	0	0.00	28.9	0.29	85.1	0.52	0.00	0.00	3.00	0.75	2.00	0.40	65.00	0.22	**0.35**
Marodi	7	202.38	0.04	79.6	0.11	0.00	0.00	**0.05**	39.30	0.41	43.7	0.45	84.3	0.88	77	0.77	95.3	0.90	0.00	0.00	2.00	0.50	0.00	0.00	208.20	0.70	**0.51**
Mundaje	7	413.57	0.07	99.12	0.14	0.00	0.00	**0.07**	44.10	0.46	14.1	0.14	92.7	0.96	50.5	0.51	97.2	0.97	1.00	1.00	3.00	0.75	5.00	1.00	85.90	0.29	**0.68**
Nalkuru	7	334	0.06	162.67	0.23	9.00	0.05	**0.12**	43.80	0.46	6.3	0.06	65.9	0.69	75.9	0.76	95.4	0.90	0.00	0.00	1.00	0.25	2.00	0.40	30.20	0.10	**0.40**
Padangady	7	34.8	0.01	149.15	0.21	0.00	0.00	**0.07**	39.20	0.41	39.7	0.41	53.5	0.56	0.4	0.00	87	0.59	1.00	1.00	3.00	0.75	5.00	1.00	197.30	0.67	**0.60**
Panapila	7	129.95	0.02	9.31	0.01	0.00	0.00	**0.01**	20.10	0.18	13.3	0.13	0	0.00	1	0.01	87.5	0.61	0.00	0.00	3.00	0.75	0.00	0.00	74.35	0.25	**0.21**
Peradi	7	88.36	0.02	19.11	0.03	0.00	0.00	**0.01**	5.50	0.00	38.9	0.40	83.1	0.86	70.6	0.71	88.3	0.64	0.00	0.00	0.00	0.00	2.00	0.40	115.45	0.39	**0.38**
Ujire	7	372.87	0.07	175.79	0.25	0.00	0.00	**0.11**	64.70	0.71	29.6	0.30	31.9	0.33	49.2	0.49	93.5	0.83	1.00	1.00	3.00	0.75	5.00	1.00	279.37	0.94	**0.71**
Chibidre	10	2025.4	0.36	18.87	0.03	17.90	0.11	**0.17**	29.40	0.29	7.1	0.07	37.4	0.39	74.8	0.75	88	0.63	0.00	0.00	2.00	0.50	2.00	0.40	124.40	0.42	**0.38**
Daregudde	10	78.94	0.01	20.24	0.03	0.00	0.00	**0.01**	51.40	0.55	10	0.10	76.4	0.80	4.5	0.04	77.3	0.23	0.00	0.00	3.00	0.75	2.00	0.40	69.47	0.23	**0.35**
Gardadi	10	12.97	0.00	100.60	0.14	0.00	0.00	**0.05**	47	0.50	12.3	0.12	40.9	0.43	50.5	0.51	89.2	0.67	1.00	1.00	1.00	0.25	0.00	0.00	163.81	0.55	**0.45**
Hirgana	10	420.7	0.08	23.58	0.03	4.05	0.02	**0.04**	71.70	0.80	8.6	0.08	86.4	0.90	17.7	0.18	87.9	0.63	1.00	1.00	3.00	0.75	4.00	0.80	63.30	0.21	**0.59**
Kalamanja	10	101.69	0.02	59.09	0.08	0.00	0.00	**0.03**	32.00	0.32	17.4	0.18	58.8	0.61	30.2	0.30	90.3	0.71	1.00	1.00	3.00	0.75	2.00	0.40	68.80	0.23	**0.50**
Kaliya	10	215.18	0.04	97.02	0.14	31.60	0.19	**0.12**	35.00	0.35	42.6	0.44	88.5	0.92	45.2	0.45	91	0.74	1.00	1.00	4.00	1.00	2.00	0.40	84.60	0.29	**0.62**
Karimanelu	10	411.1	0.07	85.66	0.12	0.00	0.00	**0.07**	33.10	0.33	9.3	0.09	93.3	0.97	89.8	0.90	94.7	0.88	1.00	1.00	2.00	0.50	2.00	0.40	46.00	0.16	**0.58**
Kashipatna	10	100	0.02	58.75	0.08	0.00	0.00	**0.03**	49.00	0.52	24.3	0.25	0	0.00	66.3	0.67	97.4	0.98	0.00	0.00	3.00	0.75	2.00	0.40	55.80	0.19	**0.42**
Koyyur	10	734.25	0.13	704.60	1.00	27.40	0.17	**0.43**	22.50	0.20	14.8	0.15	6.5	0.07	42.3	0.42	84.3	0.49	0.00	0.00	4.00	1.00	4.00	0.80	160.67	0.54	**0.41**
Moodukodi	10	404	0.07	85.4	0.12	0.00	0.00	**0.06**	31.90	0.32	5.2	0.05	77.1	0.80	63.4	0.64	90.2	0.71	1.00	1.00	2.00	0.50	0.00	0.00	92.70	0.31	**0.48**
Nittade	10	429	0.08	30	0.04	0.00	0.00	**0.04**	65.10	0.72	35.7	0.37	20.8	0.22	99.4	1.00	96.2	0.93	1.00	1.00	2.00	0.50	2.00	0.40	75.10	0.25	**0.60**
Nyayatarpu	10	143.32	0.03	15.29	0.02	1.2	0.01	**0.02**	36.00	0.37	26	0.27	0	0.00	71.7	0.72	94	0.85	0.00	0.00	2.00	0.50	2.00	0.40	90.83	0.31	**0.38**
Odilnala	10	308.98	0.06	105.7	0.15	78.06	0.48	**0.23**	48.80	0.52	10.3	0.10	95.6	0.99	98.5	0.99	93.7	0.84	0.00	0.00	2.00	0.50	2.00	0.40	177.94	0.60	**0.55**
Shirthadi	10	55.15	0.01	30.21	0.04	0.00	0.00	**0.02**	37.30	0.38	3.1	0.03	0.6	0.01	62.6	0.63	89.7	0.69	0.00	0.00	1.00	0.25	2.00	0.40	71.77	0.24	**0.29**
Sonandur	10	14.5	0.00	7.3	0.01	25.74	0.16	**0.06**	26.10	0.25	32.8	0.34	56.7	0.59	97.8	0.98	82.4	0.42	1.00	1.00	2.00	0.50	2.00	0.40	64.40	0.22	**0.52**
Thotathadi	10	255.6	0.05	42.01	0.06	27.60	0.17	**0.09**	24.60	0.23	5	0.05	19.9	0.21	48.9	0.49	94.1	0.86	0.00	0.00	2.00	0.50	2.00	0.40	222.80	0.75	**0.39**
Valpadi	10	15.52	0.00	22.12	0.03	0.00	0.00	**0.01**	84.40	0.95	14.4	0.14	0.4	0.00	56.9	0.57	86.1	0.56	0.00	0.00	3.00	0.75	2.00	0.40	174.23	0.59	**0.44**



Annexure 2 (for section 3.4.3): Forest Livelihood Service Dependency

Human Capital					Social Capital							Financial Capital						
Literacy Rate		Total Workers		Human Capital	SHG		Nutritional centre &		ASHA Status		Social Capital	Mandi		Banks		Agriculture Credit Society		Financial Capital
Value	Normalized score	Value	Normalized score		Value	Normalized score	Value	Normalized score	Value	Normalized score		Value	Normalized score	Value	Normalized score	Value	Normalized score	
84.09	0.91	1325	0.15	0.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.56	0.89	2320	0.31	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.62	0.92	2900	0.40	0.66	1.00	1.00	1.00	1.00	0.00	0.00	0.67	1.00	1.00	1.00	1.00	0.00	0.00	0.67
82.38	0.89	2218	0.29	0.59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.92	0.90	818	0.07	0.48	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.04	0.91	1595	0.19	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.85	0.88	1003	0.10	0.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88.01	0.96	3824	0.54	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.43	0.88	3309	0.46	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.67
75.89	0.81	1721	0.21	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78.58	0.84	2246	0.30	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.90	0.88	1979	0.25	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.86	0.92	1919	0.24	0.58	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.33
79.20	0.85	457	0.01	0.43	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80.78	0.87	1613	0.20	0.53	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85.10	0.93	1328	0.15	0.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87.06	0.95	1066	0.11	0.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80.76	0.87	1205	0.13	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.33
82.34	0.89	1288	0.15	0.52	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79.31	0.85	426	0.01	0.43	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.98	0.89	720	0.06	0.47	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.76	0.88	2020	0.26	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.33
85.59	0.93	1147	0.12	0.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90.91	1.00	3532	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
87.35	0.95	481	0.02	0.49	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	1.00	1.00	0.00	0.00	0.33
78.48	0.84	1317	0.15	0.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79.41	0.85	652	0.04	0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.20	0.89	1083	0.11	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80.95	0.87	559	0.03	0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.23	0.90	368	0.00	0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.12	0.00	576	0.03	0.02	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.33
83.92	0.91	1052	0.11	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.18	0.91	2958	0.41	0.66	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.67
85.96	0.94	579	0.03	0.48	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.58	0.91	3188	0.44	0.68	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.33
83.58	0.91	1617	0.20	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.73	0.91	675	0.05	0.48	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79.75	0.86	872	0.08	0.47	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.68	0.89	1225	0.14	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80.95	0.87	1241	0.14	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.03	0.87	850	0.08	0.47	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85.04	0.92	1780	0.22	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.09	0.91	730	0.06	0.48	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88.39	0.97	3160	0.44	0.70	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
83.79	0.91	907	0.08	0.50	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79.32	0.85	1467	0.17	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87.34	0.95	1932	0.25	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.33
82.20	0.89	832	0.07	0.48	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85.03	0.92	2009	0.26	0.59	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.22	0.90	918	0.09	0.49	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76.66	0.82	835	0.07	0.45	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89.59	0.98	6710	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85.00	0.92	1035	0.11	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.82	0.92	720	0.06	0.49	1.00	1.00	1.00	1.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84.46	0.92	1220	0.13	0.53	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.33
86.03	0.94	2423	0.32	0.63	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.33
86.29	0.94	1664	0.20	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85.68	0.93	1639	0.20	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	0.33
86.09	0.94	1219	0.13	0.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.90	0.88	1320	0.15	0.52	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.45	0.90	2228	0.29	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.45	0.90	1471	0.17	0.54	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81.95	0.88	1205	0.13	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.66	0.89	876	0.08	0.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.64	0.89	1679	0.21	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87.27	0.95	1263	0.14	0.55	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80.59	0.87	1285	0.14	0.51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83.90	0.91	1909	0.24	0.58	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.72	0.89	1959	0.25	0.57	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



Annexure 2 (for section 3.4.3): River Livelihood Service Dependency

Name	Micro watershed Buffer	Natural Capital									Human Capital						
		Distance from the river		Forest Area		Barren Land		Presence of waterbody		Natural Capital	Literacy Rate		Agriculture Workers		Public transport		Human Capital
		Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score		Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	
Addur CT	2	3	1.00	0	0.00	8.4	0.03	0	0.00	**0.26**	4130	0.14	206	0.16	1.00	1.00	**0.43**
Ammunje	2	3	1.00	16	0.08	47	0.15	0	0.00	**0.31**	4190	0.14	268	0.23	0.00	0.00	**0.12**
Arala	2	3	1.00	19	0.09	91.03	0.29	0	0.00	**0.34**	2867	0.08	495	0.49	0.00	0.00	**0.19**
Badagaulipady CT	2	3	1.00	0	0.00	1.6	0.00	0	0.00	**0.25**	5522	0.20	149	0.09	1.00	1.00	**0.43**
Ervuailu	2	3	1.00	0	0.00	11.1	0.03	0	0.00	**0.26**	2233	0.06	634	0.65	0.00	0.00	**0.24**
Hosangadi	2	3	1.00	99	0.48	168.17	0.53	61.1	1.00	**0.75**	2447	0.07	608	0.62	1.00	1.00	**0.56**
Kariyangala CT	2	3	1.00	0	0.00	2.3	0.01	1.81	0.03	**0.26**	3766	0.12	937	1.00	1.00	1.00	**0.71**
Kolavooru	2	3	1.00	0	0.00	6.4	0.02	0	0.00	**0.25**	1813	0.04	629	0.65	1.00	1.00	**0.56**
Mallur	2	3	1.00	0	0.00	28.86	0.09	0	0.00	**0.27**	2708	0.08	102	0.04	1.00	1.00	**0.37**
Mogaru	2	3	1.00	0	0.00	10	0.03	0	0.00	**0.26**	2013	0.05	187	0.14	0.00	0.00	**0.06**
Mulur CT	2	3	1.00	0	0.00	18.2	0.06	0	0.00	**0.26**	4446	0.15	86	0.02	1.00	1.00	**0.39**
Muthuru	2	3	1.00	0	0.00	6.7	0.02	0	0.00	**0.26**	1425	0.02	297	0.26	0.00	0.00	**0.10**
Puchhamoguru	2	3	1.00	66.31	0.32	80.23	0.25	0	0.00	**0.39**	1664	0.03	68	0.00	0.00	0.00	**0.01**
Rayee	2	3	1.00	0	0.00	16.92	0.05	0	0.00	**0.26**	1569	0.03	306	0.27	0.00	0.00	**0.10**
Sangabettu	2	3	1.00	48	0.23	232.72	0.73	0	0.00	**0.49**	3348	0.10	278	0.24	0.00	0.00	**0.12**
Tankaulipady	2	3	1.00	0	0.00	22.64	0.07	0	0.00	**0.27**	1682	0.03	154	0.10	0.00	0.00	**0.04**
Ulaibettu	2	3	1.00	0	0.00	20.81	0.06	0	0.00	**0.27**	3164	0.10	199	0.15	0.00	0.00	**0.08**
Adyapady	5	2	0.50	0	0.00	6.2	0.02	0	0.00	**0.13**	1614	0.03	123	0.06	1.00	1.00	**0.36**
Arambodi	5	2	0.50	107.14	0.52	28	0.09	10.8	0.18	**0.32**	2614	0.07	358	0.33	0.00	0.00	**0.14**
Badaga Bellur	5	2	0.50	3	0.01	318.1	1.00	0	0.00	**0.38**	2832	0.08	619	0.63	0.00	0.00	**0.24**
Badakodi	5	2	0.50	121	0.59	67.92	0.21	0	0.00	**0.32**	991	0.00	190	0.14	0.00	0.00	**0.05**
Bondathila CT	5	2	0.50	0	0.00	0.2	0.00	0	0.00	**0.13**	4699	0.16	325	0.30	1.00	1.00	**0.49**
Hosabettu	5	2	0.50	173.36	0.84	124.07	0.39	0	0.00	**0.43**	1876	0.04	172	0.12	0.00	0.00	**0.05**
Kandavara	5	2	0.50	0	0.00	20.08	0.06	0	0.00	**0.14**	2683	0.08	464	0.46	1.00	1.00	**0.51**
Karpe	5	2	0.50	14	0.07	128.26	0.40	0	0.00	**0.24**	1215	0.01	572	0.58	0.00	0.00	**0.20**
Killenjaru	5	2	0.50	0	0.00	12.72	0.04	0	0.00	**0.13**	2492	0.07	698	0.72	0.00	0.00	**0.26**
Koila	5	2	0.50	47	0.23	71.47	0.22	0	0.00	**0.24**	1663	0.03	277	0.24	0.00	0.00	**0.09**
Kukkipady	5	2	0.50	79	0.38	179.3	0.56	0	0.00	**0.36**	2410	0.06	554	0.56	0.00	0.00	**0.21**
Kuriyala	5	2	0.50	9	0.04	146	0.46	0	0.00	**0.25**	1779	0.04	573	0.58	1.00	1.00	**0.54**
Mudushedde CT	5	2	0.50	0	0.00	11.3	0.03	7.74	0.13	**0.17**	6468	0.24	101	0.04	1.00	1.00	**0.42**
Neermarga CT	5	2	0.50	0	0.00	14.3	0.04	0	0.00	**0.14**	4627	0.16	334	0.31	1.00	1.00	**0.49**
Padukonaje	5	2	0.50	119.74	0.58	4.8	0.01	0	0.00	**0.27**	1014	0.00	153	0.10	1.00	1.00	**0.37**
Tenkabellur	5	2	0.50	0	0.00	16	0.05	0	0.00	**0.14**	982	0.00	132	0.07	0.00	0.00	**0.03**
Tenkayedapadavu	5	2	0.50	110.31	0.53	6.04	0.02	0	0.00	**0.26**	4784	0.17	313	0.28	0.00	0.00	**0.15**
Eliyanadugodu	7	1	0.00	39	0.19	43.71	0.14	0	0.00	**0.08**	1091	0.01	378	0.36	0.00	0.00	**0.12**
Gunduri	7	1	0.00	201	0.97	83	0.26	0	0.00	**0.31**	909	0.00	335	0.31	0.00	0.00	**0.10**
Kolambe CT	7	1	0.00	0	0.00	8.1	0.02	0	0.00	**0.01**	4480	0.15	608	0.62	1.00	1.00	**0.59**
Malavoor	7	1	0.00	0	0.00	8.42	0.03	0	0.00	**0.01**	2639	0.07	143	0.09	0.00	0.00	**0.05**
Moodukonaje	7	1	0.00	1.02	0.00	41.16	0.13	0	0.00	**0.03**	1493	0.02	262	0.22	1.00	1.00	**0.42**
Mudbidri	7	1	0.00	0	0.00	10.9	0.03	6.26	0.10	**0.03**	24377	1.00	424	0.41	1.00	1.00	**0.80**
Venooru	7	1	0.00	206.3	1.00	1.7	0.00	27.7	0.45	**0.36**	1765	0.04	218	0.17	1.00	1.00	**0.40**



Annexure 2 (for section 3.4.3): River Livelihood Service Dependency

Physical Capital																		
% HH with permanent house		Tap Water %		Septic Tank %		Drainage %		Improved Latrine %		Access to road		Educational facility		Healthcare		Wells & tube wells		Physical Capital
Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	Value	Normalized Score	
94.60	1.00	91	0.94	94	0.95	93	0.94	92.2	0.76	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
69.80	0.71	38.7	0.39	20.3	0.20	36.3	0.37	95	0.86	1.00	1.00	1	1.00	1.00	1.00	181.30	0.53	0.67
70.10	0.71	49.1	0.49	16.7	0.17	27.7	0.28	90.3	0.70	0.00	0.00	1	1.00	1.00	1.00	167.40	0.49	0.54
84.40	0.88	96	0.99	95	0.96	93	0.94	94.3	0.84	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
66.40	0.67	42.3	0.42	86.6	0.87	2.9	0.03	89	0.65	0.00	0.00	1	1.00	1.00	1.00	81.00	0.24	0.54
11.60	0.02	37	0.37	58.3	0.59	75.5	0.76	95.3	0.87	1.00	1.00	1	1.00	1.00	1.00	218.40	0.64	0.69
81.30	0.84	97	1.00	94	0.95	93	0.94	94.2	0.83	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
71.10	0.72	51.9	0.52	0	0.00	0	0.00	89.1	0.66	0.00	0.00	1	1.00	1.00	1.00	78.36	0.23	0.46
61.00	0.60	58.6	0.59	0.6	0.01	84.4	0.85	90.7	0.71	0.00	0.00	1	1.00	1.00	1.00	48.73	0.14	0.55
71.60	0.73	2.2	0.00	0	0.00	33.3	0.34	91.5	0.74	0.00	0.00	1	1.00	1.00	1.00	101.44	0.30	0.46
83.20	0.86	96	0.99	94	0.95	94	0.95	92.3	0.77	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
61.30	0.61	14.9	0.13	30.5	0.31	69.7	0.70	93	0.79	0.00	0.00	1	1.00	1.00	1.00	87.32	0.26	0.53
69.40	0.70	2.8	0.01	75.8	0.76	59.2	0.60	91.3	0.73	0.00	0.00	1	1.00	0.00	0.00	110.20	0.32	0.46
61.90	0.61	66.1	0.67	63	0.63	32.5	0.33	91.8	0.75	0.00	0.00	1	1.00	1.00	1.00	128.11	0.38	0.60
19.10	0.11	35.3	0.35	37.2	0.37	40.1	0.41	92.2	0.76	0.00	0.00	1	1.00	1.00	1.00	199.80	0.59	0.51
61.10	0.60	50	0.50	90.5	0.91	8.2	0.08	99.1	1.00	0.00	0.00	1	1.00	1.00	1.00	122.47	0.36	0.61
11.60	0.02	51.6	0.52	92.5	0.93	46.4	0.47	96	0.89	0.00	0.00	1	1.00	1.00	1.00	124.30	0.36	0.58
81.10	0.84	57.5	0.58	86.4	0.87	0	0.00	86.8	0.58	0.00	0.00	1	1.00	1.00	1.00	0.00	0.00	0.54
81.90	0.85	7	0.05	0.5	0.01	82	0.83	90.8	0.72	0.00	0.00	1	1.00	1.00	1.00	268.80	0.79	0.58
11.70	0.02	63.7	0.65	2.3	0.02	64.2	0.65	92.6	0.78	0.00	0.00	1	1.00	1.00	1.00	211.10	0.62	0.53
30.40	0.24	9.1	0.07	90.1	0.91	98.9	1.00	90.5	0.71	0.00	0.00	1	1.00	0.00	0.00	181.70	0.53	0.50
84.80	0.88	92	0.95	92	0.93	91	0.92	92.3	0.77	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.83
77.80	0.80	28.8	0.28	94.4	0.95	9	0.09	94.6	0.85	0.00	0.00	1	1.00	1.00	1.00	111.14	0.33	0.59
87.80	0.92	52.3	0.53	92.4	0.93	1.1	0.01	94.1	0.83	0.00	0.00	1	1.00	1.00	1.00	84.22	0.25	0.61
21.10	0.13	40.3	0.40	87.3	0.88	78.8	0.80	90.5	0.71	0.00	0.00	1	1.00	1.00	1.00	124.70	0.37	0.59
81.80	0.85	45.7	0.46	98.1	0.99	96.3	0.97	98.9	0.99	0.00	0.00	1	1.00	1.00	1.00	117.34	0.34	0.73
78.90	0.81	21.5	0.20	84.4	0.85	8.7	0.09	94.2	0.83	0.00	0.00	1	1.00	0.00	0.00	119.11	0.35	0.46
11.60	0.02	44	0.44	65.8	0.66	94.3	0.95	93	0.79	0.00	0.00	1	1.00	1.00	1.00	119.11	0.35	0.58
10.20	0.00	27.8	0.27	21.2	0.21	97.3	0.98	98.4	0.98	0.00	0.00	0	0.00	1.00	1.00	174.40	0.51	0.44
87.20	0.91	94	0.97	95	0.96	92	0.93	94.3	0.84	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
94.10	0.99	92	0.95	96	0.97	94.5	0.96	91	0.72	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
17.70	0.09	30.6	0.30	99.3	1.00	2.5	0.03	72.2	0.08	0.00	0.00	1	1.00	0.00	0.00	146.20	0.43	0.32
14.70	0.05	36.2	0.36	93.3	0.94	27.3	0.28	91.8	0.75	0.00	0.00	0	0.00	1.00	1.00	81.40	0.24	0.40
86.10	0.90	13.2	0.12	89.4	0.90	48.9	0.49	92.6	0.78	1.00	1.00	1	1.00	1.00	1.00	341.36	1.00	0.80
40.10	0.35	18.7	0.17	60.9	0.61	43.6	0.44	90.8	0.72	0.00	0.00	1	1.00	1.00	1.00	133.80	0.39	0.52
11.30	0.01	21.4	0.20	47.3	0.48	58.9	0.60	87.9	0.62	1.00	1.00	1	1.00	1.00	1.00	81.10	0.24	0.57
93.30	0.98	94	0.97	92	0.93	91	0.92	91.3	0.73	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.84
86.70	0.91	58	0.59	83.2	0.84	1.1	0.01	91.8	0.75	1.00	1.00	1	1.00	1.00	1.00	88.41	0.26	0.71
12.70	0.03	6.3	0.04	80.2	0.81	1.7	0.02	69.9	0.00	0.00	0.00	1	1.00	1.00	1.00	116.60	0.34	0.36
84.30	0.88	92	0.95	94	0.95	92	0.93	93.2	0.80	1.00	1.00	1	1.00	1.00	1.00	0.00	0.00	0.83
17.10	0.08	15.6	0.14	15.7	0.16	78.8	0.80	87.9	0.62	1.00	1.00	1	1.00	1.00	1.00	197.70	0.58	0.60



Annexure 2 (for section 3.4.3): River Livelihood Service Dependency

Social Capital							Financial Capital							
SHG		Nutritional centre &		ASHA Status		Social Capital	Mandi		Banks		Agricultural Credit		Financial Capital	Dependency
Value	Normalized Score	Value	Normalized Score	Value	Normalized Score		Value	Normalized Score	Value	Normalized Score	Value	Normalized Score		
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.71**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.35**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.35**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.71**
0.00	0.00	1.00	1.00	0.00	0.00	**0.33**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.27**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.53**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.76**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.39**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.37**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.29**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.70**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.31**
0.00	0.00	1.00	1.00	0.00	0.00	**0.33**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.24**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.33**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	1.00	1.00	0.00	0.00	**0.33**	**0.42**
0.00	0.00	1.00	1.00	0.00	0.00	**0.33**	1.00	1.00	0.00	0.00	0.00	0.00	**0.33**	**0.32**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.32**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.34**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.34**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.36**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.31**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.69**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	1.00	1.00	0.00	0.00	0.00	0.00	**0.33**	**0.41**
0.00	0.00	1.00	1.00	0.00	0.00	**0.33**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.32**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	1.00	1.00	0.00	0.00	0.00	0.00	**0.33**	**0.41**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.36**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	1.00	1.00	0.00	0.00	0.00	0.00	**0.33**	**0.36**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.36**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.38**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.69**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.69**
0.00	0.00	1.00	1.00	0.00	0.00	**0.33**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.26**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.25**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.38**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.28**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.33**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.69**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.29**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.30**
1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**	**0.73**
0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	0.00	0.00	1.00	1.00	1.00	1.00	**0.67**	**0.54**



Annexure 3 (for section 3.6.7): Prioritization of Sub-watersheds

Indicators	Ecological Indicators																Demographic Indicators				Socio-Economic Indicators						LULC Indicators								Institutional	Total
Analytical tool used	Abiotic aspect						Biotic				Basin Morphometry				Flooding				Demography & livelihood analysis				Scalogram		Dependency & Livelihood analysis		Impact Matrix		Change detection								Governance	
Parameter	Rainfall		Slope		Groundwater		Mangrove Area		NDVI		Bifurcation ratio		Drainage density		Flow		Flood susceptibility		Population density		Urban populaiton		Order of settlements		Ecosystem service dependency ratio		Impact of economic activities		Forest area expansion		Built-up area expansion		Waterbody		Agriculture area expansion		Master plan	
Relevance	More rainfall higher the priority		Gentle slope, higher priority		Deeper the water table, higher the priority		Presence- High priority		Less NDVI, High priority		Higher the value, higher the flood risk		Higher the value, higher the flood risk		Higher the value, higher the flood susceptibility		Higher the value, higher the flood risk		Higher the density, higher the priority		More urban populaiton, more the priority		More number of higher order settlements, higher the priority		More the ratio, more the priority		More the presence of economic activities more the priority		More forest area, lesser priority for development		Higher the built up, more the priority		Presence of waterbody (In this case River) is always prefered for development, high priority		More the area, more scope for population growth more the priority		Presence of masterplan, high priority	
Subwatershed	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Score	
4D4D3F	< 3900	1	High	1	1-15M	1	Absent	1	Low	3	Medium	2	Low	1	low	1	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	Low	1	Low	1	Low	1	Low	1	1	24
4D4D3T	< 3901	1	High	1	1-15M	1	Absent	1	Low	3	Medium	2	Low	1	low	1	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	Low	3	Low	1	Low	1	Low	1	1	24
4D4D7P	< 3902	1	High	1	1-15M	1	Absent	1	Medium	2	Low	1	Low	1	low	1	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Low	1	Low	3	Low	1	Low	1	Low	1	1	21
5A3A7F	< 3903	1	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	Low	1	low	1	<30%	1	5-10PPH	2	Low	1	Medium	2	Low	1	Low	1	Medium	2	Low	1	Low	1	Low	1	1	24
5A3A7I	< 3904	1	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	Low	1	low	1	30-60%	2	5-10PPH	2	Low	1	High	3	Low	1	Low	1	Medium	2	Low	1	Low	1	Low	1	1	28
5A3A7N	3900 - 4100	2	Low	3	>20M	3	Present	3	Low	3	Low	1	Low	1	Medium	2	30-60%	2	>10PPH	3	High	3	Low	1	High	3	Medium	2	Low	1	Medium	2	Low	1	High	3	3	45
5A3B1A	>4100	3	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	Low	1	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	Medium	2	High	1	Medium	2	Low	1	Low	1	1	27
5A3B1B	>4100	3	Low	3	1-15M	1	Absent	1	High	1	Low	1	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	Medium	2	High	1	Medium	2	Medium	2	Medium	2	1	29
5A3B1C	>4100	3	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	Medium	2	Medium	2	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Medium	2	High	1	Medium	2	Low	1	Low	1	1	27
5A3B1D	>4100	3	Low	3	1-15M	1	Absent	1	Low	3	Low	1	Medium	2	High	3	30-60%	2	5-10PPH	2	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	High	3	Low	1	1	33
5A3B1E	>4100	3	Low	3	1-15M	1	Absent	1	Medium	2	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	Medium	2	Medium	2	1	32
5A3B1F	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Low	1	Medium	2	High	3	>60%	3	5-10PPH	2	Medium	2	Low	1	Medium	2	Low	1	Medium	2	Low	1	Low	1	Low	1	1	31
5A3B1G	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	High	3	High	3	>60%	3	5-10PPH	2	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	High	3	High	3	1	37
5A3B1H	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Low	1	Medium	2	Medium	2	>60%	3	5-10PPH	2	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	Low	1	Medium	2	1	32
5A3B1I	3900 - 4100	2	Low	3	>20M	3	Present	3	Low	3	Low	1	High	3	High	3	>60%	3	>10PPH	3	High	3	High	3	High	3	Medium	2	Low	3	Medium	2	High	3	Low	1	3	48
5A3B1J	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Low	1	High	3	High	3	>60%	3	>10PPH	3	High	3	Medium	2	High	3	High	3	Medium	2	High	3	High	3	High	3	1	43
5A3B2P	< 3900	1	High	1	1-15M	1	Absent	1	High	3	Low	1	High	3	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	Low	1	1	21
5A3B2R	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Medium	2	Low	1	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	High	1	Low	1	Medium	2	Low	1	1	24
5A3B2V	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Medium	2	Low	1	High	3	<30%	1	<5PPH	1	Low	1	High	3	Low	1	Low	1	High	1	Low	1	Medium	2	Low	1	1	25
5A3B2Y	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	Low	1	High	3	30-60%	2	5-10PPH	2	Low	1	Medium	2	Low	1	Low	1	High	1	Low	1	High	3	Low	1	1	29
5A3B3A	3900 - 4100	2	High	1	1-15M	1	Absent	1	Medium	2	Medium	2	Medium	2	High	5	<30%	1	<5PPH	1	Low	1	Medium	2	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	24
5A3B3B	>4100	3	High	1	1-15M	1	Absent	1	Medium	2	Medium	2	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	25
5A3B3C	>4100	3	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	High	3	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	26
5A3B3D	< 3900	1	High	1	1-15M	1	Absent	1	High	1	High	3	Low	1	Medium	2	<30%	1	<5PPH	1	Low	1	High	3	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	23
5A3B3E	>4100	3	Low	3	15-20M	2	Absent	1	Medium	2	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	High	3	Medium	2	Medium	2	High	1	Medium	2	Low	1	Low	1	1	32
5A3B3F	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	Medium	2	High	5	<30%	1	<5PPH	1	Low	1	Medium	2	Medium	2	High	1	Medium	2	Low	1	Low	1	Low	1	1	26
5A3B3G	3900 - 4100	2	High	1	1-15M	1	Absent	1	High	1	Medium	2	Low	1	High	3	<30%	1	<5PPH	1	Low	1	High	3	Low	1	Low	1	High	1	Low	1	Low	1	Low	1	1	21
5A3B3H	< 3900	1	High	1	1-15M	1	Absent	1	High	1	Medium	2	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	High	3	Low	1	Low	1	High	1	Low	1	Medium	2	Low	1	1	23
5A3B3I	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	High	1	Low	1	High	3	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	Medium	2	Low	1	Low	1	Low	1	1	22
5A3B3J	< 3900	1	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	Low	1	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	Low	1	1	21
5A3B3K	< 3900	1	Medium	2	1-15M	1	Absent	1	High	1	High	3	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	High	1	Low	1	Medium	2	Medium	2	Medium	2	1	27
5A3B3L	>4100	3	Low	3	15-20M	2	Absent	1	Medium	2	Medium	2	High	3	High	3	30-60%	2	<5PPH	1	Low	1	High	3	Medium	2	Medium	2	High	1	Medium	2	Medium	2	Medium	2	1	32
5A3B3M	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Low	1	High	3	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	High	1	High	1	Low	1	Low	1	Low	1	1	24
5A3B3N	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Low	1	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	High	1	Low	1	Medium	2	Low	1	1	24
5A3B3O	>4100	3	Medium	2	15-20M	2	Absent	1	Medium	2	Medium	2	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	High	1	Low	1	Low	1	Low	1	1	26
5A3B3P	>4100	3	Low	3	15-20M	2	Absent	1	Medium	2	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Medium	2	High	1	Medium	2	Low	1	Low	1	Low	1	1	31
5A3B3Q	>4100	3	Low	3	1-15M	1	Absent	1	High	1	Low	1	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	High	3	Medium	2	High	1	Low	3	Low	1	High	1	Low	1	1	29
5A3B3R	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Medium	2	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	High	3	Low	1	Medium	2	High	1	Medium	2	Low	1	Low	1	1	27
5A3B3S	>4100	3	Low	3	1-15M	1	Absent	1	High	1	Medium	2	High	3	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Medium	2	High	1	Medium	2	Low	1	Low	1	Low	1	1	29
5A3B3T	>4100	3	Low	3	1-15M	1	Absent	1	High	1	Low	1	High	3	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	High	1	Low	1	Medium	2	Low	1	1	26
5A3B3U	>4100	3	Low	3	1-15M	1	Absent	1	Medium	2	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	Medium	2	High	1	Low	1	Low	1	1	29
5A3B4A	>4100	3	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	High	3	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Medium	2	High	1	Low	1	Low	1	Low	1	1	29
5A3B4B	>4100	3	Medium	2	1-15M	1	Absent	1	Medium	2	Low	1	High	3	High	3	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Low	1	High	1	Low	1	Low	1	Low	1	1	24
5A3B4C	>4100	3	Low	3	1-15M	1	Absent	1	High	1	Low	1	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	Low	1	High	1	Low	1	Low	1	Low	1	1	24
5A3B4D	>4100	3	High	1	1-15M	1	Absent	1	Medium	2	Low	1	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Low	1	High	1	Low	1	Low	1	Low	1	1	22
5A3B4E	>4100	3	Low	3	1-15M	1	Absent	1	High	1	High	3	Medium	2	High	3	>60%	3	<5PPH	1	Low	1	Low	1	Low	1	Medium	2	High	1	Medium	2	Low	1	Low	1	1	30
5A3B4F	>4100	3	Low	3	1-15M	1	Absent	1	Medium	2	High	3	Low	1	Medium	2	30-60%	2	<5PPH	1	Low	1	Medium	2	High	3	Medium	2	High	1	Medium	2	Low	1	Medium	2	1	32
5A3B4G	>4100	3	Low	3	1-15M	1	Absent	1	Medium	2	High	3	Medium	2	High	3	>60%	3	<5PPH	1	Low	1	Medium	2	Medium	2	High	1	Medium	2	Medium	2	Medium	2	Medium	2	1	34
5A3B4H	>4100	3	Medium	2	1-15M	1	Absent	1	High	1	High	3	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	27
5A3B4I	>4100	3	Low	3	15-20M	2	Absent	1	Medium	2	Medium	2	High	3	High	3	30-60%	2	<5PPH	1	Low	1	Low	1	Low	1	Medium	2	High	1	Medium	2	Low	1	Medium	2	1	31
5A3B4J	3900 - 4100	2	Low	3	>20M	3	Absent	1	Medium	2	High	3	Low	1	High	3	>60%	3	<5PPH	1	Medium	2	Low	1	High	3	High	1	High	3	Low	1	High	3	High	3	1	35
5A3B4K	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	High	3	High	3	<30%	1	<5PPH	1	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	Medium	2	Medium	2	1	29
5A3B4L	3900 - 4100	2	Low	3	15-20M	2	Absent	1	Medium	2	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Medium	2	Low	1	Low	1	Medium	2	High	1	Medium	2	Medium	2	Medium	2	1	31
5A3B4M	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Medium	2	High	3	High	3	30-60%	2	5-10PPH	2	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	Low	1	High	3	1	32
5A3B4N	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	High	3	High	3	>60%	3	5-10PPH	2	High	3	Low	1	High	3	Medium	2	High	1	Medium	2	Low	1	High	3	1	37
5A3B4O	3900 - 4100	2	Low	3	15-20M	2	Absent	1	Low	3	Medium	2	Medium	2	High	5	>60%	3	>20PPH	3	High	3	Low	1	High	3	High	3	Medium	2	Medium	2	Medium	2	Medium	2	2	42
5A3B4P	3900 - 4100	2	Low	3	1-15M	1	Present	3	Low	3	Low	1	Medium	2	High	3	>60%	3	5-10PPH	2	High	3	Medium	2	High	3	High	3	Medium	2	High	3	Medium	2	Medium	2	3	49
5A3B4Q	3900 - 4100	2	Low	3	>20M	3	Present	3	Low	3	Low	1	High	3	High	3	>60%	3	>10PPH	3	High	3	High	3	High	3	Medium	2	High	3	High	3	Low	1	Low	1	1	48
5A3B5D	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Medium	2	Low	1	Low	1	30-60%	2	<5PPH	1	Low	1	High	3	Low	1	Low	1	Low	1	Low	1	Low	1	Low	1	1	29
5A3B5L	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	High	3	Low	1	Medium	2	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	Medium	2	Low	1	Low	1	Low	1	Low	1	1	27
5A3B5M	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Low	1	Medium	2	Medium	2	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Medium	2	Low	1	Low	1	Low	1	Low	1	1	22
5A3B5N	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	Low	1	Medium	2	Medium	2	30-60%	2	<5PPH	1	Low	1	Low	1	Low	1	High	1	Low	1	Low	1	Medium	2	Low	1	1	24
5A3B5O	3900 - 4100	2	Low	3	15-20M	2	Absent	1	Low	3	Medium	2	Low	1	Medium	2	30-60%	2	<5PPH	1	Medium	2	Medium	2	High	3	High	3	High	1	High	3	Low	1	Low	1	1	34
5A3B5P	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	Medium	2	High	3	Medium	2	Low	1	Medium	2	Low	1	Low	1	1	26
5A3B5Q	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Low	3	High	3	Low	1	High	3	>60%	3	<5PPH	1	Low	1	Low	1	Low	1	Low	1	Low	3	Low	1	Low	1	Low	1	1	29
5A3B5R	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	Low	1	High	3	30-60%	2	<5PPH	1	Low	1	Low	1	Low	1	High	1	Medium	2	Low	1	Low	1	Low	1	1	26
5A3B5S	3900 - 4100	2	Low	3	1-15M	1	Present	3	Low	3	Low	1	Low	1	High	3	>60%	3	5-10PPH	2	Medium	2	Medium	2	High	3	High	3	Medium	2	Medium	2	Medium	2	Medium	2	3	41
5A3B5T	3900 - 4100	2	Low	3	15-20M	2	Absent	1	Medium	2	Low	1	Medium	2	High	3	30-60%	2	<5PPH	1	Medium	2	Medium	2	Low	1	Medium	2	High	1	Medium	2	Medium	2	Medium	2	1	30
5A3B5U	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	Medium	2	Medium	2	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	Medium	2	High	1	Medium	2	Low	1	Medium	2	1	28
5A3B5V	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Medium	2	Medium	2	Medium	2	>60%	3	5-10PPH	2	Low	1	Medium	2	Low	1	Medium	2	High	1	Medium	2	Low	1	Low	1	1	30
5A3B5W	3900 - 4100	2	Low	3	1-15M	1	Present	3	Low	3	Medium	2	High	3	High	3	>60%	3	5-10PPH	2	High	3	High	3	High	3	High	3	High	1	High	3	Medium	2	Medium	2	3	49
5A3B6A	>4100	3	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	High	3	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	High	3	Medium	2	Low	1	Medium	2	Low	1	Low	1	1	32
5A3B6B	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Medium	2	High	3	High	3	30-60%	2	<5PPH	1	Low	1	High	3	Medium	2	Low	1	High	1	Medium	2	Low	1	Low	1	1	30
5A3B6C	3900 - 4100	2	Low	3	15-20M	2	Absent	1	High	1	Medium	2	Low	1	High	3	30-60%	2	<5PPH	1	Low	1	High	3	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	27
5A3B6D	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	Medium	2	High	3	<30%	1	<5PPH	1	Low	1	High	3	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	25
5A3B6E	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	High	1	High	3	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	Low	1	1	26
5A3B6F	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Medium	2	Low	1	High	1	Low	1	Medium	2	Low	1	1	27
5A3B6G	3900 - 4100	2	Low	3	1-15M	1	Absent	1	High	1	Medium	2	Medium	2	High	3	30-60%	2	<5PPH	1	Low	1	Medium	2	Low	1	High	1	Low	1	Low	1	Medium	2	Low	1	1	27
5A3B6H	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	High	1	Low	1	Medium	2	Low	1	<30%	1	<5PPH	1	Low	1	Low	1	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	1	22
5A3B6I	3900 - 4100	2	Low	3	1-15M	1	Absent	1	Medium	2	Low	1	High	3	30-60%	2	<5PPH	1	Low	1	High	3	Medium	2	Low	1	Medium	2	Low	1	Medium	2	Low	1	Low	1	1	29
5A3B6K	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	High	1	Medium	2	Low	1	Medium	2	<30%	1	<5PPH	1	Low	1	Medium	2	Low	1	High	1	Low	1	Low	1	Low	1	Low	1	1	23
5A3B6L	3900 - 4100	2	High	1	1-15M	1	Absent	1	High	1	Medium	2	Low	1	High	3	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Medium	2	Low	1	Low	1	Low	1	Low	1	1	21
5A3B7A	3900 - 4100	2	Medium	2	1-15M	1	Absent	1	Medium	2	Low	1	Low	1	Low	1	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Low	1	Low	3	Low	1	Low	1	Low	1	1	23
5A3B7B	3900 - 4100	2	High	1	1-15M	1	Absent	1	High	1	Low	1	Low	1	Low	1	<30%	1	<5PPH	1	Low	1	Low	1	Low	1	Medium	2	Low	1	Low	1	Low	1	Low	1	1	20

Indicators	Ecological Indicators										Demographic Indicators		Socio-Economic Indicators			LULC Indicators				Institutional	Total
Analytical tool used	Abiotic aspect			Biotic		Basin Morphometry		Flooding			Demography & livelihood analysis		Scalogram	Dependency & Livelihood analysis	Impact Matrix	Change detection				Governance	
Parameter	Rainfall	Slope	Groundwater	Mangrove Area	NDVI	Bifurcation ratio	Drainage density	Flow	Flood susceptibility		Population density	Urban populaiton	Order of settlements	Ecosystem service dependency ratio	Impact of economic activities	Forest area expansion	Built-up area expansion	Waterbody	Agriculture area expansion	Master plan	
Relevance	More rainfall higher the priority	Gentle slope, higher priority	Deeper the water table, higher the priority	Presence- High priority	Less NDVI, High priority	Higher the value, higher the flood risk	Higher the value, higher the flood risk	Higher the value, higher the flood susceptibility	Higher the value, higher the flood risk		Higher the density, higher the priority	More urban populaiton, more the priority	More number of higher order settlements, higher the priority	More the ratio, more the priority	More the presence of economic activities more the priority	More forest area, lesser priority for development	Higher the built up, more the priority	Presence of waterbody (In this case River) is always prefered for development, high priority	More the area, more scope for population growth more the priority	Presence of masterplan, high priority	



Annexure 4 (for section 5.6.4): Impact Matrix (Mangaluru City)

Affected Aspect			Economic Activities																										
			Agriculture					Fishing							Industry														
Category	Components affected	Total Score	Plowing	Use of chemical fertilizers & pesticides	Irrigation using ground water	Average	Observation	Mechanized trawling in estuary/coast	Traditional riverine and estuarine fishing	Use of outboard motors (diesel/ petrol)	Fish processing and waste disposal	Drying and marketing of fish	Average	Observation	Manufacturing (chemicals, paper, food, etc.)	Use of boilers (firewood, diesel)	Effluent discharge to water bodies	Handling of produce	Solid/hazardous waste handling	Industrial transport & logistics	Average	Observation
Physical Environment	Air	11.0	2	2	1	1.7	The agricultural practice in the urban area is mainly through ground water & is impacting the ground water levels, modifying river quality through chemical use	2	1	3	2	1	1.8	Mechanised operations & waste handling is polluting the water & generating noise	3	3	2	1	3	3	2.5	Air & Water pollution is significant. CEPI Area with73.68 score in 2018
	Costal waterbody & Estuarian	13.2	1	3	1	1.7		3	3	3	3	2	2.8		3	2	3	3	3	2	2.7	
	Inland Rivers	14.4	1	3	2	2.0		2	1	2	3	2	2		2	2	3	3	3	2	2.5	
	Inland waterbodies	10.1	1	3	2	2.0		1	1	1	2	2	1.4		1	1	2	2	2	1	1.5	
	Ground water	11.3	1	3	3	2.3		1	1	1	2	1	1.2		2	1	3	2	3	2	2.2	
	Land & Soil	12.4	2	3	2	2.3		2	1	1	3	2	1.8		2	1	2	1	3	2	1.8	
	Micro-climate	9.0	2	1	2	1.7		1	1	2	1	1	1.2		2	2	1	1	1	2	1.5	
Biological Aspect	Terrestrial Flora	12.0	2	3	2	2.3	Intensive agriculture reduces biodiversity & harms terrestrial & aquatic species & alters habitat die to chemical run-off	2	1	1	2	1	1.4	Mechanised trawling, pollution is degrading the habitat, reduced fish population is an issue	2	2	2	1	2	2	1.8	Chemical & effluent discharge is impacting the aquatic flora and fauna. Reduced mangrove area & fish deaths have been observed.
	Terrestrial Fauna	11.7	2	3	2	2.3		2	1	1	2	1	1.4		2	2	2	1	2	2	1.8	
	Aquatic Flora	12.8	1	3	1	1.7		3	1	2	2	1	1.8		2	1	3	1	3	2	2.0	
	Aquatic Fauna	13.0	1	3	1	1.7		3	1	2	3	1	2		2	1	3	1	3	2	2.0	
Socio-cultural Aspect	Livelihood	10.4	1	1	1	1.0	No significant impact noticed	2	1	2	3	1	1.8	Fising supports the livelihood of the local fishermen community, but the unsaitary practices is exposing them to health hazards	2	2	3	1	3	2	2.2	While the industry sector supports livelihood of the local population, it has high impact on their health
	Health	12.3	1	2	1	1.3		2	1	3	3	2	2.2		3	3	3	2	3	3	2.8	
	Culture	8.9	1	1	1	1.0		3	1	2	2	1	1.8		2	2	2	1	2	1	1.7	
Average			1.4	2.4	1.6	25.0		2.1	1.1	1.9	2.4	1.4	24.6		2.1	1.8	2.4	1.5	2.6	2.0	29.0	

Port								Built-up						Tourism					
Cargo handling (loading/unloading)	Ship docking & maintenance	Oil/fuel transfer and refueling	Dredging of river mouth and estuary (Old Port)	Land reclamation & warehousing	Average	Observation	Untreated-sewage	Solid waste dumping	Impervious surface run-off	Flood plain encroachment	Average	Observation	Beach and river-based tourism (boating, recreation)	Hotel and resort development	Tourist waste generation	Road transport & parking	Average	Observation
2	2	2	1	2	1.8	Port operations & expansion has lead to altered coastal landform though dredging & reclamation	2	2	1	1	1.5	untreated sewage inflow, solid waste dumping, and altered stormwater pathways, degrading the Gurupura's water	2	2	1	2	1.75	Waste generation, land use changes, increased vehicular emissions, and strain on local air, water, and soil quality.
2	1	2	2	1	1.6		3	2	2	2	2.25		2	3	2	2	2.25	
2	2	3	3	2	2.4		3	3	3	3	3		3	2	3	2	2.5	
1	1	2	1	1	1.2		3	3	2	2	2.5		1	2	2	1	1.5	
1	2	2	2	2	1.8		3	1	3	1	2		2	2	2	1	1.75	
2	2	2	2	3	2.2		2	2	2	1	1.75		2	3	3	2	2.5	
1	1	1	2	2	1.4		1	1	3	1	1.5		2	2	1	2	1.75	
2	2	2	3	3	2.4	Dredging, spillage during handling & shoreline modification has impacted the biodiversity	2	2	2	1	1.75	Encroachment and pollution from built-up areas reduce mangroves, disturb aquatic life, and fragment riparian habitats.	2	3	2	2	2.25	Habitat disturbance from construction and tourist footfall stresses local flora and fauna, especially in sensitive riverine
2	2	2	3	3	2.4		2	2	2	1	1.75		2	2	2	2	2	
2	2	3	3	3	2.6		3	2	2	2	2.25		3	2	3	2	2.5	
2	2	3	3	3	2.6		3	2	2	2	2.25		3	2	3	2	2.5	
2	2	3	3	2	2.4	Exposes workers to health hazards	1	1	1	1	1	No significant impact observed	2	2	2	2	2	Boosts local income and cultural visibility but can commercialize traditions and
2	2	3	3	2	2.4		2	1	1	1	1.25		2	2	3	2	2.25	
2	2	2	3	2	2.2		1	1	1	1	1		1	2	1	1	1.25	
1.8	1.8	2.3	2.4	2.2	29.4		2.2	1.8	1.9	1.4	25.8		2.1	2.2	2.1	1.8	28.8	



Annexure 5 (for section 5.12): Identification of Critical Ward

Ward No	Physical Infrastructure			Flood Risk				Coastal Hazard			Water Stress	Land Use			Total
	Solid waste	Storm water drainage	Physical Infrastructure Average	Pluvial Flooding	Fluvial Flooding	Coastal Flooding	Flood Risk Average	Sea level rise	Coastal Erosion	Coastal Hazard Average	Primary Survey (Use of tanker supply)	Water intensive activities	Water quality	Land use average	
1	0.76	1.00	0.88	0.00	0.00	1.00	0.33	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.30
2	0.54	1.00	0.77	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.19
3	0.69	1.00	0.84	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.26
4	0.78	1.00	0.89	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.31
5	0.82	1.00	0.91	0.00	0.00	1.00	0.33	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.49
6	0.76	1.00	0.88	0.00	0.00	1.00	0.33	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.46
7	0.63	1.00	0.82	0.00	0.00	0.50	0.17	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.07
8	0.78	1.00	0.89	0.00	0.00	1.00	0.33	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.47
9	0.89	1.00	0.94	0.00	0.50	0.50	0.33	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.36
10	0.16	1.00	0.58	0.00	0.00	0.50	0.17	0.50	1.00	0.75	0.23	1.00	1.00	1.00	2.73
11	0.00	1.00	0.50	0.00	0.00	0.50	0.17	1.00	1.00	1.00	0.25	1.00	1.00	1.00	2.91
12	0.68	0.50	0.59	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.56	1.00	1.00	1.00	2.82
13	0.69	1.00	0.84	0.00	1.00	0.50	0.50	0.00	0.00	0.00	0.56	1.00	1.00	1.00	2.91
14	0.66	1.00	0.83	0.00	0.50	0.00	0.17	0.00	0.00	0.00	0.42	0.50	0.50	0.50	1.92
15	0.54	1.00	0.77	0.00	0.50	0.50	0.33	0.00	0.00	0.00	0.00	0.50	1.00	0.75	1.85
16	0.66	0.50	0.58	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.56	1.00	0.00	0.50	2.31
17	0.86	0.00	0.43	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.71	0.50	0.00	0.25	2.06
18	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.25
19	0.64	1.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.07
20	0.74	1.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.12
21	0.66	1.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.08
22	0.92	1.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.21
23	0.83	1.00	0.92	1.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.67
24	0.76	1.00	0.88	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.30
25	0.65	1.00	0.83	0.00	0.50	0.50	0.33	0.00	0.00	0.00	0.71	0.50	1.00	0.75	2.62
26	0.73	1.00	0.86	0.00	0.50	0.50	0.33	0.00	0.00	0.00	0.56	0.50	1.00	0.75	2.51
27	0.54	1.00	0.77	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.85	0.50	1.00	0.75	3.04
28	0.50	1.00	0.75	0.00	0.50	1.00	0.50	0.00	0.00	0.00	0.71	0.50	0.00	0.25	2.21
29	0.49	0.00	0.25	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.56	0.50	0.00	0.25	1.73
30	0.47	0.00	0.23	0.00	0.50	0.50	0.33	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.82
31	0.66	0.00	0.33	0.00	0.50	0.50	0.33	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.92
32	0.54	0.50	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.77
33	0.48	0.50	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.74
34	0.47	0.50	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.73
35	0.71	1.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.11
36	0.57	1.00	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.04
37	0.61	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.55
38	0.56	0.50	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.78
39	0.60	0.00	0.30	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.72
40	0.52	0.50	0.51	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.93
41	0.41	0.00	0.21	0.00	0.00	0.50	0.17	0.00	0.00	0.00	0.00	0.50	0.00	0.25	0.62
42	0.54	0.00	0.27	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.85	0.50	0.00	0.25	2.04
43	0.45	0.00	0.23	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.27	0.50	1.00	0.75	1.92
44	0.50	0.00	0.25	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.42	1.00	0.50	0.75	2.09
45	0.57	0.00	0.29	0.50	1.00	1.00	0.83	0.00	0.00	0.00	0.71	1.00	0.50	0.75	2.58
46	0.52	0.00	0.26	1.00	1.00	0.50	0.83	0.00	0.00	0.00	0.13	0.50	0.00	0.25	1.47
47	0.63	0.00	0.31	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.23
48	0.68	0.00	0.34	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.26
49	0.76	0.00	0.38	1.00	0.50	1.00	0.83	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.46
50	0.53	0.50	0.52	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.43
51	0.62	1.00	0.81	1.00	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.56
52	0.63	1.00	0.82	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.73
53	0.69	1.00	0.84	0.50	1.00	0.50	0.67	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.76
54	0.56	0.50	0.53	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.78
55	0.67	0.00	0.33	1.00	0.50	1.00	0.83	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.42
56	0.65	0.00	0.32	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.42	0.50	0.00	0.25	1.99
57	0.55	0.50	0.53	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.27	0.50	0.00	0.25	2.05
58	0.47	0.50	0.48	0.50	1.00	1.00	0.83	0.00	0.00	0.00	0.56	0.50	0.00	0.25	2.13
59	0.60	0.00	0.30	0.50	1.00	1.00	0.83	0.00	0.00	0.00	0.00	0.50	0.00	0.25	1.38
60	0.68	0.50	0.59	0.00	0.50	1.00	0.50	0.50	0.67	0.58	1.00	0.00	0.00	0.00	2.67



Annexure 6 (for section 5.14): Urban River Management Index

Indicator 1: Floodplain Management Score			
No	**Desirable Feature**	**Fixed Floodplain management points**	**Points earned**
1	Floodplain boundaries clearly demarcated	15	0
2	Floodplain boundaries protected through embankments, roads, or other means	5	5
3	Demarcation of no development zone adjacent to the river in the active floodplain	5	5
4	Strict enforcement in no development zone	10	0
5	Updated database of existing land use in flood plain available	10	0
6	Master Plan has clearly indicated permissible and non-permissible activities in the floodplain/river zone	15	0
7	All regulations in the Master Plan are enforced (10 points if at least 50% of the regulations are enforced)	15 (10)	10
8	Presence of river friendly landscaping (e.g. constructed wetlands, bioswales, etc.)	5	0
9	Strict monitoring mechanism in place	5	0
10	No solid waste dumping on river banks	10	0
11	Only organic farming practiced in river zone	5	0
Total		**100**	**20**
Floodplain management points <30		**Therefore, Floodplain management score = 1**	

Indicator 2 : Net Dissolved Oxygen Score			
No	**Particular**	**Value**	
1	DO Inlet (DO_i)	2.5	
2	DO Outlet (DO_o)	3.5	
3	Net DO [(DO_o - DO_i / DO_i) * 100]	40	
Net DO > 0		**Therefore, Net DO score = 5**	

Indicator 3: Water Body Revival Score		
No	**Particular**	**Value**
1	Total number of water bodies	7
2	Number of Water bodies in accetable condition	0
3	Water body revival factor [(2/1)* 100)]	0
Water body revival factor < 40		**Therefore, Water Body Revival score = 1**

Indicator 4: Riparian Buffer Score		
No	**Particular**	**Value**
1	Total length of river edge in the city	46 km
2	Total length of riparian buffer (Within the city limits)	20.15 km
3	Riparian buffer factor [(2/1)*100]	43.80
Riparian buffer factor = 30 - 49		**Riparian buffer score = 2**

Indicator 5: Wastewater reuse score		
No	**Particular**	**Value**
1	Waste water generated annually	70,390.25 Million Liters
2	Waste water reused annually	13870 Million Liters
3	Waste water reuse factor (2/1*100)	18.87
Waste water reuse factor <20		**Therefore, Waste water reuse score = 1**

Indicator 6: Return flow score		
No	**Particular**	**Value**
1	Actual annual return flow	88.75 MLD
2	Committed annual return flow (50% standard)	89.35 MLD
3	Return flow factor [(1-2)/2]	-0.67
Return flow factor = -5 to <0		**Therefore, return flow score = 4**

Indicator 8: River economy score	
No	**Economic uses**
1	Navigation (Ferry and goods transport)
2	Livelihood of fisherfolk
3	Livelihood of farmers
4	Supports tourism
5	Sand mining
6	Water supply
Total number of economic use (6) > 3	
Therefore, River economy score = 5	

Indicator 7: Eco-friendly riverfront score			
No	**Desirable Feature**	**Fixed Eco-friendly riverfront points**	**Points earned**
1	The riverfront project is a source of revenue for the ULB	15	15
2	The riverfront project supports commercial activities like shops, stalls, etc	15	15
3	The riverfront project has a footfall of more than 100 people/day	10	0
4	The riverfront project is listed as an attraction spot on travel-related websites	15	15
5	The riverfront project has good waste management facilities	15	0
6	The riverfront project is made up of predominantly natural material	10	0
7	The riverfront project has soft landscaping elements	10	0
8	The riverfront project does not block the natural path of the river	10	10
Total		**100**	**55**
Eco-friendly riverfront points = 40 - 59		**Eco-friendly riverfront score = 3**	

Indicator 9: Citizen sensitization score			
No	**Desirable Feature**	**Fixed Citizen sensitization points**	**Points earned**
1	Dedicated Information, Education and Communication (IEC) programme for the river-related aspects	20	0
2	River related sensitization is part of existing citizen awareness raising programmes	15	0
3	Presence of a dedicated website for river-related aspects	5	0
4	Use of traditional sensitization media (e.g. hoardings, murals, competitions, radio)	10	0
5	Use of social media for river-related sensitization	10	0
6	A dedicated river day for the city	10	0
7	Earmarked budget for citizen sensitization	15	0
8	Sensitization of school children through special events	10	0
Total		**95**	**0**
Citizen sensitization points <20		**Citizen sensitization score = 1**	

Indicator 10: Citizen engagement score		
No	**Modalities**	**Implemented/Attempted**
1	Participation of citizens in river health monitoring	Yes
2	Participation of citizens in river clean-up activities	Yes
3	Presence of citizen groups for river conservation	No
4	Presence of citizens in committees related to river decisions	No
5	CSR funds invested in river-related projects	Yes
6	Any other citizen engagement modality that can be verified	NA
The city has >= 3 modalities of citizen engagement		**Citizen engagement score = 5**

**** Refer to URMP Framework Section C6.1.1 to C6.2.2 for scoring of indicators***

Each indicator has a value between 1 and 5. An average of all the indicators results in URM index

$URM_{index} = (I1 + I2 + I3 + I4 + I5 + I6 + I7 + I8 + I9 + I10) / 10$

Scoring Scale for Proposed Indicators of Urban River Resilience Index

Proposed Indicator 11: The CRZ Compliance score is calculated as below:	
If CRZ Compliance points = > 80	CRZ Compliance Score = 5
If CRZ Compliance points = 60 - 79	CRZ Compliance Score = 4
If CRZ Compliance points = 40 - 59	CRZ Compliance Score = 3
If CRZ Compliance points = 20 - 39	CRZ Compliance Score = 2
If CRZ Compliance points < 20	CRZ Compliance Score = 1

Proposed Indicator 12: Mangrove and Estuarine Habitat Health score is calculated as below:	
If Mangrove and Estuarine Habitat Health Points > 80	Mangrove and Estuarine Habitat Health = 5
If Mangrove and Estuarine Habitat Health Points 60 - 79	Mangrove and Estuarine Habitat Health = 4
If Mangrove and Estuarine Habitat Health Points 40 - 59	Mangrove and Estuarine Habitat Health = 3
If Mangrove and Estuarine Habitat Health Points 20 - 39	Mangrove and Estuarine Habitat Health = 2
If Mangrove and Estuarine Habitat Health Points < 20	Mangrove and Estuarine Habitat Health = 1

The Urban Flood Resilience score is then calculated as below:	
If Urban Flood Resilience points > 80	Urban Flood Resilience score = 5
If Urban Flood Resilience points 60 - 79	Urban Flood Resilience score = 4
If Urban Flood Resilience points 40 - 59	Urban Flood Resilience score = 3
If Urban Flood Resilience points 20 - 39	Urban Flood Resilience score = 2
If Urban Flood Resilience points < 20	Urban Flood Resilience score = 1

Each indicator has a value between 1 and 5. An average of all the indicators results in URRI index

$URRI_{index} = (I1 + I2 + I3 + I4 + I5 + I6 + I7 + I8 + I9 + I10 + I11 + I12 + I13) / 13$



Annexure 7 (for section 8.1): Land Suitability

Region

Pair wise matrix - scoring

Parameters	Forest	Rivers	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways
Forest	1.00	2.00	3.00	3.00	4.00	4.00	5.00	5.00
Rivers	0.50	1.00	2.00	2.00	2.00	3.00	3.00	4.00
CRZ	0.33	0.50	1.00	2.00	2.00	3.00	3.00	4.00
Flood Susceptibility	0.33	0.50	0.50	1.00	2.00	2.00	3.00	3.00
Faults & Lineaments	0.25	0.33	0.50	0.50	1.00	2.00	2.00	3.00
Slope percentage	0.25	0.33	0.33	0.50	0.50	1.00	2.00	2.00
Major Roads	0.20	0.25	0.33	0.33	0.50	0.50	1.00	2.00
Railways	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1.00
Total	3.07	5.17	7.92	9.67	12.33	16.00	19.50	24.00

Pair wise matrix - scoring

Parameters	Forest	Rivers	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Priority vector	Weighted average
Forest	0.33	0.39	0.38	0.31	0.32	0.25	0.26	0.21	0.31	31
Rivers	0.16	0.19	0.25	0.21	0.16	0.19	0.15	0.17	0.19	19
CRZ	0.11	0.10	0.13	0.21	0.16	0.19	0.15	0.17	0.15	15
Flood Susceptibility	0.11	0.10	0.06	0.10	0.16	0.13	0.15	0.13	0.12	12
Faults & Lineaments	0.08	0.06	0.06	0.05	0.08	0.13	0.10	0.13	0.09	9
Slope percentage	0.08	0.06	0.04	0.05	0.04	0.06	0.10	0.08	0.07	7
Major Roads	0.07	0.05	0.04	0.03	0.04	0.03	0.05	0.08	0.05	5
Railways	0.07	0.05	0.03	0.03	0.03	0.03	0.03	0.04	0.04	4

Consistency Matrix

Parameters	Forest	Rivers	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Weighetd sum	Ratio (WS/PV)
Forest	0.31	0.37	0.45	0.35	0.35	0.26	0.25	0.19	2.53	8.30
Rivers	0.15	0.19	0.30	0.23	0.17	0.20	0.15	0.15	1.55	8.33
CRZ	0.10	0.09	0.15	0.23	0.17	0.20	0.15	0.15	1.25	8.30
Flood Susceptibility	0.10	0.09	0.08	0.12	0.17	0.13	0.15	0.11	0.96	8.16
Faults & Lineaments	0.08	0.06	0.08	0.06	0.09	0.13	0.10	0.11	0.71	8.12
Slope percentage	0.08	0.06	0.05	0.06	0.04	0.07	0.10	0.08	0.53	8.05
Major Roads	0.06	0.05	0.05	0.04	0.04	0.03	0.05	0.08	0.40	8.05
Railways	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.04	0.31	8.11

CI (Consisistency Index) (Ratio-n)/(n-1)	0.03	Ratio = 8.11, n = number of parameters considered
CR (Consistency Ratio) (CI/RI)	CI/1.41 = 0.02	RI for n = 8 is 1.41
CR <1, Hence, Matrix is Consistent		

Mangaluru Planning Area

Pair wise matrix - scoring

Parameters	Rivers	Waterbodies	CRZ	Flood Susceptibility	Faults & Lineaments	Slope percentage	Major Roads	Railways
Rivers	1.00	2.00	2.00	3.00	3.00	4.00	4.00	5.00
Waterbodies	0.50	1.00	2.00	2.00	2.00	3.00	3.00	4.00
CRZ	0.50	0.50	1.00	2.00	2.00	3.00	3.00	4.00
Flood Susceptibility	0.50	0.50	0.50	1.00	2.00	2.00	3.00	3.00
Faults & Lineaments	0.33	0.50	0.50	0.50	1.00	2.00	2.00	3.00
Slope percentage	0.33	0.33	0.33	0.50	0.50	1.00	2.00	2.00
Major Roads	0.25	0.33	0.33	0.33	0.50	0.50	1.00	2.00
Railways	0.25	0.25	0.25	0.33	0.33	0.50	0.50	1.00
Total	**3.67**	**5.42**	**6.92**	**9.67**	**11.33**	**16.00**	**18.50**	**24.00**

Pair wise matrix - scoring

Parameters	Rivers	Waterbodies	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Priority vector	Weighted average
Rivers	0.27	0.37	0.29	0.31	0.26	0.25	0.22	0.21	0.27	28
Waterbodies	0.14	0.18	0.29	0.21	0.18	0.19	0.16	0.17	0.19	19
CRZ	0.14	0.09	0.14	0.21	0.18	0.19	0.16	0.17	0.16	16
Flood Susceptibility	0.14	0.09	0.07	0.10	0.18	0.13	0.16	0.13	0.12	12
Faults & Lineaments	0.09	0.09	0.07	0.05	0.09	0.13	0.11	0.13	0.09	9
Slope percentage	0.09	0.06	0.05	0.05	0.04	0.06	0.11	0.08	0.07	7
Major Roads	0.07	0.06	0.05	0.03	0.04	0.03	0.05	0.08	0.05	5
Railways	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.04	0.04	4
									1.00	**100.00**

Consistency Matrix

Parameters	Rivers	Waterbodies	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Weighetd sum	Ratio (WS/PV)
Rivers	0.27	0.38	0.32	0.37	0.28	0.28	0.21	0.20	2.31	8.47
Waterbodies	0.14	0.19	0.32	0.25	0.19	0.21	0.16	0.16	1.60	8.49
CRZ	0.14	0.09	0.16	0.25	0.19	0.21	0.16	0.16	1.35	8.48
Flood Susceptibility	0.14	0.09	0.08	0.12	0.19	0.14	0.16	0.12	1.04	8.36
Faults & Lineaments	0.09	0.09	0.08	0.06	0.09	0.14	0.11	0.12	0.78	8.31
Slope percentage	0.09	0.06	0.05	0.06	0.05	0.07	0.11	0.08	0.57	8.28
Major Roads	0.07	0.06	0.05	0.04	0.05	0.03	0.05	0.08	0.44	8.25
Railways	0.07	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.33	8.35
										8.37

CI (Consisistency Index) (Ratio-n)/(n-1)	0.05	Ratio = 8.37, n = number of parameters considered
CR (Consistency Ratio) (CI/RI)	CI/1.41 = 0.04	RI for n = 8 is 1.41
CR <1, Hence, Matrix is Consistent		

Annexure 8 Primary Survey Questionnaire: Household Survey

Household Survey - Urban								
Location		**Ward name/no**				**Household Size**		
General profile								
Sl no	Name	Relation with head of the family	Age	Sex	Martial Status	**Education** a. Illiterate b. Primary (Upto 5) c. Secondary (Upto 10th) d. Sr. secondary (10+2) e. Graduate f. Post graduate g. Vocational school of higher education h. Others (specify)	**Employment** a. Service (Gov.) b. Service (private) c. Business(formal) d. Business(Informal) e. Industrial worker f. Farmer/cultivation g. agricultural labourer h. Self employed i. Student j. Retired k. Others(specify)	**Income** a. <15000 b. 15001-25,000 c. 25,001-40,000 d. 40,001-50,000 e. 50,001-75,000 f. 75,001-1,00,000 g.1,00,001-1,50,000 h. >1,50,000
1								
2								
3								
4								
5								
6								
7								
8								
Migrated: Yes/No		**If yes, No of Years** a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs					**Origin** a) Within Tehsil b) Within District c) Within State d)Other State	
Reason for migration								
Housing								
Typology: a) Row b) Detached c) Plot d) Semi-detached					**Neighbourhood type:** a) Organic b) Planned c) Unauthorised colony d) Squatter			
Housing typology: a) Plotted b) Group housing c) Others, Specify							**If plotted:** a) Row b) Semi-detached c) Detached	
Number of floors: a) G b) G+1 c) G+3 d) G+4 e) Others, specify						**Material:** a) Roof b) Wall c) Floor		
Plot size: _____ (sq.m)			**Flat/Apartement size:** _____ sq.m				**House Structure:** a) Pucca b) Semi-pucca c) Kutcha	
Building age: a) <5 Yrs b) 5-20 Yrs c) 20-40 Yrs d) 40-60 Yrs e) 80 & above							**House ownership:** a) Owned b) Rented c) Employer housing	
Have you been affected by Flood/Cyclone/Drought?								



Annexure 8 Primary Survey Questionnaire: Household Survey

Solid Waste Management		
Where is the household waste disposed?		
Waste collection service a) Daily b) Alternate days c) weekly d) Irregular	**Disposal method:** a) Dispoed at a collection point b) Burning c) Dumping d) Composting e) Door-to-Door collection	
Location of waste dumping loaction in neighbourhood, if any:		
Waste Segregation at Household level, if at all (e.g., wet waste, dry waste, e-waste)?		
Collection charge: Yes/No	**Availability Community Dust Bins**: a) Yes b) No	**Awareness about Swacch Survekshan:** Yes / No
Do community people participate in community cleaning & Awareness? a) Yes b) No		

Water Supply			
Main Source of drinking water supply a) Tap water b) Bore well c) Hand pump d) Tankers e) Others (Specify)			
Is connection available within Premises a) Yes b) No	**If borewell, Reason:**		
Source of water for purposes other than drinking a) Tap water b) Bore well c) Hand pump d) Tankers e) Others (Specify)			
Is connection available within Premises a) Yes b) No	**If borewell, Reason:**		
Metered connection: a) Yes b) No	**Type of water connection** a) Individual b) Shared c) Multiple		
If shared connection, no of households a) one b) Two c) More than two	**Type of water storage** a) Tank b) Bottle c) Bucket d) others		
Colour of water a) Clear b) Yellow c) Other	**Odour of water** a) Yes b) No	**Taste of water** a) Normal b) Sweet c) Other	
Are you satisfied with Quality of water a) Yes b) No c) If No, Reason			
Access to adequate water a) Yes b) No	**Frequency of supply** a) Daily b) Alternative days c) Once in three days d) others		
Duration of supply a) 0-2 hrs b) 2-4 hours c) 4-8 hours d)>8 hours	**Are you paying water bill** a) Yes b) No c) If yes, Rs_____		
Whom do you pay for water? a) Municipality b) Private water supply c) Others	**Do you experience Water shortage?** a) Yes b) No		
Condition of water supply pipeline connection: a) Good b) Average c) Bad			
If any leakage occurs/damage, how many days will it take to repair? a) 1 day b) 2-4 days c) >3 days			
Any alternative water supply during water pipeline leakage/repair? a) Yes b) No	**Any water bodies around?** a) Yes b) No		
Do you visit to water bodies for recreational purpose? a) Yes b) No	**Is the water body polluted?** a) Yes b) No c) If yes, Reason_____		
Water borne diseases and health issues: a) Yes b) No	**If yes, what diseases and Health issues?** _____		
Rain water harvesting pit at your house? a) Yes b) No	**Community Rain water harvesting pit** a) Yes b) No		
Any awareness programmes on water conservation/management? a) Yes b) Yes			
Does community people involve in any programmes/awareness or in complaint readressal? a) Yes b) Yes			
Is there storm water drainage connection? a) Yes b) No			



Annexure 8 Primary Survey Questionnaire: Household Survey

Sewage & Sanitation			
Type of On -Site Toilet: a) individual b) community toilet c) public toilets d) open defecation d) others			
Type of Toilet: a) Septic Tank with Soak Pit b) Septic Tank without Soak pit c) Dry pit Latrine- Single pit/Two Pit d) others			
If septic Tanks, frequency of cleaning: a) 1year b) 2 years c) >2years		**Average amount spent on cleaning (Rs):**	
If not connected to sewerage Network, Alternative Grey water (Water from kitchen) Disposal: a) Directly to Public Drain b) Reuse in the garden after passing through Soak pit c) Discharge to rivers /pond /Nallah			
Are there storm water drains in your area: Yes/ No		**Are storm water drains well maintained:** Yes / No, if No, Reason_____	
Is there water logging in your area? Yes/ No		**Duration of Water logging:** Hours/Days _____	
Waterlogging resolved by the authority? Yes / No		**Time taken for Redressal:** Hours/Days _____	
Parks & Open Spaces			
Do **you visit to community parks?** a) Yes b) No		**Are plants and trees protected?** a) Yes b) No	
Does city have good green cover? a) Yes b) No			
Transport			
Roads	a) CC Road b) Asphalt Road c) Mud Road	**Condition**	a) Good b) Average c) Bad



Annexure 8 Primary Survey Questionnaire: Forest and River Ecosystem Service Dependency

Ecosystem Service Identification & Dependency - Forest cosystem

Location/Village Name | **Tehsil**

General Information

Name of the respondent: | **Age:** | **Sex** (M/F) : | **Householed Size:**

Houschold information

Sl.no	Name	Relation with Respondent	Age	Sex M/F	Martial Status	Education a. Illiterate b. Primary (Upto 5) c. Secondary (Upto 10th) d. Sr. secondary (10+2) e. Graduate f. Post graduate g. Vocational school of higher education h. Others (specify)	Employment a. Service (Gov.) b. Service (private) c. Business(formal) d. Business(Informal) e. Industrial worker f. Farmer/cultivation g. Agricultural labourer h. Self employed i. Student j. Retired k. Others(specify)	Income a. <15000 b. 15001-25,000 c. 25,001-40,000 d. 40,001-50,000 e. 50,001-75,000 f. 75,001-1,00,000 g.1,00,001-1,50,000 h. >1,50,000
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How long have you been living here a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs | **Migrated:** Yes/No

Reason for migration: | **If yes, No. of Years** a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs | **Origin** a) Within Tehsil b) Within District c) Within State d)Other State

Provisioning Services

What resources do you collect from the forest? a) timber b) fuelwood c) medicinal plants d) fruits e) fodder f) Others (Specify)

Frequency of collection a) Daily b) Weekly c) Monthly d) Others (Specify)

Do you use forest resources for traditional practices or rituals? Please specify.

Regulating Services

Have you observed the forest helping in regulating the local climate (e.g., cooler temperatures, wind protection)?

Do you think the forest reduces risks of floods, soil erosion, or landslides? How?

Are there any wildlife species in the forest that support local livelihoods (e.g., pollinators, pest controllers)?

Cultural Services

Purpose of visiting forest: a) Rcreational purposes b) Tourism c) Spiritual activities d) Others (Specify)

Are there cultural or religious practices tied to this forest? If yes, explain.

Dependency & Challenges

How has your dependency on the forest changed over time?

What are the challenges or threats facing the forest (e.g., deforestation, over-extraction, climate change)?

Ecosystem Service Identification & Dependency - River cosystem

Location/Village Name | **Tehsil**

General Information

Name of the respondent: | **Age:** | **Sex** (M/F) : | **Householed Size:**

Houschold information

Sl.no	Name	Relation with Respondent	Age	Sex M/F	Martial Status	Education a. Illiterate b. Primary (Upto 5) c. Secondary (Upto 10th) d. Sr. secondary (10+2) e. Graduate f. Post graduate g. Vocational school of higher education h. Others (specify)	Employment a. Service (Gov.) b. Service (private) c. Business(formal) d. Business(Informal) e. Industrial worker f. Farmer/cultivation g. Agricultural labourer h. Self employed i. Student j. Retired k. Others(specify)	Income a. <15000 b. 15001-25,000 c. 25,001-40,000 d. 40,001-50,000 e. 50,001-75,000 f. 75,001-1,00,000 g.1,00,001-1,50,000 h. >1,50,000
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How long have you been living here a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs | **Migrated:** Yes/No

Reason for migration: | **If yes, No of Years** a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs | **Origin** a) Within Tehsil b) Within District c) Within State d) Other State

Provisioning Services

What resources do you obtain from the river? a) Water for drinking b) Irrigation c) fish d) sand c) Others (Specify)

Do you or your community depend on the river for agriculture or livestock?

Is the river used for transportation or trade?

Regulating Services

Do you believe the river helps in reducing the impacts of floods or maintaining water quality? How?

Are there changes in the river flow or quality that have affected your activities?

Cultural Services

Is the river a part of cultural, recreational, or religious activities in your community?

Are there any festivals, rituals, or ceremonies linked to the river?

Dependency & Challenges

How has your dependency on the river changed over time?

What challenges do you face concerning the river (e.g., pollution, reduced flow, over-extraction)?



Annexure 8 Primary Survey Questionnaire: Estuarian Ecosystem Service Dependency and Ecological & Cultural Memories

Ecosystem Service Identification & Dependency - Coastal & Esturian Ecosystem								
Location/Village Name					**Tchsil**			
General Information								
Name of the respondent:			**Age:**		**Sex (M/F) :**	**Household Size:**		
Household information								
Sl.no	**Name**	**Relation with Respondent**	**Age**	**Sex M/F**	**Martial Status**	**Education** a. Illiterate b. Primary (Upto 5) c. Secondary (Upto 10th) d. Sr. secondary (10+2) e. Graduate f. Post graduate g. Vocational school of higher education h. Others (specify)	**Employment** a. Service (Gov.) b. Service (private) c. Business(formal) d. Business(Informal) e. Industrial worker f. Farmer/cultivation g. Agricultural labourer h. Self employed i. Student j. Retired k. Others(specify)	**Income** a. <15000 b. 15001-25,000 c. 25,001-40,000 d. 40,001-50,000 e. 50,001-75,000 f. 75,001-1,00,000 g. 1,00,001-1,50,000 h. >1,50,000
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How long have you been living here a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs							**Migrated:** Yes/No	
Reason for migration:			**If yes, No of Years** a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs				**Origin** a) Within Tehsil b) Within District c) Within State d)Other State	
Provisioning Services								
What resources do you collect from the coastal area? a) Fish b) seaweed c) shellfish d) salt c) Others (Specify)								
Do you use the coastal area for farming, aquaculture, or other economic activities?								
Are there mangroves or seagrass beds that you rely on for resources?								
Regulating Services								
Do you believe the coastal ecosystem (Dunes, Mangroves & Coral reefs) helps in reducing the impacts of floods, storm & coastal erosion? How?								
How would you rate the current condition of the coastal ecosystem? (Scale: 1-5, where 1 is "Poor" and 5 is "Excellent")								
Cultural Services								
Is the coastal area important for tourism or recreational activities?								
Are there traditional practices or cultural events tied to the coastal area?								
Dependency & Challenges								
How has your reliance on the coastal area changed over time?								
What are the major challenges faced by the coastal ecosystem (e.g., sea-level rise, pollution, habitat loss)?								

Ecological & Cultural Memories - Agricultural Village		
Aspect	**Then (atleast 20-30 years)**	**Now**
Memory about the Gurupura River		
Any festival associated with the river		
Migration of local communities to other occupation		
Traditional practices of farming		
Farming techniques		
Yield		
Market		
Development projects		
Nature conservation awareness		
Ecological & Cultural Memories - Fishing Village		
Aspect	**Then (atleast 20-30 years)**	**Now**
Memory about the Gurupura River		
Any festival associated with the river		
Migration of local communities to other occupation		
Traditional practices of fishing		
Fishing equipments		
Dealing with External Users (Forest Department/Fisheries Department)		
Market		
Riverine species health issues, if any		
Marine Species health issues, if any		
Development projects		
Nature conservation awareness		



Annexure 8 Primary Survey Questionnaire: Rural Livelihood Survey - Fishermen

Rural - Livelihood Analysis - Fishermen								
Location/Village Name					**Tehsil**			
General Information								
Name of the respondent:				**Age:**	**Sex** (M/F) :	**Household Size:**		
Household information								
Sl.no	**Name**	**Relation with Respondent**	**Age**	**Sex M/F**	**Martial Status**	**Education** a. Illiterate b. Primary (Upto 5) c. Secondary (Upto 10th) d. Sr. secondary (10+2) e. Graduate f. Post graduate g. Vocational school of higher education h. Others (specify)	**Employment** a. Service (Gov.) b. Service (private) c. Business(formal) d. Business(Informal) e. Industrial worker f. Farmer/cultivation g. Agricultural labourer h. Self employed i. Student j. Retired k. Others(specify)	**Income** a. <15000 b. 15001-25,000 c. 25,001-40,000 d. 40,001-50,000 e. 50,001-75,000 f. 75,001-1,00,000 g.1,00,001-1,50,000 h. >1,50,000
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Migrated: Yes/No		**If yes, No of Years** a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs					**Origin** a) Within Tehsil b) Within District c) Within State d)Other State	
Reason for migration								
Card holder: a) Ration Card b) BPL Card c) Others, Specify								
Fishing Activity Details								
How long have you been involved in fishing?								
Type of fishing practiced (marine, inland, aquaculture, etc.):								
Human Capital								
Skills & Knowledge								
What skills or training do you have related to fishing?								
Received any training related to fishing or aquaculture? (Topics & duration)								
health status of the household members? (Chronic illnesses, access to healthcare facilities, Cost of healthcare)								

Education & Awareness	
Highest level of education in the household:	
Are you aware of any government schemes or programs supporting fishermen? (Details of Schemes/Programs availed)	
Have you been trained in sustainable fishing practices or marine resource conservation?	
Social Capital	
Community Network	
Are you a member of any fishing associations or cooperatives? (Details of association/cooperatives)	
Do you collaborate with other fishermen for shared resources or activities?	
Do you participate in community meeting or decision-making processes? (Details)	
Access to Support	
Do you receive support from **local government or NGOs**? If yes, specify from whom & the type of support.	
What are your sources of information on on fishing regulations, weather, or market prices?	
Social Infrastructure	
Nearest Hospital and Distance:	**Nearest PHC**
Nearest school: (PS/SS/HS)	
Natural Capital	
Access to Natural Resources	
What type of waterbody do you fish in (river, ocean, estuary, etc.)?	Do you own a waterbody (ex. Fishing pond/Prawn Pond) ? Yes/ No If Yes, Area:
Have you observed changes in fish availability over time?	
What is the quality of the waterbody you fish in?	
What do you feed the fish/prawn?	
Name some of the local species Any particular to/endemic to Gurupura/Netravati?	
Local species - fishes	
Local species - prawns	
Local species - crabs	

Any other commercial produce? (Sea weed/ amphibians/turtles/ aquatic plants/ shrimps)		
Have you noticed the disappearance of any species in the recent years? And Reason if yes.		
Environmental Challenges		
Have you experienced environmental challenges like pollution, climate change, or overfishing?		
What measures have you taken to adapt to these changes?		
Physical Capital		
Fishing Infrastructure & Tools		
Do you own or have access to fishing equipment? Specify types (boats, nets, traps, etc.).		
Is your equipment modern or traditional?		
Are there facilities for repairing fishing equipment in your area?		
Do you have access to fish storage, processing, or cold storage facilities?		
How far is the nearest market where you sell your fish?		
Housing & Basic Services		
Housing type a)Pucca b)Semi-Pucca c)Kutcha	**Ownership status:**	
Affected by Flood/Cyclone/Drought: Yes / No	**Compensated for the same:** Yes/No, If Yes, How?	
Do you have access to electricity, clean water, and sanitation facilities? **Electricity:** Yes/No **Clean water:** Yes/No **Sewerage:** Yes/No		
Water supply network available: Yes/No	**No of supply hours:**	**Tap water connection:** Yes/No
If tanker system: How many hours/day? Or how many days/week? **Water quality: Colour**: a) Clear b) Yellow c) Other **Smell:** Yes/No **Taste:** a) Normal b) Sweet c) Others		
Dependent on any water bodies? If yes, Which (Ex. River/Lake/Pond) **Water quality: Colour**: a) Clear b) Yellow c) Other **Smell**: Yes/No **Taste:** a) Normal b) Sweet c) Others		
Connection to sewerage network: Yes/No	**If Septic Tank:** a) Individual b)Community	**Cleaning frequency:**
Type of Toilet : a) Individual b) Community c)Fields	**Pit Laterine or What type?**	
Septic tanks (Cleansing and Maintenance Details)		
Open /Closed Drainage		
Garbage management: a) Bins b) Roadside c) Burning d) Open land e) Others		
Hosehold Composite Pit/ Community Pit:	**Plastic waste management:** a) Resell b) Reuse c) Others, Specify	
Any issues or difficulty in accessing the basic infrastructure? (ex. Distance to access water/Availability of clean water)		
Finacial Capital		
Income & Savings		
What are your primary sources of income?		
Do you have savings? If yes, in what form (cash, bank, livestock, etc.)?		
Credit & Financial Services		
Have you taken loans for fishing or personal purposes? If yes, from where (banks, cooperatives, informal lenders)?		
Do you face any challenges in accessing credit?		
Market Access		
Are you allowed to fish directly from river without any restriction?		
How do you sell your catch (direct sales, middlemen, cooperatives)?		
Price Range for different fishes		
Price Range for different Prawns		
Price Range for different Crabs		
Are you satisfied with the prices you get for your fish?		
What are the major challenges you face in your livelihood (e.g., low catch, competition, high costs, etc.)?		



Annexure 8 Primary Survey Questionnaire: Rural Livelihood Survey - Farmers

Rural - Livelihood Analysis - Farmers								
Location/Village Name						**Tehsil**		
General Information								
Name of the respondent:				**Age:**		**Sex** (M/F) :	**Household Size:**	
Household information								
Sl.no	**Name**	**Relation with Respondent**	**Age**	**Sex M/F**	**Martial Status**	**Education** a. Illiterate b. Primary (Upto 5) c. Secondary (Upto 10th) d. Sr. secondary (10+2) e. Graduate f. Post graduate g. Vocational school of higher education h. Others (specify)	**Employment** a. Service (Gov.) b. Service (private) c. Business(formal) d. Business(Informal) e. Industrial worker f. Farmer/cultivation g. Agricultural labourer h. Self employed i. Student j. Retired k. Others(specify)	**Income** a. <15000 b. 15001-25,000 c. 25,001-40,000 d. 40,001-50,000 e. 50,001-75,000 f. 75,001-1,00,000 g.1,00,001-1,50,000 h. >1,50,000
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Migrated: Yes/No		**If yes, No of Years** a) 0-5 Yrs b) 5-10 Yrs c)10-20 Yrs d) > 20 yrs					**Origin** a) Within Tehsil b) Within District c) Within State d)Other State	
Reason for migration:								
Card holder: a) Ration Card b) BPL Card c) Others, Specify								
Land Ownership and Usage								
Own Land (Yes/No):				**If yes, Land Tenure** a) Ownership b) Leased c)Communal				
Land Area (Ha):		**Land area under cultivation:**				**Types of crops grown:**		
Human Capital								
Skills & Knowledge								
Agriculture labourer/ Cultivator: Marginal, Main, Alternative Employment								
Since how many years are you practicing?								
What agricultural skills or knowledge do you possess?								
Received any training related to farming or other livelihood activities? (Topics & duration)								

Agriculture Cycle/ Number of harvest time
health status of the household members? (Chronic illnesses, access to healthcare facilities, Cost of healthcare)
Education & Awareness
Highest level of education in the household:
Are you aware of any government schemes or programs supporting farmers? (Details of Schemes/Programs availed)
Have you participated in any farmer education programs? (Details of program & duration)
Social Capital
Community Network
Are you a member of any farmer associations or cooperatives? (Details of association/cooperatives)
How often do you interact with other farmers in your community? a) Daily b) Weekly c)Monthly d) Quaterly e) Yearly **Frequency:**
Do you participate in community activities or decision-making processes? (Details)
Access to Support
Do you receive support from **local government or NGOs**? If yes, specify from whom & the type of support.
What are your sources of information on farming (e.g., Local leaders, NGOs, Internet, Community)?
Social Infrastructure
Nearest Hospital and Distance: **Nearest PHC**
Nearest school: (PS/SS/HS)
Natural Capital
Access to Natural Resources
Do you have access to irrigation facilities? What is its source?
What is the quality of soil and water in your fields?
What are the Non Timber Forest Produce you are dependent on?
Are there any challenges related to water availability or quality?

Environmental Challenges	
How has the yield been in the recent years? a) Good b) Less c) Disease affected	**Causes for loss in yield:**
Have you observed changes in the environment affecting your farming (e.g., climate change, deforestation)?	
What measures have you taken to adapt to these changes?	
Physical Capital	
Infrastructure & Tools	
Organic Manure/ Chemical Fertilizer/ Combination/ Where do you buy from?	
How many kilograms of Fertlizer per h.a ?	
Do you own or have access to agricultural equipment and tools? Specify types.	
Is your farm connected to markets via roads or transportation? (Can be based on observation)	
Do you have access to storage facilities for your produce? (If yes, Details of structure type & capacity)	
Housing & Basic Services	
Housing type a)Pucca b)Semi-Pucca c)Kutcha	**Ownership status:**
Affected by Flood/Cyclone/Drought: Yes / No	**Compensated for the same:** Yes/No, If Yes, How?
Do you have access to electricity, clean water, and sanitation facilities?	
Electricity: Yes/No **Clean water:** Yes/No **Sewerage:** Yes/No	
Water supply network available: Yes/No	**No of supply hours:** **Tap water connection:** Yes/No
If tanker system: How many hours/day? Or how many days/week?	
Water quality: Colour: a) Clear b) Yellow c) Other **Smell:** Yes/No **Taste:** a) Normal b) Sweet c) Others	
Dependent on any water bodies? If yes, Which (Ex. River/Lake/Pond)	
Water quality: Colour: a) Clear b) Yellow c) Other **Smell:** Yes/No **Taste:** a) Normal b) Sweet c) Others	
Connection to sewerage network: Yes/No	**If Septic Tank:** a) Individual b)Community **Cleaning frequency:**
Type of Toilet : a) Individual b) Community c)Fields	**Pit Laterine or What type?**
Septic tanks (Cleansing and Maintenance Details)	
Open /Closed Drainage	
Garbage management: a) Bins b) Roadside c) Burning d) Open land e) Others	
Hosehold Composite Pit/ Community Pit:	**Plastic waste management:** a) Resell b) Reuse c) Others, Specify
Any issues or difficulty in accessing the basic infrastructure? (ex. Distance to access water/Availability of clean water)	

Finacial Capital
Income & Savings
What are your primary sources of income?
Any other alternative occupation apart from Farming?
Animal Husbandry/ Horticulture/ Floriculture
Do you have savings? If yes, in what form (cash, bank, livestock, etc.)?
Credit & Financial Services
Have you taken loans for agricultural or personal purposes? If yes, from where (banks, cooperatives, informal lenders)?
Do you face any challenges in accessing credit?
Market Access
Where do you sell your produce? a) Local Market b) APMC Yard c) Others (Specify)
How do you sell your agricultural produce (middlemen, markets, cooperatives)?
Type of Toilet : a) Individual b) Community c)Fields



Annexure 8 Primary Survey Questionnaire: Tourist Survey and Political Ecology

Tourist Survey	
General	
Tourist name	
Origin:	Destination:
Indian/Foreigner	
Purpose of Visit	a) Nature b) Religious c) Leisure d)Adventure e) Stop over
Group of/ Single	
Where are he/she/they from?	
How often do you visit Dakshin Kannada? Which is the most frequented destination?	
About the Gurupura River	
Do you know about Gurupura/Phalguni River?	
Have you attended/known about Gurupur river festival?	
Can you name some local products of this place?	
Did you purchase them?	
Preferences	
Stay Type	a) Hotel/Lodge b) Resort c) Tent d) Dormitory
Duration of stay (in no. of nights)	
Mode of Transport to reach:	Mode of transport to move around:
Infrastructure quality (Rating on a scale of 5)	
Drinking Water provision	Public toilets
Access to Public Transport/Transport	Dust Bins
Access to Food/Eat-outs	Access to Medical assistance

Political Ecology of water - Gender based	
Demigraphic details	
Age	A) 18-25 B) 26-35 C) 36-45 D) 46 and above
Occupation	A) Student B) Homemaker C) Employed D) Unemployed
Access to water	
How often do you have access to clean drinking water?	A) Daily B) Every other day C) Once a week D) Rarely
Where do you primarily collect water from?	A) Tap at home B) Public tap or well C) Borewell D) Other (please specify)
Methods of Storing Water	
How do you store water at home?	A) Plastic containers (buckets, jars) B) Metal drums or tanks C) Water purifiers with storage tanks D) I do not store water
How often do you clean your water storage containers?	A) Weekly B) Monthly C) Rarely D) Never
Water Scarcity & Shortage - Experience	
Have you experienced any water shortages in the past month?	A) Yes, frequently B) Yes, occasionally C) No, not at all D) Not sure
What measures have you taken during water shortages?	A) Collected rainwater B) Purchased bottled water C) Relied on tanker supplies D) No measures taken
How has water scarcity affected your household's daily life?	A) Significantly disrupted (e.g., unable to cook, bathe)B) Somewhat disrupted (e.g., longer collection times) C) No significant impact D) Not sure
Has water scarcity affected your family's health?	A) Yes, increased illness (e.g., waterborne diseases) B) Yes, but only minor issues C) No noticeable impact D) Not sure
Has your family faced any economic challenges due to water scarcity?	A) Yes, significantly (e.g., loss of income from agriculture) B) Yes, somewhat (e.g., increased expenses for water) C) No significant impact D) Not sure
Responsibilities and Time Spent	
Who is primarily responsible for collecting water in your household?	A) Female (you or another woman) B) Male (husband, son, etc.) C) Both equally D) Other (please specify)
How much time do you spend collecting water each day?	A) Less than 30 minutes B) 30 minutes to 1 hour C) 1-2 hours D) More than 2 hours
Decision-Making and Participation	
Are you involved in any local groups or committees related to water management?	A) Yes, actively involved B) Yes, occasionally involved C) No, but I would like to be D) No, not interested
Do you feel that women's opinions are considered in water-related decisions in your community?	A) Always B) Sometimes C) Rarely D) Never
Awareness and Impact of Policies	
Have you heard of any policies that support women's rights regarding water access?	A) Yes, I am well-informed B) Yes, but not in detail C) No, I have not heard of any D) Not sure
How have recent changes in local water policies affected you?	A) Positively B) Negatively C) No effect D) Not sure
Health and Socioeconomic Effects	
Has access to clean water improved your family's health?	A) Yes, significantly B) Yes, somewhat C) No change D) It has worsened
Has access to clean water affected your ability to work or attend school?	A) Yes, positively B) Yes, negatively C) No effect D) Not applicable



Introduction

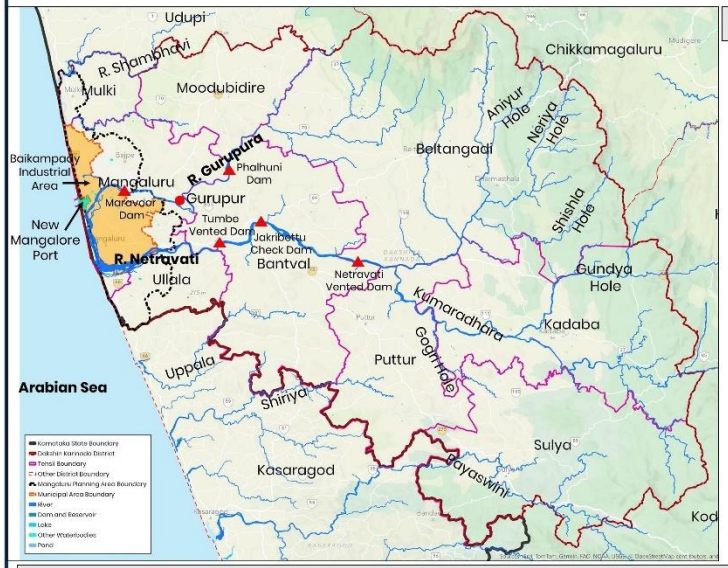
Urban River "**Rivers that flow through cities**", and in an analytical sense as "**those rivers that have been folded into the process of urbanization, whether flowing through urban centres or not**"

River have historically supported development & now **urbanisation** pressurizes its existence.

Global & National Context In India, **NMCG with NIUA** initiated **River Cities alliance** in **2021** & expanded it globally **(COP28)** with **Global River cities alliance** in **2023**. Being a leader enables it to create standards for river-centric policies that align with both the management of rivers.

Focus of RCA : Urban River Management Plans & River related initiatives in Inland cities along East flowing rivers – **30 Member cities & 75 river related interventions.**

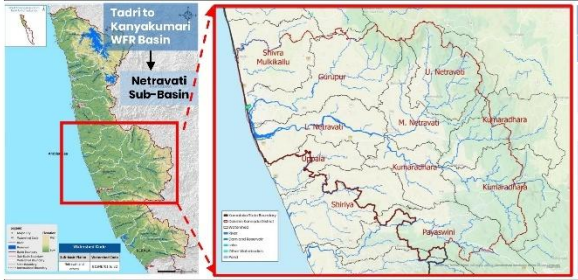
Gap: West Flow Rivers are often overlooked due to small catchments & other characteristics



Why Mangalore?

- Largest urban settlement on the west coast of Karnataka with **2** major west flowing rivers: **Gurupura & Netravati**
- **Ecology & economic:** Major port city, industrial hub, hosts coastal & riverine ecosystem.
- **Planning area** stretches along the entire coastal length of Dakshin Kannada.
- Faces pollution & flooding challenges.

Why Gurupura?



Parameters compared for two rivers

Parameters	Gurupura	Netravati
Length in urban area (M.Corp)	**11.7 km (13.44%)**	8.8 km (8.54%)
Total Population	**7,99161**	4,25,576
Mangaluru M.Corp	**32 Wards**	20 Wards
Industrial Area	Baikampady, NMPA	-
Tourist Locations	**13**	6

NEED OF THE STUDY

SIGNIFICANCE
- Water for irrigation & drinking use in rural areas
- Hosts temples & festivals like Gurupur Teru
- National waterway 43

COMPLEXITY
- Transition from rural lifeline to urban infrastructure asset
- Diverse ecosystem – Coastal, Estuarine and Riverine.

ISSUES
- **Pollution:** from various sources
- **Baikampady:** CEPI area with a score of 73.68
- Fish deaths, mangrove destruction & flooding.

Aim

To devise **Environmental Planning Strategies** for Gurupura River Basin that support sustainable River Basin Management Principles and also encourage River Centric Urban Planning for reinstating the ecological health of the Gurupura River.

Objective 1: Understand the interface between Basin Wide (River) & Spatial Planning Approach w.r.t WFR in Karnataka's coastal ecosystem.

Objective 2: Delineate study area based on environmental & anthropogenic parameters & establish baseline for prioritizing ecosystem services that bare a connect with environmental resources, human settlements & land use within the study area

Objective 3: Arrive at critically degraded watersheds & sub-watersheds containing urban settlements that have a bearing on the river water ecology & develop River Centric Urban Plans

Objective 4: Develop Environmental planning strategies & guidelines that are multi scalar, encouraging green field development that support symbiotic relation between the river & human settlements .

Methodology

Literature

Objective 1
1. Concepts and Definitions
2. Frameworks and toolkits related to River Basin Management
3. Spatial planning concepts
4. Case Study on River Centric Urban Planning
5. State and Government documents - Environment, Planning and Management reports
6. Studies related to Gurupura and Netravati River Basins and Dakshin Kannada District.
7. Studies and Reports on Mangaluru City

1. Conceptual Framework
2. Themes & Sub-themes for Baseline Study

Site visit for primary surveys of various planning aspects and secondary data collection from relevant organisations

Baseline & Analysis

Objective 2

Region
- Contextualizing, & understanding regional classification → Scoping of study area: environment & man-made aspects
- Environmental Resources: 1. Climate, 2. Land, 3. Water, 4. Biotic → 1. Climate variability, 2. Slope, elevation, 3. Basin Morphometry, 4. NDVI & NDWI, 5. Ecosystem services
- Hazard → Hazard Types
- Settlement Analysis → 1. Settlement Hierarchy, 2. Scalogram, 3. Livelihood analysis
- LULC → Change Detection
- Stakeholders → Stakeholder Mapping
- Economic Base: 1. Stakeholder, 2. Agriculture, 3. Tourism, 4. Industry → 1. Sectoral analysis, 2. Impact matrix
- Watershed & Flooding → Flood Susceptibility, Watershed Prioritization

Planning Area
- Land Use & Development Plan → DP review w.r.t to water resources
- Fluvial Flood → Fluvial Flood Risk

Objective 3

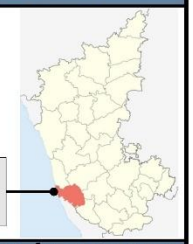
City
- Introduction → Evolution of Mangaluru City
- Environmental Resources: 1. Land, 2. Water, 3. Biotic → 1. Water body analysis & water quality, 2. Mangrove Ecosystem Services, 3. CRZ & Coastal Hazard
- Domography & Socio-economics → Ward level Analysis
- Land Use → Land use analysis w.r.t to impact on the river
- Economic Activities → 1. GIDC Industry Sustainability Standard Assessment, 2. Impact Matrix
- **Physical Infrastructure**: 1. Water Supply, 2. Soworago, 3. Storm Water, 4. Solid Waste, 5. Road → 1. Gap Analysis, 2. Water Stress, 3. Water Balance, 4. Pluvial Flooding
- **Social Infrastructure**: 1. Housing, 2. Open Spaces, 3. Healthcare & Education → Analysis & Gap
- Resilience → URMP Index & Urban River Resilience Index (URRI)
- Ward Analysis → 1. Critical ward identification, 2. Analysis of Critical Wards

River Governance
SWOC
Land Suitability & Population Projections

Proposals

Objective 4
- Spatial planning & Management strategies for Gurupura River Basin
- Road Map for Phase wise Implementation
- Governance
- Integration with Development Plan
- Comprehensive Environmental Planning Strategies for Gurupura River

KEY MAP



LEGEND / INFERENCE

- **District coast length – 62 km, 48.4% coast line erosion**
- **Origin** – Western Ghats in the Kudremukh ESZ within Udupi District
- **R. Gurupura Length – 87 km** (WS Area: 874.6 sq.km)
- **R. Netravati Length – 103 km** (WS Area: 1082.79 sq.km)

NGT report (OA 151/2023): River basin management to address these issues.

SCALE :

N

SHEET NO: **1**

SHEET TITLE: **Introduction**

SOURCE:
- *NIUA guidelines & toolkits*
- *Compilation of various literature by Author*

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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Literature Review

Basic Concepts & Terminologies

Concepts	Relevance	Terms
River Ecology	Hydrological process, & cross section	**Basin Morphometry** & 4 Spatial Dimensions: Length, Width, Height, Time
Rivers & human settlements	Settlements along the banks & shift to inland	**River corridor, River Precinct**
River Basin	Hierarchy of Hydrological units	**River basin**

River Basin Frameworks & Watershed Management & Planning Concepts

Theme	Sub-theme	Co-relation with River Management	Co-relation with Gurupura River & Spatial Planning
IWRM	Water governance	Promotes coordinated management of water, land resources across sectors & stakeholders.	Decision-making across rural & urban areas of Gurupura basin with cross-sectoral planning.
IUWM	Urban water cycle integration	Synergy between water supply, wastewater, & stormwater in urban areas.	Water infrastructure planning in critical urban wards of Mangalore
WSUDP	Nature-based solutions	low-impact design & green infrastructure to manage water sustainably.	Eco-sensitive river corridor and peri-urban village planning in flood-prone zones.
River Basin Planning (ADB)	Catchment-based planning	Spatially coordinated basin-level planning to balance development and ecosystem needs.	Regional-scale planning for Gurupura watershed considering up & downstream impacts.
URMP (NIUA)	City-river integration	Provides framework for integrating river health in urban governance and infrastructure.	Forms the backbone of city-level river interventions and stakeholder engagement
River Sensitive Master Plan	Development regulations	Zoning, development control, and spatial planning tools for river-sensitive growth.	Spatial zoning and land use near Gurupura for flood resilience & buffer creation.
Compendium of River Plans (NIUA)	Best practices and case studies	Strategies and actions from multiple river cities across India.	Replicable ideas and benchmarking examples for settlements along Gurupura.

Climate resilience & SDG's

Theme	Sub-theme	Co-relation with River Management	Co-relation with Gurupura River & Spatial Planning
IAdapt (ICLEI)	Climate adaptive decision-making	Iterative, stakeholder-driven planning for locally relevant adaptation actions.	Community-based & eco-village planning via adaptive water-use & land-use measures.
ClimateSmart Cities (NIUA) 3.0	Climate action benchmarking	Offers performance indicators across sectors like water, energy, and biodiversity.	Helps assess current urban planning gaps and guides river-sensitive city interventions
SDGs (UN)	Sustainability targets	Integrates water (6), cities (11), and climate action (13) into river basin governance.	Goal-based framework for spatial planning proposals with sustainability & equity

Stakeholders, Ecosystem Services & Livelihood Analysis

Theme	Sub-theme	Co-relation with River Management	Co-relation with Gurupura River & Spatial Planning
Stakeholder Analysis	Stakeholder engagement	Identifies interests, influence, & roles of actors in river governance & management.	Mapping users of Gurupur river - agriculture, industries, Communities - for targeted & inclusive river strategies.
Ecosystem Services (TEEB by GIZ)	Ecosystem valuation	Inclusion of ecological benefits (water purification, flood regulation) in planning.	Rural development and land-use proposals by valuing Gurupura' s provisioning & regulatory services.
Sustainable Livelihoods Framework(UNDP)	Livelihood analysis	Dependency of communities on natural systems & resilience to changes.	Proposals for livelihood diversification along Gurupura and spatial strategies in peri-urban zones.

Spatial Planning

Theme	Sub-theme	Co-relation with River Management	Co-relation with Gurupura River & Spatial Planning
URDPFI Guidelines (MoHUA)	Urban form & land use planning	Land use & infrastructure planning, with environmental considerations.	Guides development control & zoning near Gurupura to protect floodplains & enable river-sensitive growth.
RADPFI Guidelines	Rural and peri-urban planning	Spatial planning for villages with infrastructure & environmental sustainability.	Supports sustainable village planning & infrastructure provision in flood-prone villages along Gurupura.
Green City Toolkit (ADB)	Environmental infrastructure	Green infrastructure, resource-efficient cities with natural capital protection.	Sustainable planning for small towns & river corridors, integrating natural buffers and green mobility.
City Blueprint Approach (KWR/EIP)	Urban water governance & spatial indicators	Indicators to for water management performance across spatial & governance dimensions.	Spatial assessment of water-related infrastructure gaps in Mangalore, guiding resilient riverfront interventions.

Government Documents

Theme	Sub-theme	Co-relation with River Management	Co-relation with Gurupura River & Spatial Planning
Karnataka SAPCC	Climate vulnerability & sectoral action	Climate risks to water, biodiversity, & agriculture with adaptation measures.	Integration of climate-responsive land use & water management strategies in Gurupura basin planning.
D.K. DDMP (2019–20)	Flood & hazard mitigation planning	Vulnerable areas, response mechanisms, & early warning systems.	Spatial prioritization of flood-prone zones & disaster-resilient infrastructure
D.K. DEP (2022)	Environmental monitoring & enforcement	Key polluting sources, action plans, & compliance measures for river health.	Target pollution hotspots and plan for solid waste, sewage, & industrial discharge near Gurupura.
Madhav Gadgil Report	Ecological sensitivity mapping	Decentralized governance & zoning in Western Ghats.	Conservation-first planning & regulation of development in Gurupura' s upper catchment areas.
Kasturirangan Report	Eco-sensitive zones with development balance	Proposes graded zones balancing conservation and livelihoods.	Zoning rural areas & align planning with ecological sensitivity in the watershed.

Case Studies

Theme	Sub-Theme	Co-relation with River Management	Co-relation with Gurupura Thesis & Spatial Planning
White River Plan	Landscape restoration, stewardship, economy	Emphasizes integrated, community-led river regeneration	Relevant to precinct-level planning, green infrastructure, and local economies
Ganga River Plan	Basin conservation, livelihoods, governance	Focuses on basin-scale ecological restoration and stakeholder coordination	Guides multi-scale spatial strategies, institutional integration, and land use

Scope & Limitations

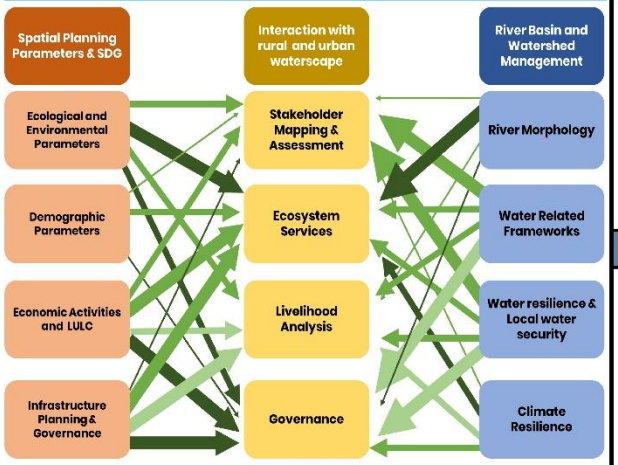
Scope

The interventions will be focused on various scales that aligns with both **Spatial planning and Watershed based planning** within the identified critically degraded watersheds.

Limitations

- Data gaps and time frame.
- Solar intensity & solar radiation
- Evaporation & evapotranspiration
- Inland fishing is absent.
- Hydrology Modelling
- River carrying capacity – Sediment load, Velocity & Discharge
- Ecosystem service valuation
- Water related health data
- Region- Water Stress
- Tourism & Carrying capacity
- Social Governance

Conceptual Framework



Parameters taken forward

Aspect	Parameter	Sub parameter	Indicator	Scale: Region	Scale: LPA	Scale: M.Corp
Climate Resilience						
Ecology	ER (Abiotic)	Land & Water	- Geomorphological & soil feature - Surface & Ground water	■	■	■
	Biotic	Forest Cover & Biodiversity	Change in biodiversity	■		
Climate	Climate	Temperature & Rainfall	Change in climate	■	■	■
	Hazard	Inland & Coastal	- Coastal erosion - Flood risk		■	■
Water Resilience						
Health & Wellbeing	Governance & Access to social services	Local Governance Socio-economic profile Healthcare & Education	- Responsibility & schemes - Literacy rate, Sex Ratio & WFPR - Sex ratio			■
Political Ecology						
Stakeholder & connect with river	Stakeholders & Water	Stakeholder Assessment	- Identifying & categorizing the stakeholder	■	■	■
		Stakeholder Mapping Local Water Security	Identified concerns and interest Resources/Strategies to align the interests of stakeholders		■	■
	Livelihood Anlysis	- Natural Capital - Human Capital - Physical Capital - Social Capital - Financial Capital	- Natural resources - Socio-economic aspect & Access to watar, Housing & Infrastructure - Financial resources		■	■
Ecology	Ecosystem Service	Provision	Agriculture, Fishing		■	■
		Supporting	Biodiversity		■	■
		Cultural	Recreational, Spiritual, Tourism		■	■
Utility						
Basic infrastructure	Water	Local level water security	- Supply - extraction & allocation - Sewage, Stormwater & reuse		■	■
	Soil waste	Urban & Household level	collection, Handling & disposal			■
	Transportation	Regional & Local connectivity	Road network & Density	■	■	■
	Industry	Types of industries	Impact of industries on water	■	■	■
Built environment	Urban form	Settlement pattern & hierarchy	- LUCL - Urban centres	■	■	■
		Land use classification & open spaces	Run-off intensity & infiltration			■
	Housing & Built assets	Condition & Level of amenities	Surface run-off & RWH			■
Sustainability						
SDG	1. Social 2. Economic 3. Environment 4. Governance	Direct - SDG **6, 10, 11, 13, 15, 17** Indirect - SDG **8 & 9**	Respective UN-SDG 2030 Indicators	■	■	■

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



KEY MAP

LEGEND / INFERENCE

Intensity of Linkages
- Weak
- Medium
- Strong

Scale of Intervention
- Region
- Planning Area
- Municipal Corporation

SCALE :

N

SHEET NO: **2**

SHEET TITLE: **Study Approach & framework**

SOURCE:
- *Compiled by Author*

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Region Setting

River Basin Frameworks & Watershed Management & Planning Concepts

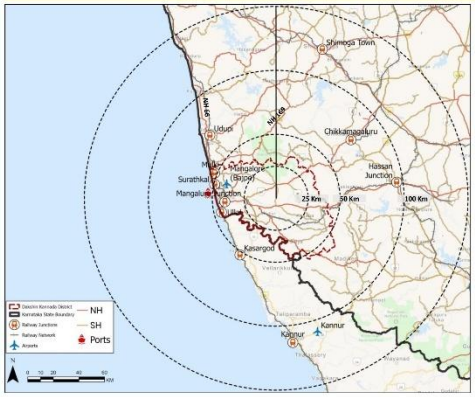


Dakshin Kannada District – Part of the **Western Ghats** & Larger **Karavali Region** of Karnataka

Geographical Area : 4859 Sq.km

Population : 20,89,649 (Census 2011)

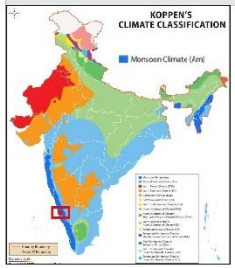
River Basin Frameworks & Watershed Management & Planning Concepts





Road : NH 66: Mangalore to Goa & Kerala on west coast., **NH 169:** Mangalore to Chikmangaluru via Karkala.

Climate Zones



Mangalore falls in Classification **Am** Monsoon Climate

Annual rainfall: 3,000–4,000 mm June–September.

Wet and Dry Seasons : Distinct monsoon (wet) and dry post-monsoon periods.

Warm Temperatures: 24°C to 34°C year-round, High Humidity

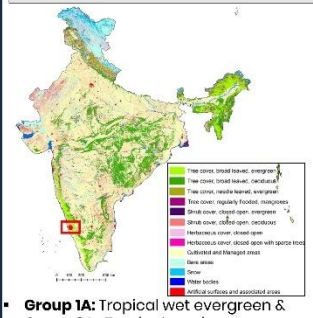
Bio-geographic Zone



Falls in **Western Ghats category** & belongs to **Malabar Coast Province.**

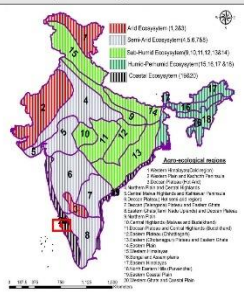
Biodiversity hotspot with **tropical evergreen forests**, high rainfall, fertile soils & rich aquatic & terrestrial ecosystem shaped by **rivers & estuaries**

Champion & Seth forest classification



- **Group 1A:** Tropical wet evergreen & **Group 2A :** Tropical semi-evergreen forest
- Forests range from **Mangrove & coastal vegetation** in lowlands to **semi evergreen forests** in hinterlands

Agro-ecological zone

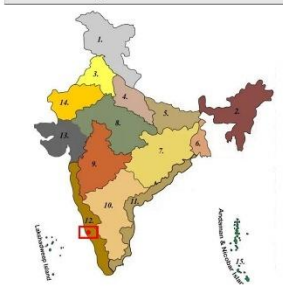


Falls in **Coastal Ecosystem,** and Agro-ecological zone for **Western ghats & Coastal Plains** & Sub region is **Hot humid to per humid**

Available Water Capacity: Low to medium

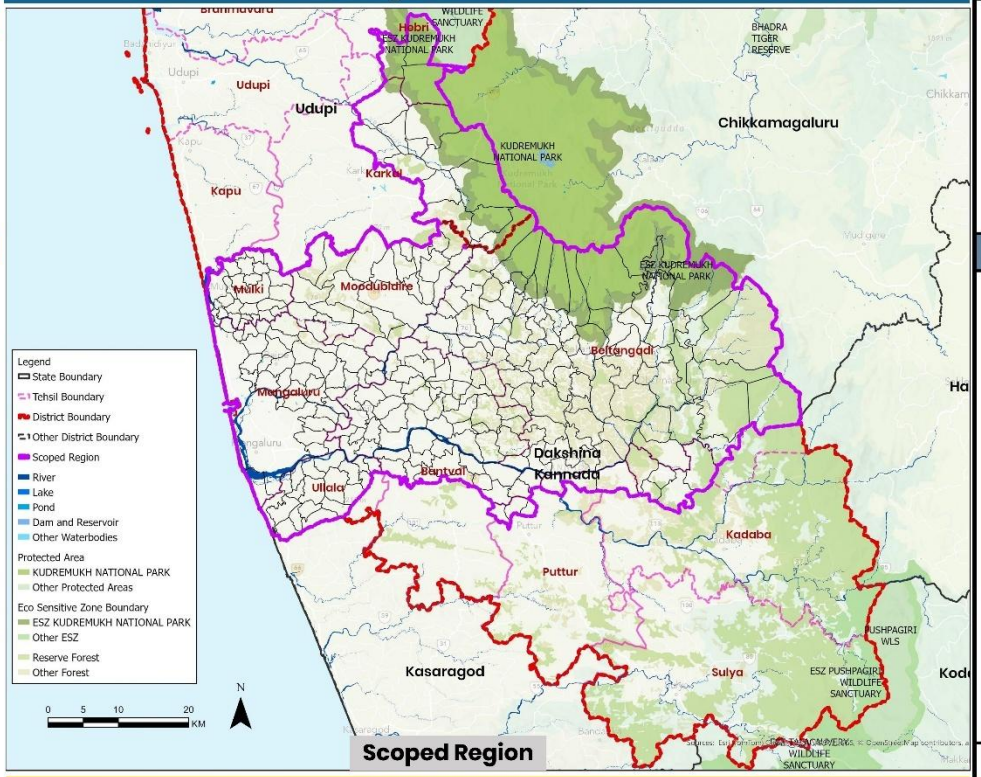
Length of growing period: 240–270 days

Agro-Climatic zone



Falls in **Coastal & Western ghats region (XII).** Climate is **Hot & Humid,** Avg. Rainfall is **2500 to 4000 mm, Crops:** Rice, Coconut, Arecanut, spices & cashew, Banana & Jackfruit **Problems:** High soil erosion, limited ground water & salinity intrusion.

Region Delineation



Scoped Region

ENVIRONMENTAL ASPECTS + MAN-MADE ASPECT -> SCOPED REGION

Environmental Aspects

- **River Basins-** The district lies on **Tadri to Kanya-Kumari River Basin**, & **Netravati Sub-basin.**
- **Rivers – Netravati, Kumaradhara & Gurupura** drain the Eastern & Central part, **Shambhavi originating in Udupi District & its tributary Nandini** drains the north-west part of district into Arabian Sea
- **Contour:** Diverse topography ranging from coastal plains to undulating terrains of the western ghats.
  - **Western coastal edge**: Flat terrain with elevation **upto 50m ASL** -broad sandy beaches & estuaries
  - **Mid-elevation Zone : 50-500m ASL**, slightly undulating terrain
  - **High elevation zone – 500-1000 ASL**, Entering the Western ghats
- **Elevation – Coastal lowlands, Mid elevation zone** with undulating terraces suitable for crops like areca nuts, Paddy , coconut, **High lands – western ghats – 500-1894 ASL**, featuring the 3rd highest peak of Karnataka **– Kudremukh Peak**
- **Faults and Lineaments – A tectonic fault** in the western ghats, **1 major fault & minor faults**, indicating geological instability & falls in the **seismic zone III**
- **Forest - 46%** of the district is under forest cover, & **Kudremukh National Park** a Biodiversity Hotspot continues into Udupi District.

Man-Made Aspects

- **Administrative Boundary:** District & 9 Tehsil.
- **Road Connectivity:** NH 66 along west coast, NH 169 to Chikmangaluru, NH 75 to Hassan, NH 275 to Kodagu district.
- **Urban Centres:** Concentrated near the coast around Mangaluru city.
- **Mangaluru Planning Area:** The Mangaluru Planning Area extends along the entire coastal length of the district.
- **Tourism:** District is known for Pilgrim located in the western ghats such as Dharmasthala, Kukke Subramanya & Nature tourism is concentrated in Mangaluru city, known for the broad coastal beaches.
- **Industries:** Concentrated in Mangaluru, Mulki & Mudabidri tehsils.

Scoped Region

- **Area: 3,350 Sq.km** (3,35,093.40 Ha)
- **Included 232 Villages & 38 Urban centres**
- **Tehsils:** Mulki, Mangaluru, Mudabidri, Beltangady, Puttur & Bantval Tehsils of **Dakshin Kannada District** & Hebri & Karkala Tehsils of **Udupi District**

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP

LEGEND / INFERENCE

SCALE :

N

SHEET NO: **3**

SHEET TITLE: **Regional Setting & Region Delineation**

SOURCE:
- *Author*

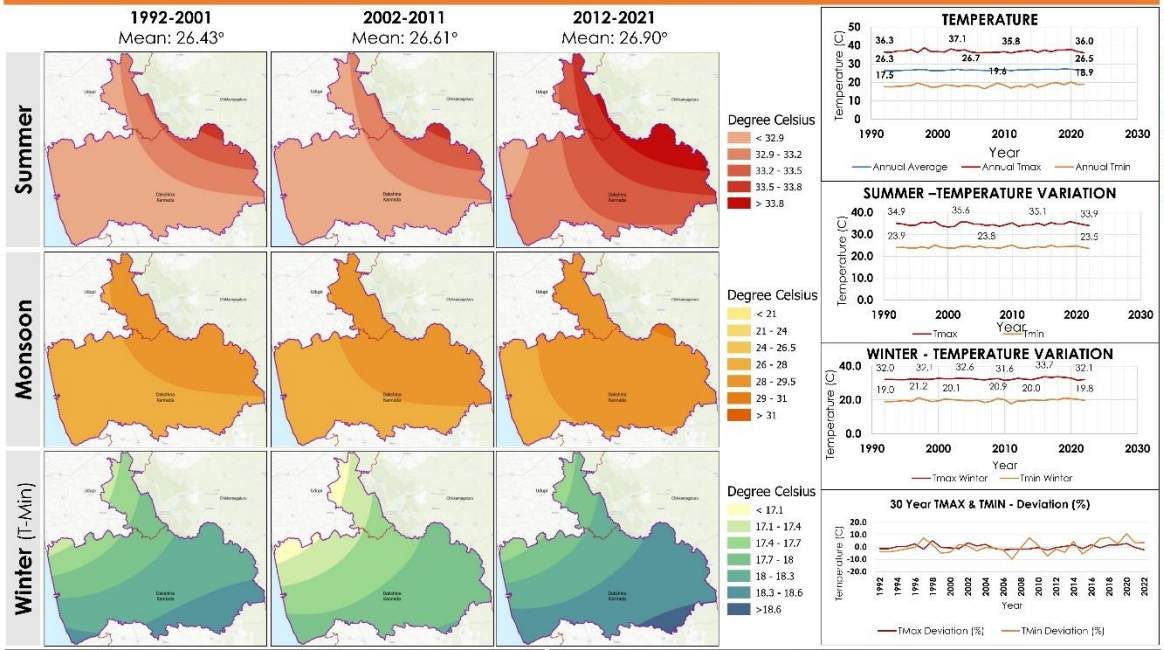
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Climate Variability

TEMPERATURE ANALYSIS – 1922 to 2021



Temperature trend:

1. **Annual Average Temperature:** Over the last 3 decades, it has fluctuated between **26.25 to 27.34 Deg C**
2. **Maximum & Minimum Temperature: Tmax** ranges between **25.84 to 38.66 Deg C**, while **Tmin** ranges between **16.43 to 20.19 Deg C.**
3. **Seasonal Variations:**

- **Summer Tmax:** Peaks between **22.30 to 35.80 Deg C**
- **Winter Tmin:** Drops between **21.25 to 17.83 Deg C**

Temperature Deviation

1. **TMax :** Peaks in **1992-02** (+5%), and in **2012-22** (+2.8%) - warmer temperatures and least deviation occurs in **2002-12** (-2.7%)
2. **TMin:** Lower '+' deviations can be observed in **1992-02** (+7.16) & the highest '+' deviation occurs post **2015**, '–' deviations has reduced post **2012**, indicating increasing temperatures
3. **The increase in '+' deviations & reduced '-' deviations** of both **TMin & TMax** indicate warmer temperatures which **may increase evaporation, higher water losses & water demand.**

KSAPCC

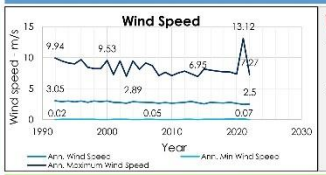
Projected Temperature Changes in Karnataka

- **Short-term (2030s):** Increase of **0.5°C to 1.5°C** depending on the region.
- **Long-term (2080s):** Increase of **2.0°C to 4.0°C** under high-emission scenarios.
- **More heatwaves** and **higher night temperatures** are expected, particularly in urban and inland regions.

Temperature in Dakshina Kannada

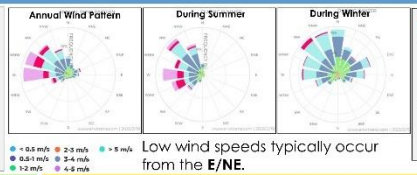
- **Lower temperature rise** in Coastal regions compared to inland Karnataka due to the moderating influence of the Arabian Sea.
- **Warmer nights and increased humidity** are expected, leading to **higher heat index values** even if the temperature rise is lower.

Wind Speed – 1922 to 2021



Wind Speed

- **Annual wind speed: 2.45 to 3.05 m/s.**
- **Max wind speed:** The wind speed can be high reaching upto **6.95 to 13.12 m /s.**



Low wind speeds typically occur from the **E/NE.**

Wind Direction:

- **W and NW** winds dominate, especially in **summer**
- Winter brings a shift towards NNW and NW winds.

Relative Humidity – 1922 to 2021



Annual RH: High relative humidity. **Avg RH:** 75% & 80% over the years.
Monthly RH: Seasonal RH : Lowest in **Jan-Mar** & highest in **Jun to Oct.**

- **Peaks :** Monsoon months (Jun-Sep), often reaching **80% to 90%**

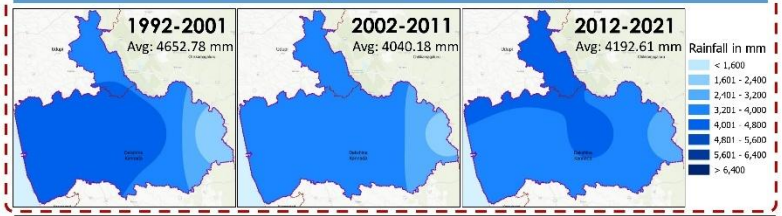
Solar Radiation – 1922 to 2021

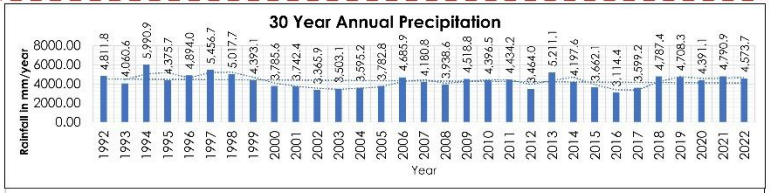


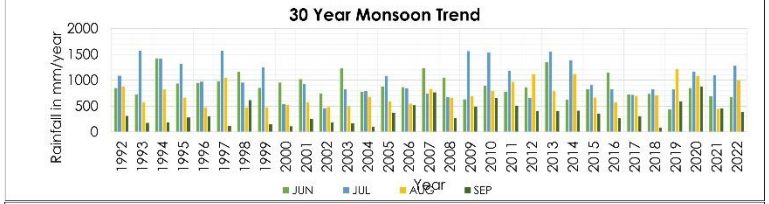
Solar Radiation: Moderate, **Avg Range : 210 to 226 W/m².**
Monthly SR: Seasonal SR : Highest in **Jan-Mar** & lowest from **Jun to Oct.**

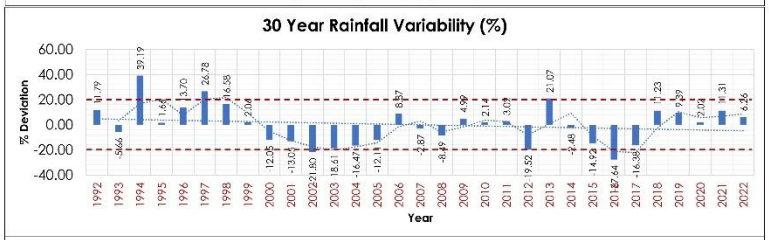
- **Peaks :** Dry months (Feb-May), reaches up to **265-267 W/m²**

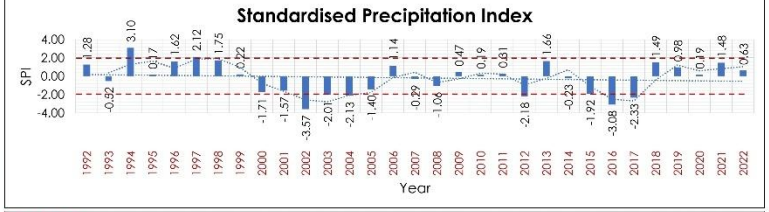
Rainfall Analysis - Decadal Averages











Rainfall : The monsoon season occurs between **June to September.**
Ann. precipitation: 3114 to 5990 mm/year
Monsoon Trends: **July** ->dominant, followed by **Aug, Jun & Sept.**
Rainfall Variability: '+20%' deviations – 1994, 1997,2013 '–20%' deviations –2002, 2016.
SPI: The initial decade shows **extremely wet conditions**, while in the last two decades, **Very wet to severely dry** conditions are frequent.

Karnataka State Action Plan on Climate Change

General Rainfall Trends in Karnataka

- Increased in most districts, with rise of up to **25%** in some areas.
- Monsoon (JJAS) rainfall: projected to increase by **15% to 25%** in the **NE and Western Ghats districts** under both **RCP 4.5 and RCP 8.5** scenarios.

Rainfall Projections for Dakshina Kannada

- **Short-term (2030s):** Monsoon rainfall increase by **15% to 20%**
- **Long-term (2080s):** Rainfall to increase by **20% to 25%.**
- **Rainy Days:** Increase by **1 to 3 days** annually (RCP 4.5) and **2 to 9** days annually (RCP 8.5)



Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE

SPI	Category
2 & Above	Extremely wet
1.5 to 1.99	Very Wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near Normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2.0 & Less	Extremely dry

Significant rainfall increases (20-25%) expected in both Monsoon & Winters

- **KSAPCC: Extreme Rainfall Events: 'Very High'** intensity rainfall events (days receiving > 100mm) to increase by **1 to 2 events annually.**
- **'High'** intensity rainfall events (> 50mm) to increase by **4 events annually.**
- **Droughts:** Marginal decline by around 2 years

SCALE :

N

SHEET NO: **4**

SHEET TITLE: **Climate Variability**

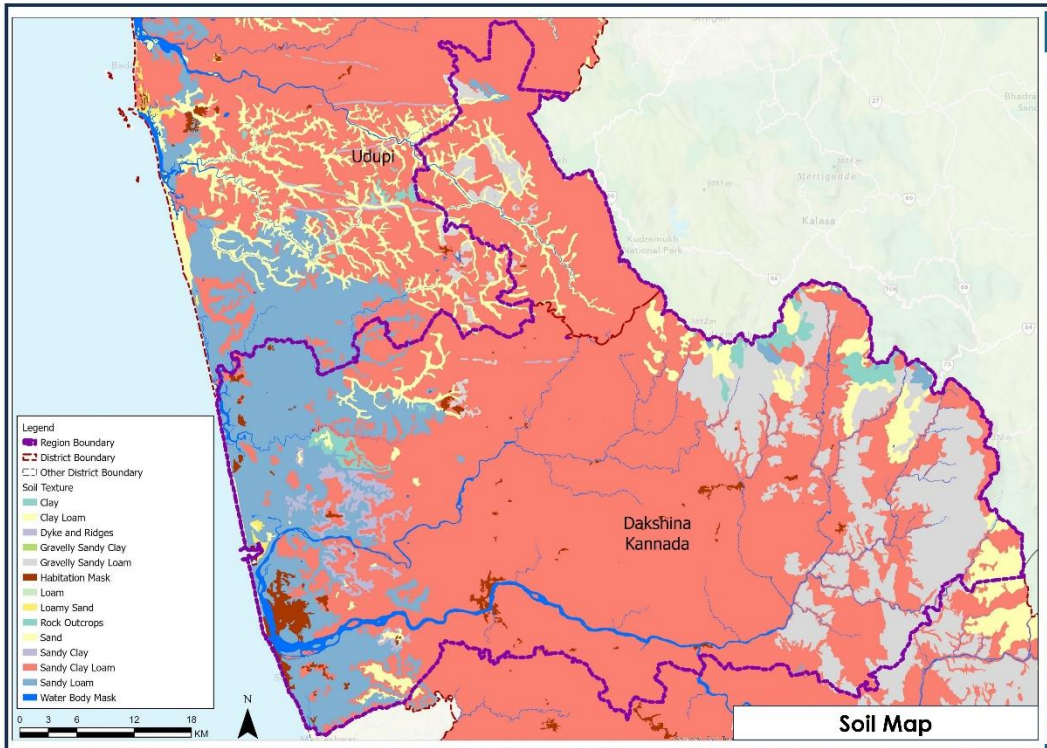
SOURCE:

- *IMD*
- *Karnataka State Action Plan for Climate Change - 2021*

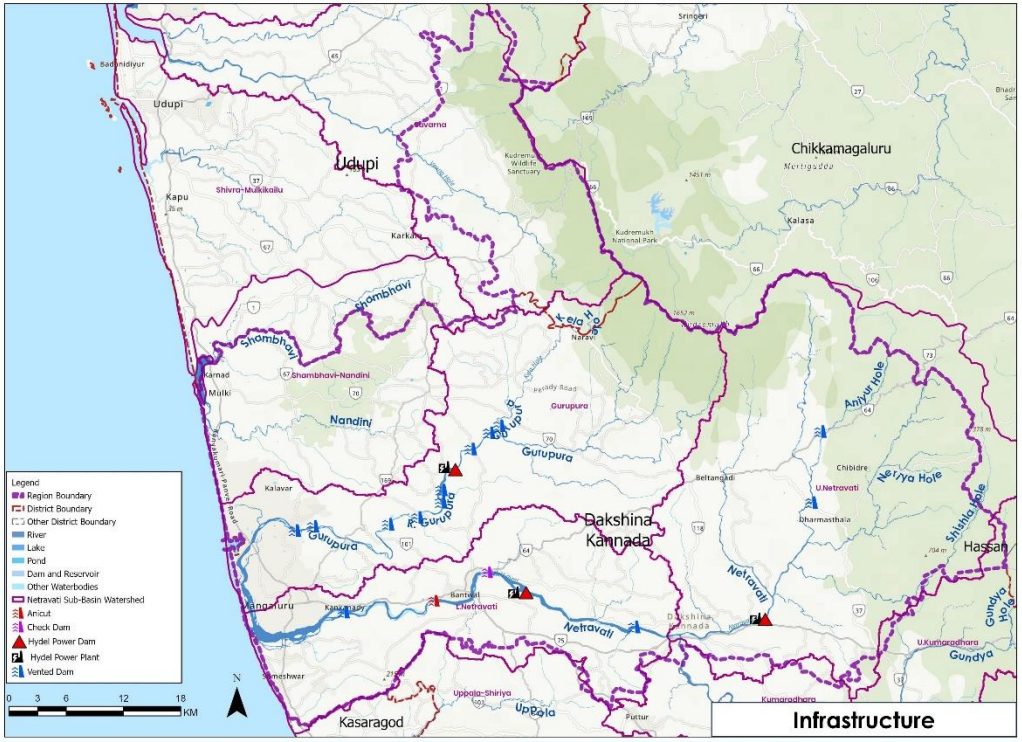
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Soil Map



Infrastructure

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Land Environment

Geology

Group	Sub-group & Age	Formation	Key Characteristics	Stability Implications
Peninsular Gneissic complex - I	Peninsular Gneissic complex, Archaean	Granitic and gneissic rocks	Hard, resistant to weathering	High stability, minimal erosion
-	Laterite/ Bauxite, Cenozoic	Ferruginous and aluminous rock, highly porous	High weathering susceptibility	Low stability, prone to erosion and mass wasting
Bababudan	Dharwar, Archaean	Quartzite, phyllite, and schist	Medium hardness, moderate fracturing	Moderate stability with some erosion risk
-	Unconsolidated Sediments, Quaternary	Alluvial, coastal, aeolian, and glacial deposits	Loose, unconsolidated, high porosity	Low stability, prone to erosion and flooding

- **Geomorphology: 58.52%** of the region is **Pediment pediplain complex**.
  - Dominated by **pediment pediplain complexes, highly dissected hills,** & **denudational valleys**, with **floodplains, coastal plains**, & **riverine areas**, indicating diverse topography & varying erosion patterns.
- **Soil:** Predominantly **clay, sandy clay, sandy clay loam**, & **gravelly sandy clay**, with patches of **loam & sandy loam.**
  - The dominance of **sandy clay loam** in the region indicates **well-drained yet moisture-retentive soil**, suitable for crops like **Arecanut, coconut, and paddy**, which require moderate water retention.

1. Geology: Dominated by **Peninsular Gneissic complex** and **laterite formations**, with **58.52% pediment pediplain complex ->** diverse landforms like floodplains & coastal plains.
2. Soils **sandy clay loam**, well-drained yet moisture-retentive—ideal for crops like Arecanut & paddy.

Water Environment

- **Watershed –** The region lie in the watersheds of **Gurupura, Upper Netravati, Lower Netravati** of **Dakshin Kannada District** & partly on **Shivra-Mulkikailu, & Suvarna Watersheds in Udupi District**
- **River systems –** The **Netravati River, Gurupura River** Drain the **North, West** and the **central parts** of the region, while the **Shambhavi & Nandini River** drains the **North westerns parts** of the region into the Arabian Sea.

River	Origin	Tributaries	Watershed	Catchment Area (Sq.km)	% Region Area
Netravati	Western Ghats, Dakshin Kannada	Kumaradhara, Neriya, Shishla, Aniyur, Gundya, Gogri	Netravati	1802.79 (U & L Netravati)	**46.18%**
Gurupura	Kudremukh National Park ESZ, Uudpi District	Kela Hole	Netravati	930.36	**31.75%**
Shambhavi	Sanoor Village, Udupi District	-	Shivra-Mulkikailu	490.70	**11.34%**
Nandini	Kanakabettu, Dakshin Kannada District	-	Shivra-Mulkikailu		
Suvarna Watershed					**10.73**

Infrastructure on Gurupura & Netravati Rivers

- **Gurupura : 9 Vented dams** for ground water recharge, water for drinking use in rural areas, & a small Hydel power project.
- **Netravati :** Tumbe Anicut/Dam - Source of water for Mangaluru City & other rural areas.
- Vented & check dams for irrigation & drinking water in rural areas & 2 small hydel power.

Surface Water Quality

No sample points & quality data available, Research papers show presence of fish, indicating **good water quality** with desirable limits of DO, BOD & COD.



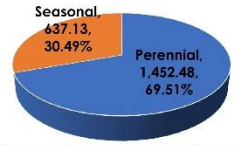


KEY MAP



LEGEND / INFERENCE

Stream Length in km



70% River network is Perennial indicating water availability throughout the year in the region.

SCALE : **1: 2,80,000**

N

SHEET NO: **5**

SHEET TITLE: **Environmental Resources**

SOURCE:
- *Bhukosh*
- *India WRIS*
- *KSRSAC - KGIS*

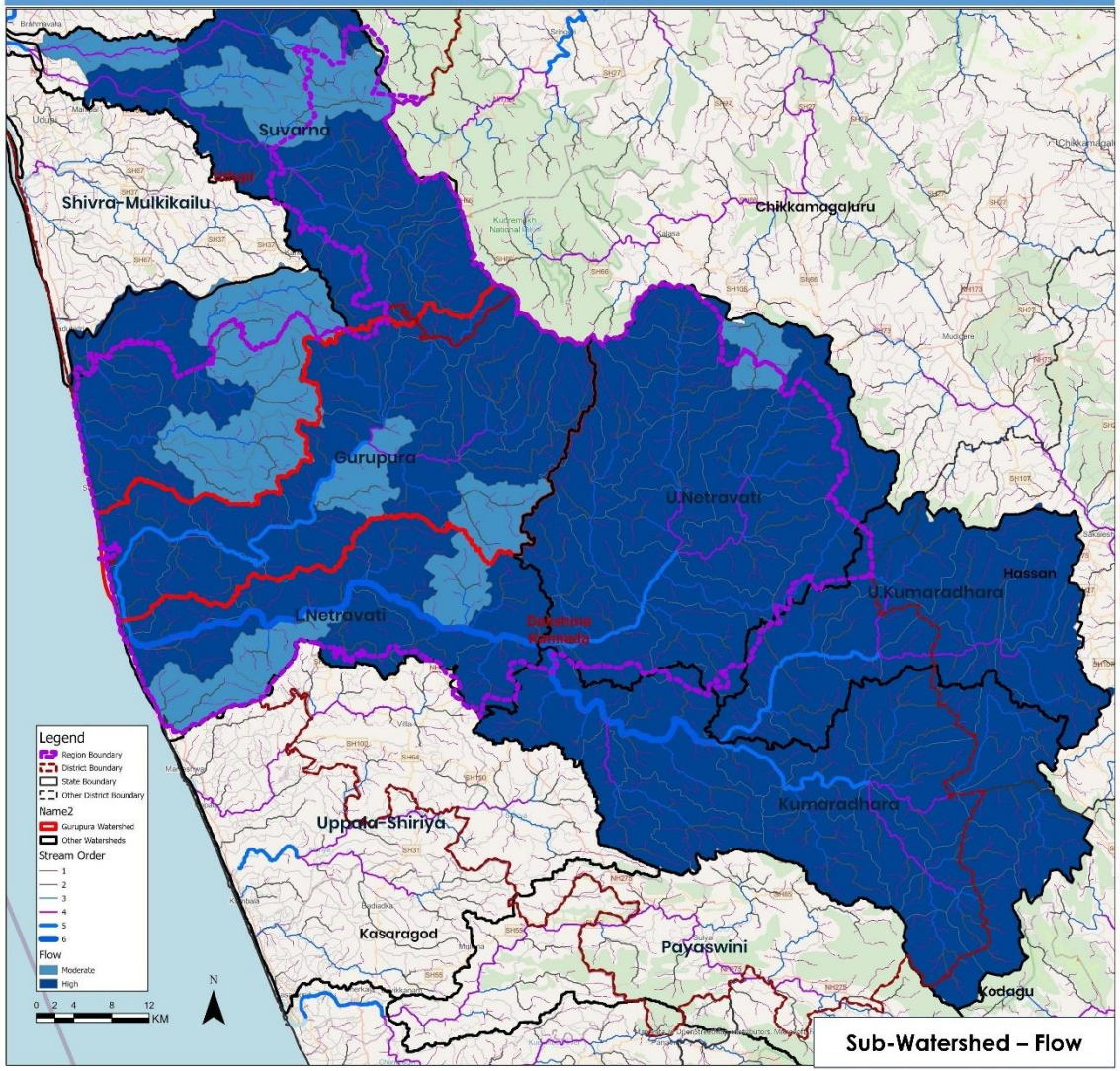
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Basin Morphometry

Sub-Watershed - Flow



Sub-Watershed – Flow

Parameter	Sub-Basins					
	Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Number of sub-watershed	17	11	21	25	8	4
Length of stream (Km)	563.11	361.88	691.74	1130.27	218.51	115.37
Sub-Basin Length (Km)	52.6	43.56	41.5	58.18	28	23.2
Sub Basin Area (km^2)	879.3	562.8	1126.74	1797.91	361.18	186.96
Sub-Basin Perimeter (Km)	243.21	197.71	2015.55	496.77		

Stream Order Analysis and Water Flow Characteristics

- Majority are 1st order: **dendritic drainage pattern** with **small tributaries.**
- Gurupura watershed has few higher-order & more low-order streams -> **moderate to low infiltration potential**, indicating urbanization & encroachments will impact drainage patterns -> higher surface runoff, flooding, & erosion.

Linear Aspect

Parameter	Sub-Basins					
	Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Bifurcation Ratio (R_b)	6.52	4.62	6.23	6.65	5.17	6.75
Length of Overland Flow (L_g) (km)	0.78	0.78	0.2	0.79	0.82	0.82

Bifurcation Ratio (Rb) & Its Flood Risk Implications

- Gurupura R_b = **6.52** Falls in the **moderate to high range** (4.7 - 9.4) -> **balanced runoff with a moderate flood susceptibility.**

Length of Overland Flow (L_o) & Its Role in Sediment Transport

- Gurupura L_o = 0.78 km, Falls in the **0.8-1 km** range -> **moderate flood duration** with **medium sediment transport.**
- Indicates a **balanced infiltration and runoff scenario.**

Aerial Aspect

Parameter	Sub-Basins					
	Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Circularity Ratio (R_c)	0.47	0.41	0.44	0.45	0.48	0.38
Stream Frequency (F_s) (Streams/km^2)	0.3	0.28	0.28	0.29	0.31	0.28
Drainage Density (Dd) (km)	0.64	0.64	0.61	0.62	0.6	0.6
Texture Ratio (R_t)	0.41	0.36	0.39	0.46	0.4	0.32
Infiltration Number (I_n)	0.19	0.18	0.17	0.18	0.19	0.17

- **Moderate circularity ratio** → Flood risk exists but is not extreme.
- **Moderate drainage density and infiltration number** → Groundwater recharge potential → Incorporate recharge wells and urban wetlands.
- **Moderately coarse texture ratio** → Risk of runoff-induced erosion

Relief Aspect

Aspect	Parameter	Sub-Basins					
		Gurupura	L.Netravati	U.Netravati	Kumaradhara	Shambhavi	Nandini
Relief - Watershed	Total Basin Relief (Meter)	1885	275	1163	1674	176	260
Relief (Avg of Sub-watersheds)	Basin Relief (H) (Meter)	509.23	194.81	806.57	762.24	157.25	151.25
	Relief Ratio (R_r)	85.36	26.53	112.09	89.15	23.58	22.28
	Ruggedness number (R_n)	0.34	0.12	0.49	0.47	0.09	0.092

1. **Basin Relief (H)** Gurupura: 509.23m, Falls in the 300-450m range -> **moderate relief.**
- **Balanced infiltration-runoff** conditions with **moderate erosion potential.**

Moderate Basin Relief → Requires slope stabilization and erosion control.

2. **Relief Ratio (Rr): 85.36**, Falls in the 50-100 range -> **moderate to high runoff** with **moderate erosion potential.** Flash flood risk is not extreme but exists

Moderate Relief Ratio → Flash floods possible

3. **Ruggedness Number (Rn): 0.34**, Falls in the 0.2 - 0.4 range -> **moderate erosion risks.**

Moderate landslide potential in steep areas.

Seasonal Flow Decision Matrix

Pre & Post monsoon			
Stream Length (km)	Drainage density km/km²		
	< 0.5	0.5 - 0.6	> 0.6
0 - 11.47	Low	Low	Moderate
11.48 - 22.94	Moderate	Moderate	High
22.95 - 34.42	Moderate	High	High

Monsoon			
Stream Length (km)	Drainage Density km/km²		
	< 0.5	0.5 - 0.6	> 0.6
0 - 11.47	Moderate	High	High
11.48 - 22.94	High	High	High
22.95 - 34.42	High	High	High

→ Cumulative Flow Decision Matrix ←

Gurupura sub-basin has **high flow sub watersheds** indicating **high run-offs.**

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE

Run-off calculations:

Q = CRA

C -> Run-off co-efficient

R -> Rainfall = 4.1 m/year

A -> Watershed Area

Q = 8,347.22 m^3

SCALE : **1: 2,80,000**

N

SHEET NO: **6**

SHEET TITLE: **Environmental Resources**

SOURCE:

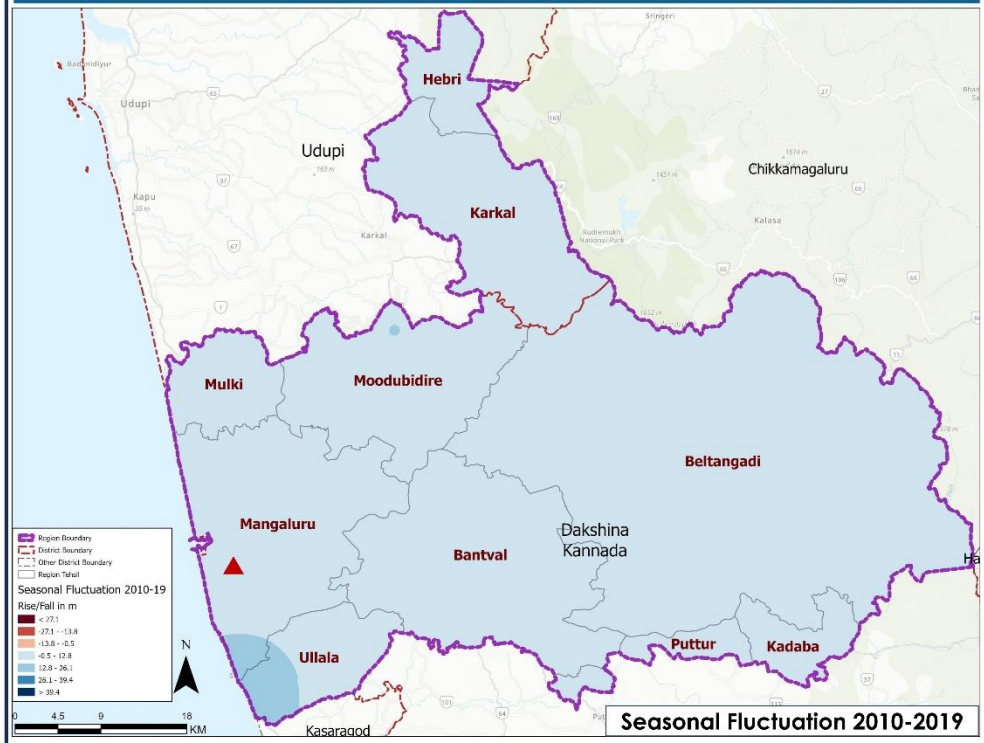
- *Generated by Author*

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Ground Water



1990–1999

- DTWL remains stable between **0. to 10.4m**, in the urban areas the depth goes up to **20.1m.**
- **Minimal fluctuation**, indicating relatively balanced recharge and extraction.

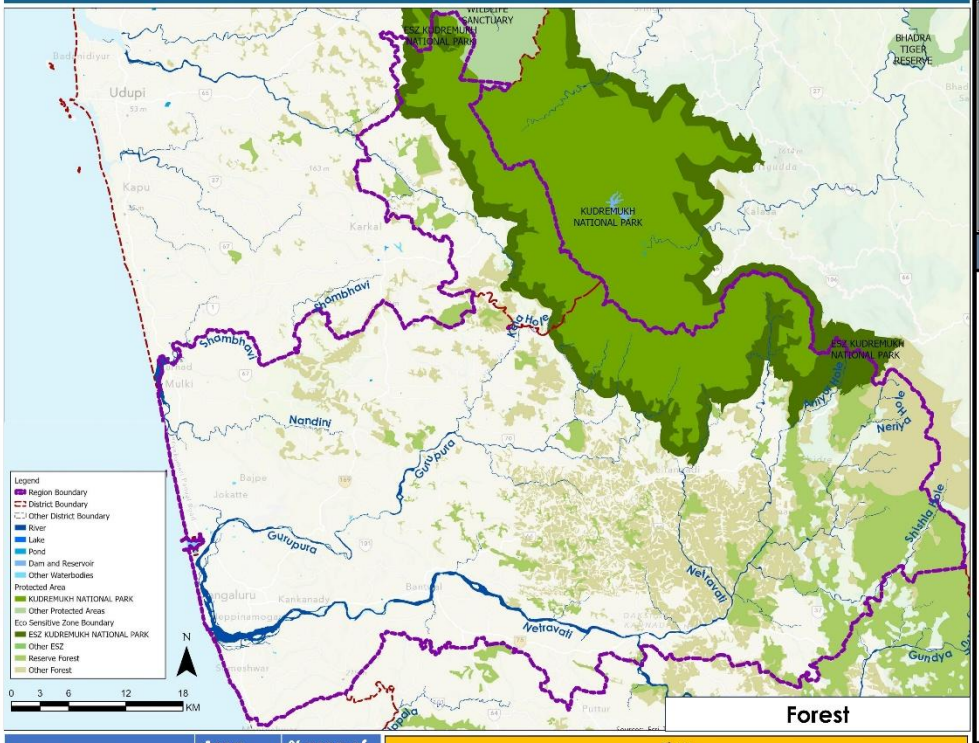
2000–2009

- **Increased urbanization** caused more significant **pre-monsoon declines**, especially in urban zones.
- Greater fluctuation in water levels than previous decade.
- Coastal regions in the South Western area show erratic recharge and depletion suggesting instability in the groundwater cycle.

2010–2019

- DTWL **exceeds 48.65m**, with severe fluctuations, **indicating** unsustainable use & reduced recharge efficiency.
- Pre-monsoon levels declined consistently
- Post-monsoon **recharge has reduced**, & **coastal areas may face saline intrusion**

Biotic Environment



Forest type	Area (Sq.km)	% area of Region
Protected area	345.30	10.30
ESZ Boundary (1km wide)	177.46	5.29
Reserve forest	466.09	13.90
Other forest	467.39	13.94

Kudremukh National Park ESZ1 - under the Western Ghats Ecology Expert Panel (WGEEP)

Geographic and Geomorphological Characteristics

- Situated in the Chikkamangaluru, Udupi & Dakshin Kannada
- Part of the Western Ghats, a UNESCO World Heritage Site, Biodiversity Hotspot, one of the world's most critical ecological regions
- Encompasses rugged terrain, rolling hills, and lush valleys, with interspersed waterfalls, streams, and dense forests.
- The Kudremukh peak, standing at **1,894 meters (6,214 feet),** is the third highest peak in Karnataka.

Flora				
Scientific Name	Common Name	IUCN Status	WPA Schedule	CITES Appendix
Trees				
Pterocarpus santalinus	Red Sandalwood	Endangered	VI	II
Hopea parviflora	-	Endangered	-	-
Dipterocarpus indicus	Doom Tree	Endangered	VI	II
Medicinal Plants				
Rauvolfia serpentina	Sarpagandha	Endangered	VI	II

Mammals				
Scientific Name	Common Name	IUCN Status	WPA Schedule	CITES Appendix
Panthera tigris	Bengal Tiger	Endangered	I	I
Macaca silenus	Lion-tailed Macaque	Endangered	I	I
Cuon alpinus	Indian Wild Dog	Endangered	I	I
Elephas maximus	Asian Elephant	Endangered	I	I
Coastal & Marine				
Chelonia mydas	Green Sea Turtle	Endangered	I	I
Amphibians				
Indirana gundia	Gundia Frog	Endangered	IV	-

Endangered Flora in the region



Endangered Fauna in the region



KEY MAP



LEGEND / INFERENCE

DTWL
- < 10.4
- 10.5 - 20
- 20.1 - 29.6
- 29.7 - 39.2
- 39.3 - 48.8
- 48.9 - 58.4
- > 58.5

Rise/Fall in m
- < 27.1
- -27.1 - -13.8
- -13.8 - -0.5
- -0.5 - 12.8
- 12.8 - 26.1
- 26.1 - 39.4
- > 39.4

SCALE : **1: 2,80,000**

N

SHEET NO: **7**

SHEET TITLE: **Environmental Resources**

SOURCE:
- *District Ground Water Board, Mangaluru*
- *Mangalore division forest working plan*
- *Maps Generated & analysed by Author*

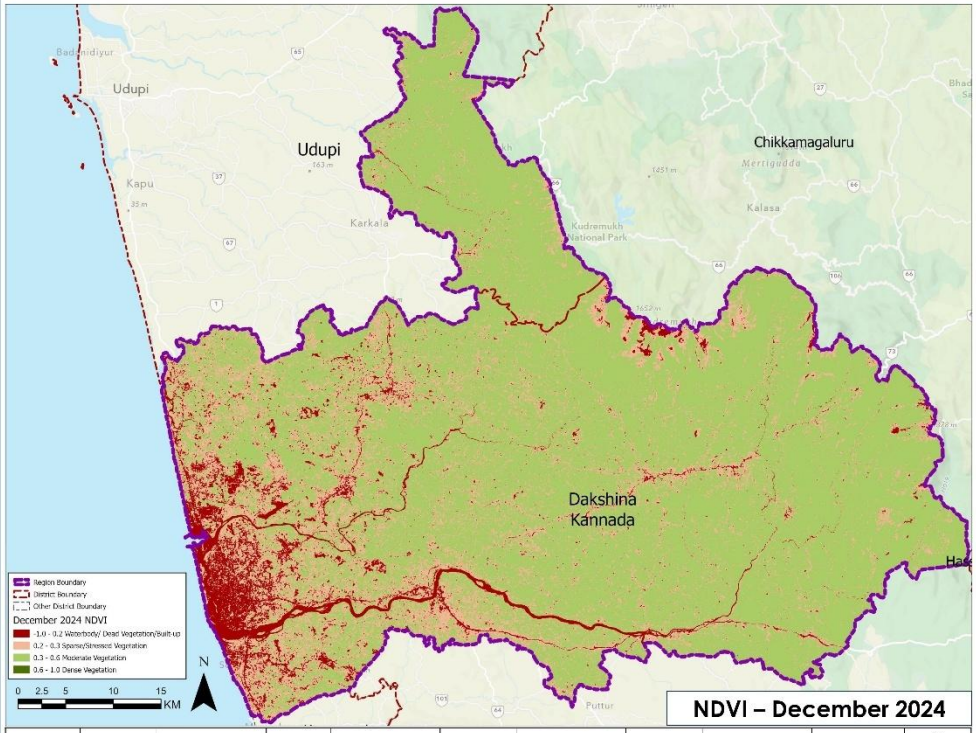
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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

NDVI

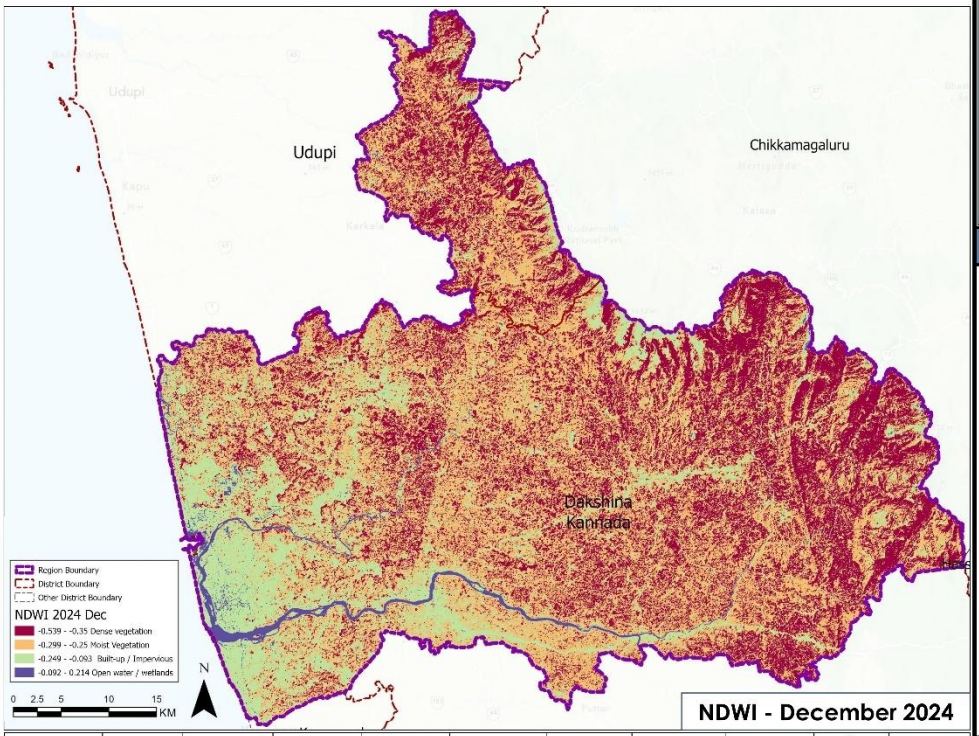


NDVI – December 2024

NDVI Value	Apr-15	% Area of Region	Dec-15	% Area of Region	Apr-24	% Area of Region	Dec-24	% Area of Region	% Change April 2015 - 2024	% Change Dec 2015 - 2024
-1.0 to 0.2	223.73	7.08	135.20	4.28	200.3806	6.34	218.45	6.91	-0.74	2.64
0.2 to 0.3	845.49	26.76	389.60	12.33	596.594	18.88	644.93	20.41	-7.88	8.08
0.3 to 0.6	2090.03	66.16	2634.45	83.39	2362.299	74.77	2295.90	72.67	8.62	-10.72
0.6 to 1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Vegetation Trends: Moderate vegetation increased from **66.16% (2015) to 74.77% (2024)** but slightly declined to **72.67% (Dec 2024)**. **Sparse/Stressed vegetation** initially reduced but increased in **Dec 2024**, indicating possible land degradation.

NDWI

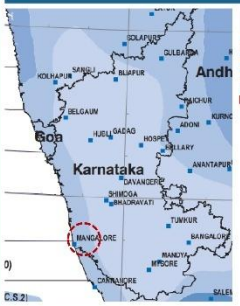


NDWI - December 2024

NDWI Value	Apr-15	% Area of Region	Dec-15	% Area of Region	Apr-24	% Area of Region	Dec-24	% Area of Region	% Change April 2015 - 2024	% Change Dec 2015 - 2024
-0.539 to -0.35	1308.64	41.42	1782.79	56.43	1,589.09	50.30	1054.72	33.39	8.88	-23.05
-0.35 to -0.25	1237.68	39.18	957.84	30.32	993.098	31.43	1404.13	44.44	-7.74	14.13
-0.25 to -0.09	564.71	17.87	368.78	11.67	538.425	17.04	646.00	20.45	-0.83	8.77
-0.09 to 0.21	48.23	1.53	49.84	1.58	48.28	1.53	54.41	1.72	0.00	0.14
Total	**3159.26**		**3,159.25**		**3,159.25**		**3,159.26**			

1. **Dense Vegetation (-0.53 to -0.35) : April 2015 - 2024: + 8.88%,** indicating '+' trend in vegetation moisture. **December 2015 – 2024: - 23.05% ->** moisture stress/degradation
2. **Moist Vegetation (-0.35 to -0.25): April 2015 - 2024: - 7.74%, Dec 2015-2024: + 14.13% ->** shift from dense to moist vegetation, noticeable in the post monsoon season -> change in vegetation composition or reduced canopy density
3. **Built-up/Impervious surface (-0.25 to -0.09): April 2015 - 2024: - 0.83%, December 2015-2024: + 14.13% -** Indicates urban expansion, contrast visible in post monsoon season due to surrounding moist land covers.

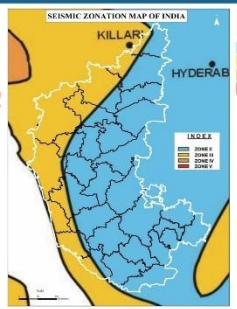
Hazard



Wind & Cyclone Zones



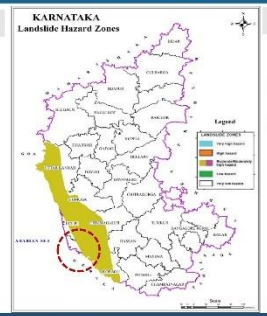
- **Falls in Moderate Damage Risk Zone – B** with wind speed up to **39m/s**
- In 2019, the region experienced 4 cyclones in Arabian Sea, No major damages were reported.



Seismic Zone

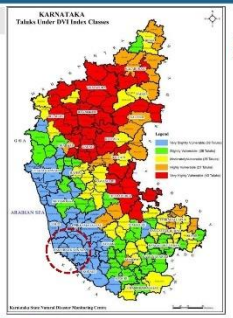


- Falls in **Seismic Zone III**
- No earthquake incidents reported in the last 100 years

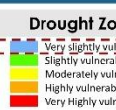


Landslide Hazard

- **Moderate landslide hazard zone**
- Landslides are likely in the ghat section in Belthangady Tehsil along the NH 75 ->Attributable to deforestation in the region.



Drought Zones



- Falls in **Very slightly vulnerable drought zone**
- Mangaluru & Bantwal Tehsils are drought affected areas within the district

Flood

- Floods in the low-lying areas along the major rivers - **Netravathi and Gurupura.**

Forest Fire

- No forest fires have been reported in the district so far.

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



KEY MAP



LEGEND / INFERENCE

NDVI Implication:

- Dense vegetation increase but its moisture retention capacity has declined in the post monsoon season.
- Increase in built-up & shift towards moist vegetation suggests ecological stress.

NDWI Implication:

- Overall, vegetation health improved, but recent declines indicate potential risks.
- Urbanization and seasonal effects may be impacting vegetation cover.

SCALE : **1: 2,80,000**

N

SHEET NO: **8**

SHEET TITLE: **Environmental Resources & Hazard**

SOURCE:

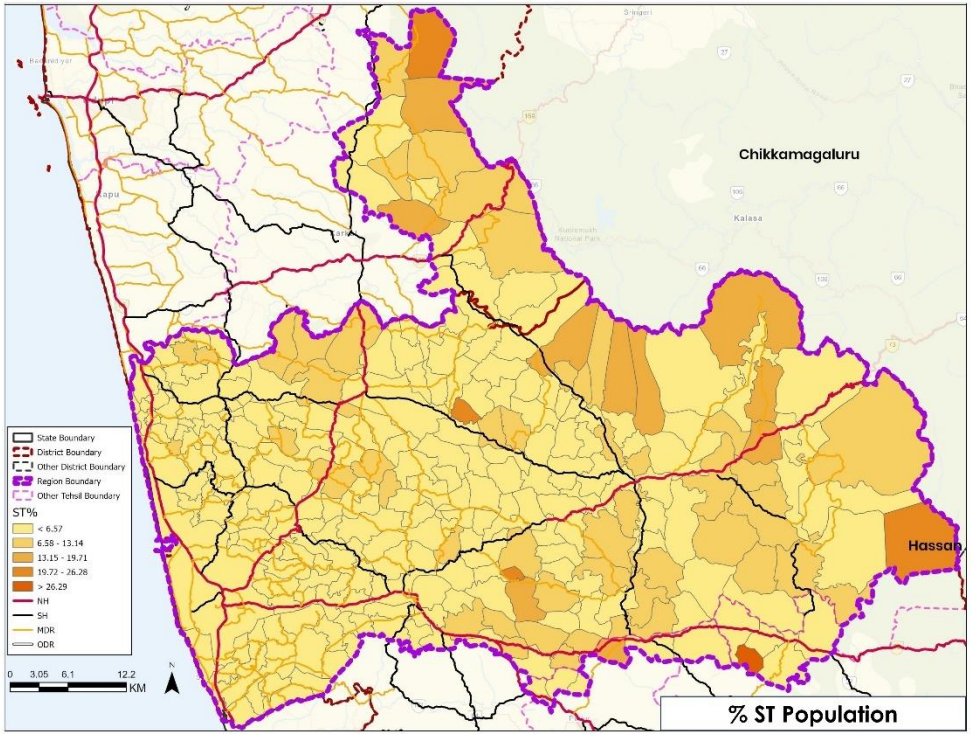
- *Landsat 8 Satellite Imagery*
- *Maps generated by Author*
- *District Disaster Management Plan 2019 - 2020*

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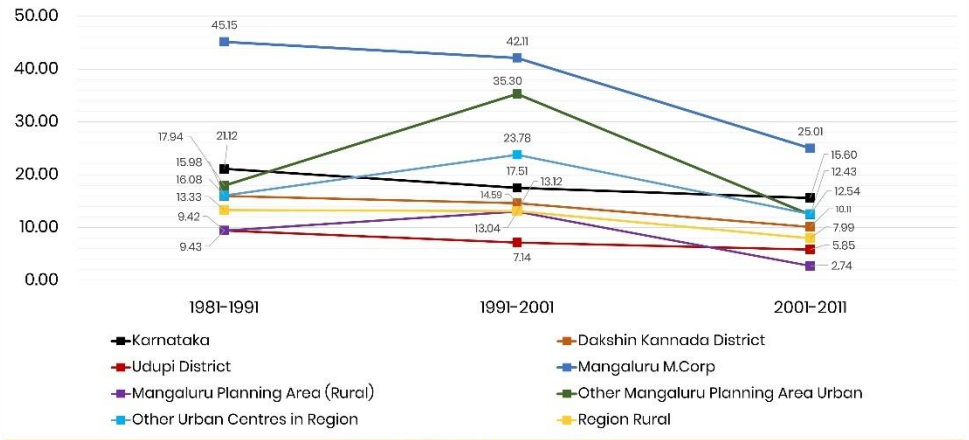
Demography



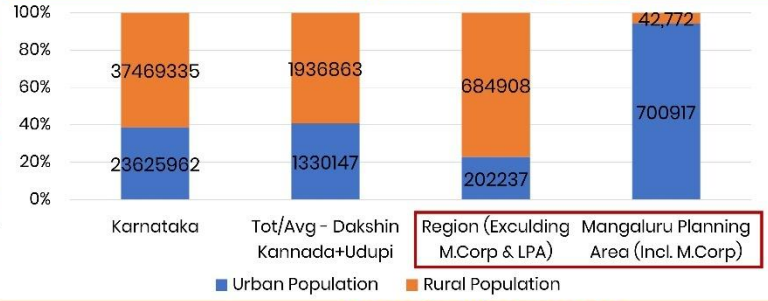
- Total Area of the Region : **3,350.93 Sq.km**
- Total Number of Village: **232,** Urban Centres: **38**
- Population of the scoped region (Incl. LPA, M.Corp & other urban centres) : **16,30,834**

Area	Population			
	1981	1991	2001	2011
Karnataka	3,71,35,714	4,49,77,000	5,28,50,562	6,10,95,297
Dakshin Kannada District	14,28,028	16,56,165	18,97,730	20,89,649
Udupi District	9,48,696	10,38,099	11,12,243	11,77,361
Mangaluru M.Corp	193699	281161	399565	499487
Mangaluru Planning Area (Rural)	33,655	36,828	41,631	42,772
Other Mangaluru Planning Area Urban	112274	132413	179161	201430
Other Urban Centres	125069	145183	179706	202237
Rural (Region)	494739	560681	634215	684908

Growth Rate

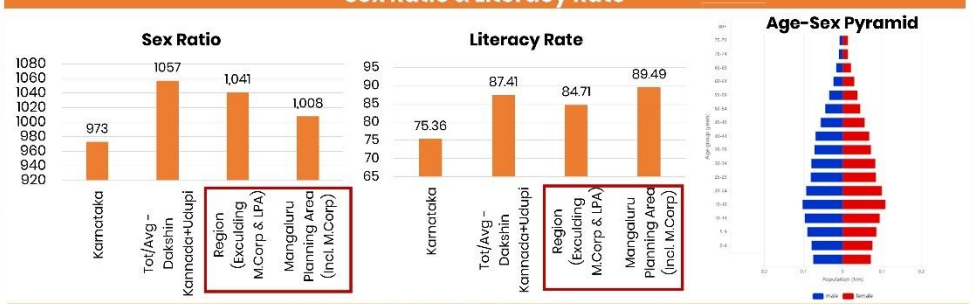


Population Composition

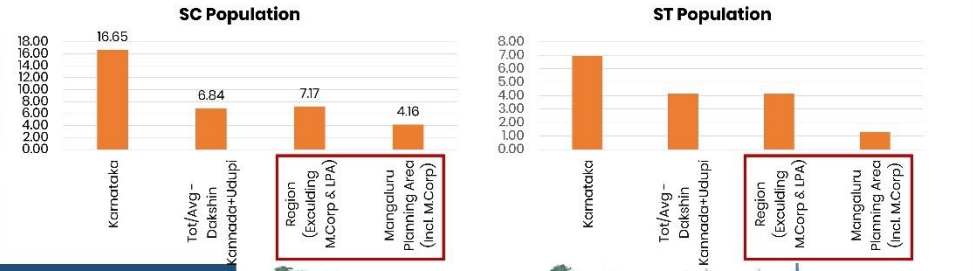


55.44% of the study region is Urban. The % of rural **(44.56)** is lower thana the state average of **61.3%.**

Sex Ratio & Literacy Rate



SC & ST Population



Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE



FULL TEHSIL (3)

PART TEHSIL (7)

- Population increasing at a deceasing rate
- Avg. Sex ratio – **1024**, higher than the state, lower than districts.
- Avg. Literacy rate **87.1%**, higher than state, lower than districts
- **5.67%** Avg. SC Population – Lower than state and districts average
- **2.72%** Avg. **ST** Population, lower than state and districts.

SCALE :
1: 2,80,000

N

SHEET NO:
9

SHEET TITLE:
Demography

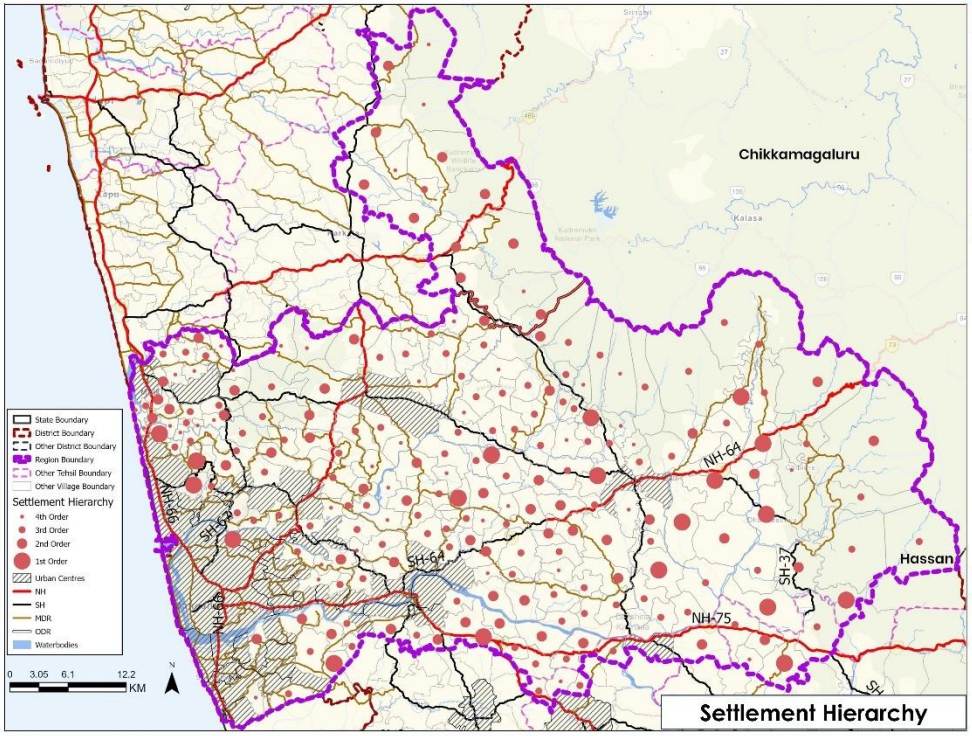
SOURCE:
- *Census of India 2011*

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Demography

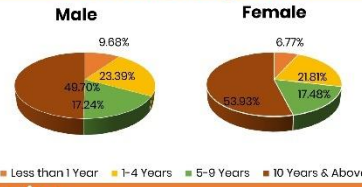


Settlement Hierarchy

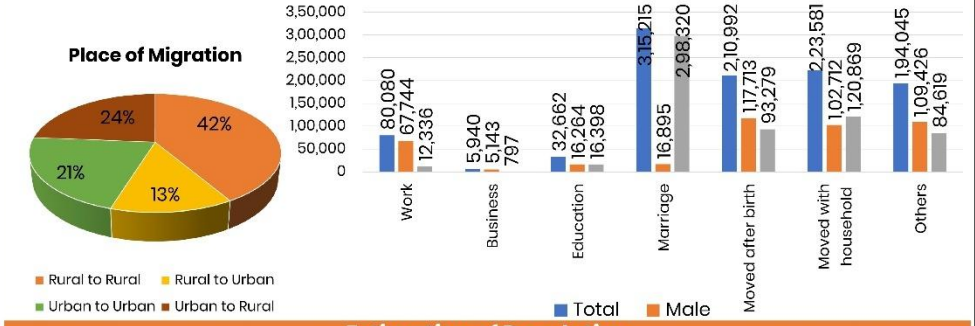
Migration

Category	Total	Male	Female
Total Population	20,89,649	10,34,714	10,54,935
Total Migrant Population	10,62,515	4,35,897	6,26,618
Total Rural Migrants	6,07,820	2,29,197	3,78,623
Total Urban Migrants	3,31,366	1,50,856	1,80,510
Total Non-Migrants	10,27,134	5,98,817	4,28,317

Duration of Migration



Place & Reason for Migration



Estimation of Population

Study Region (Excluding LPA & M.Corp)

Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
4,94,739	5,60,681	6,34,215	6,84,908	Geometric	6,86,427	1,519	0.2	**7,35,582**	**7,53,108**
				Arithmetic	6,90,242	5,334	0.8		
				Incremental	6,77,281	-7,627	1.1		

Mangaluru Planning Area (Including Mangaluru M.Corp)

Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
3,39,628	4,50,402	6,20,357	7,43,689	Geometric	7,48,978	5,289	0.7	**8,84,055**	**9,39,341**
				Arithmetic	7,45,841	2,152	0.3		
				Incremental	7,22,375	-21,314	2.9		

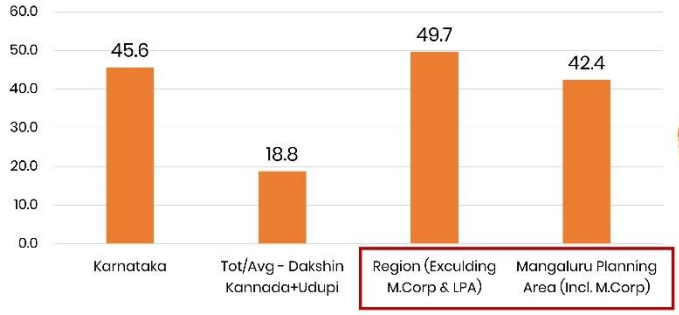
Mangaluru Municipal Corporation

Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
1,93,699	2,81,161	3,99,565	4,99,487	Geometric	5,01,959	2,472	0.5	**6,02,421**	**6,43,852**
				Arithmetic	4,98,844	-643	0.1		
				Incremental	4,84,371	-15,116	3.0		

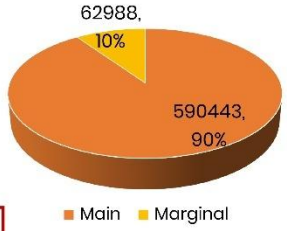
Other Urban Centres

Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
1,25,069	1,45,183	1,79,706	2,02,237	Geometric	2,03,555	1,318	0.7	2,29,557	2,40,198
				Arithmetic	2,02,954	717	0.4		
				Incremental	1,97,158	-5,079	2.5		

WFPR

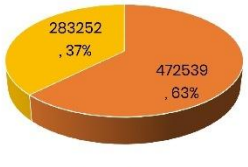


Workers Composition

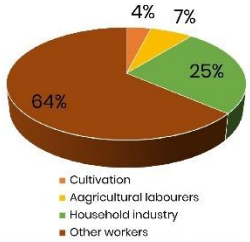


Total workers population: **7,55,791 of the Study Region (Including LPA & M.Corp)**

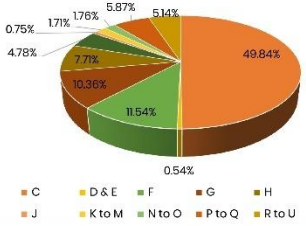
Workers based on gender



Main workers



Industrial Main Workers Occupation in District



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KEY MAP



LEGEND / INFERENCE

- **WFPR – 46%,** More than state & District
- **64%** Main workers are Industry Workers.
- **49.8%** main industry workers – Manufacturing
- Migration: Rural to Rural

Industrial Main Workers Occupation

C- Manufacturing
D - Electricity, Gas, steam and Air conditioning Supply
E - Water Supply; (Sewerage, Waste Management and remediation activities)
F- Construction; G- Wholesale and Retail Trade (Repair of motor vehicles and motor cycles)
G- Wholesale and Retail Trade (Repair of motor vehicles and motor cycles)
H- Transportation and Storage
I- Accomodation and food service activities
J- Information and Communication
K - Financial and Insurance activities
L- Real Estate activities
M- Professional, Scientific and Technical activities
N- Administrative and support service activities
O- Public Administration and Defence, Compulsory Social Security
P- Education
Q- Human Health and Social Work activities
R- Arts, Entertainment and recreation
S- Other Service Activities
T- Activities of Households as Employers: Undifferentiated Goods and Services
U - Activities of Extra-Territorial Organisations and Bodies

SCALE : **1: 2,80,000**

N

SHEET NO: **10**

SHEET TITLE: **Demography**

SOURCE:

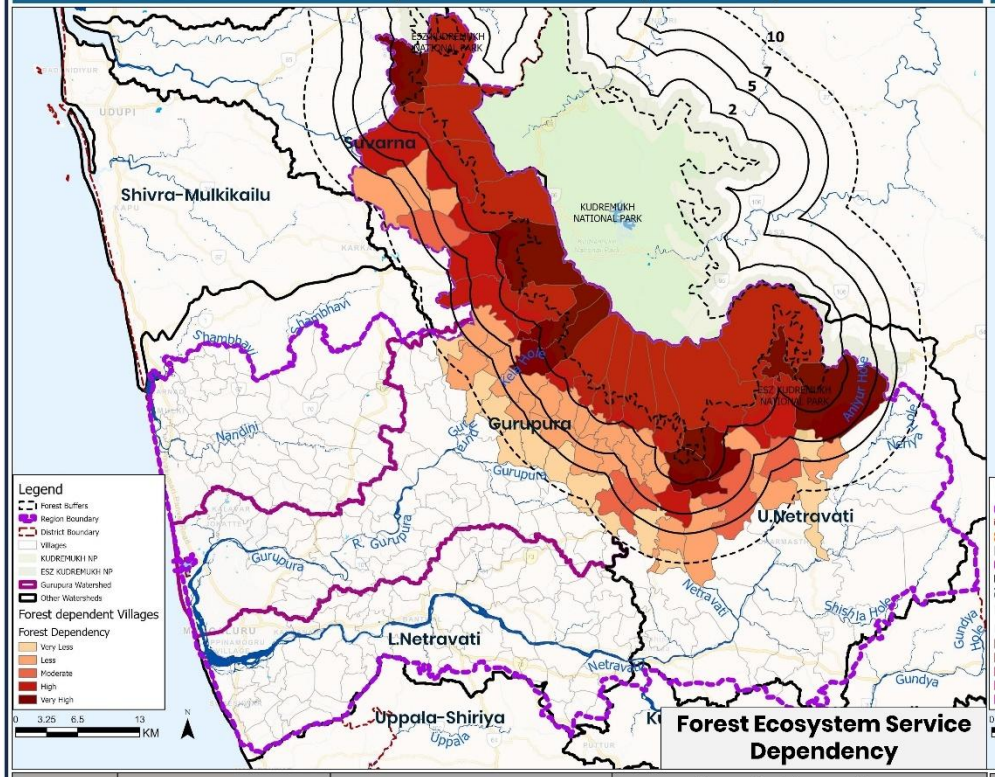
- *Census of India 2011*

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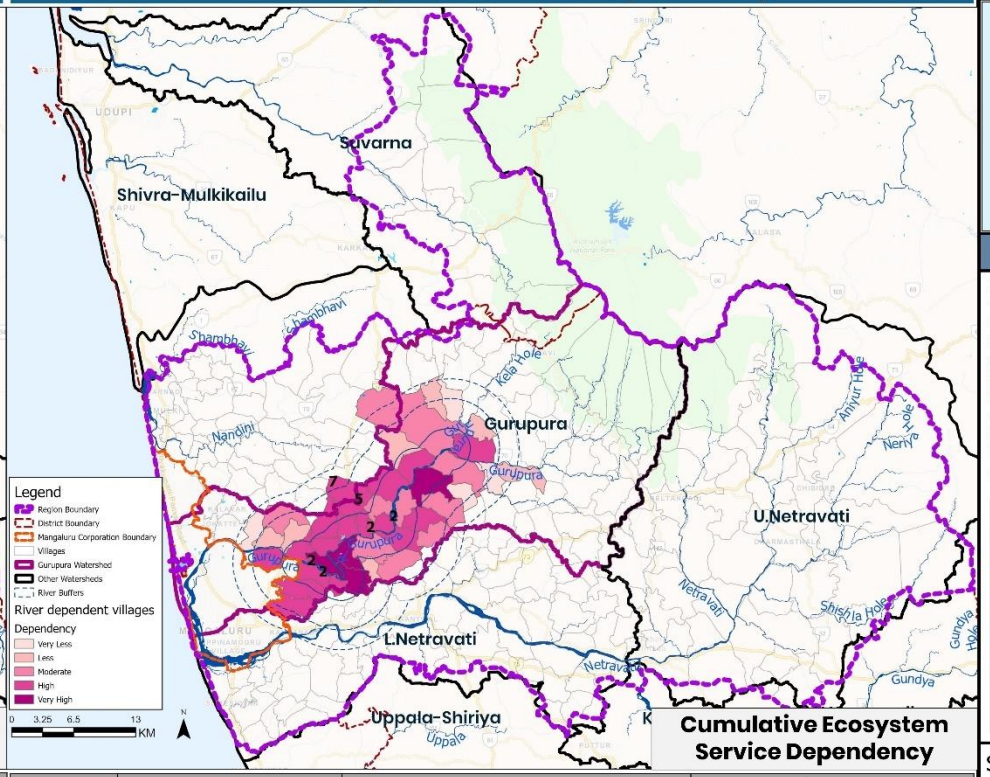
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Forest - Ecosystem Service Dependency



Forest Ecosystem Service Dependency

River - Ecosystem Service Dependency



Cumulative Ecosystem Service Dependency

Eco-system Service	Service	Indicator	Normalised Average Score			
			Core Area up to 2km buffer	2-5 Km buffer	5-7 km buffer	7-10 km Buffer
Provisioning	Water	Percentage population dependent on ground & surface water sources	0.66	0.24	0.13	0.03
	Source of food	Proximity to forest				
	Timber, Fibre, & fuel	% HH using wood for cooking + % houses made of wood				
	Medicines	Proximity to forest				
Regulating	Air quality	Proximity to forest	0.66	0.23	0.14	0.03
	Micro-climate	% waterbody area + forest				
	Ground water rejuvenation	Ground water levels				
Supporting	Nutrient cycling & soil formaiton	% waterbody area + forest	0.57	0.23	0.23	0.07
	Habitat for spcies	% Forest area				
	Employment Generation	Number of workers				
Cultural	Cultural & Religious importance	Presence of pilgrim sites	0.57	0.14	0.14	0.02
	Recreation & tourism	Tourist locations & proximity to forest				
	Aesthetic value	Proximity to forest & waterbodies				
	Research & knowledge building	Proximity to forest				
Dependency Average			0.61	0.21	0.16	0.04

Eco-system Service	Service	Indicator	Average		
			Core Area upto 2km buffer	2-5 Km buffer	5-7 km buffer
Provisioning	Fresh water	Percentage population dependent on ground & surface water sources	0.47	0.23	0.30
	Fishing	Proximity to river			
	Irrigation	Area under irrigation			
Regulating	Water quality & flooding regulation	% forest area + flooding extent	0.65	0.25	0.065
	Carbon sequestration	% waterbody area			
	Micro Climate Regulation	Proximity to waterbody			
	Ground water regulation	Ground water levels			
Supporting	Nutrient cycling & soil formaiton	% waterbody area + forest	0.50	0.20	0.08
	Habitat for species	% Forest area			
	Employment Generation	Number of Agricultural workers			
Cultural	Cultural & Religious importance	Temples and festivals along the river	0.60	0.13	0.07
	Recreation & tourism	Tourist locations & proximity to forest			
	Aesthetic value	Proximity to forest & waterbodies			
	Research & knowledge building	Presence of pilgrim sites and proximity to waterbody			
Dependency Average			0.55	0.20	0.13

The scoring is done on a scale of **1 to 3**

- **Core area villages** – 3x, **Buffer zone 1 & 2:** 2 – 5 km & 5-7 km Villages – 2X, **Buffer zone 3:** 7 – 10 km Villages – 1X
- Villages with population above the average – 2X

Buffer (km)	<2	2 - 5	5 - 7	7 - 10	Total
Villages	22	17	13	17	69

Core areas & buffer area up to 5km -> forest for **Provisioning & regulating services**

Buffer (km)	<2	2 - 5	5 - 7	Total
Micro-watersheds	21	26	12	59
Villages	17	17	7	41

- The villages in the core areas and the buffer area up to 5km are dependent on the river for **Regulating and provisioning services.**
- The Regulating service is predominant as the villages depend on the river for flood regulation

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



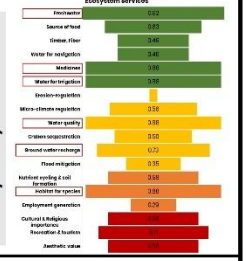
LEGEND / INFERENCE

River Zones

1. Elevation > 80M -> Head Waters (Up to the foothill of Kudremukh national park, Source Zone)

2. Elevation 20 – 80 -> Rural River (Transition zone , outside the extent of Mangaluru P.A)

3. Elevation <20m -> Urban River (Deposition Zone , up to the extent of Mangaluru P.A)



SCALE : **1: 2,80,000**

N

SHEET NO: **11**

SHEET TITLE: **Ecosystem Service Dependency**

SOURCE:

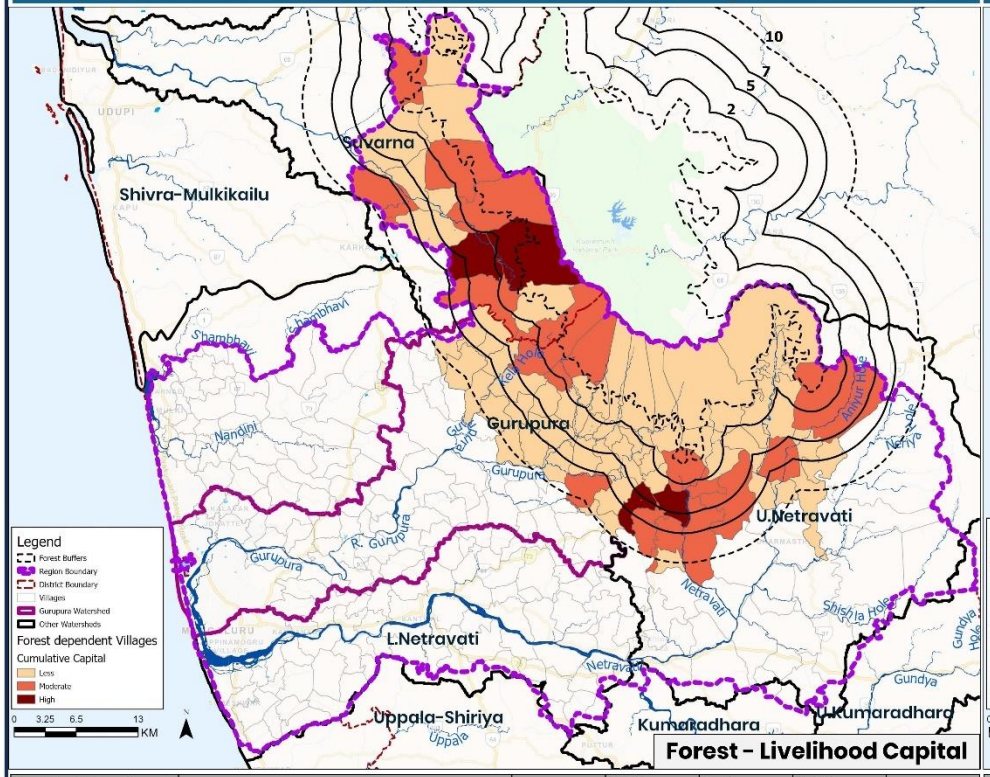
- *Author, based on various thematic analysis, census data, Observation & primary survey*

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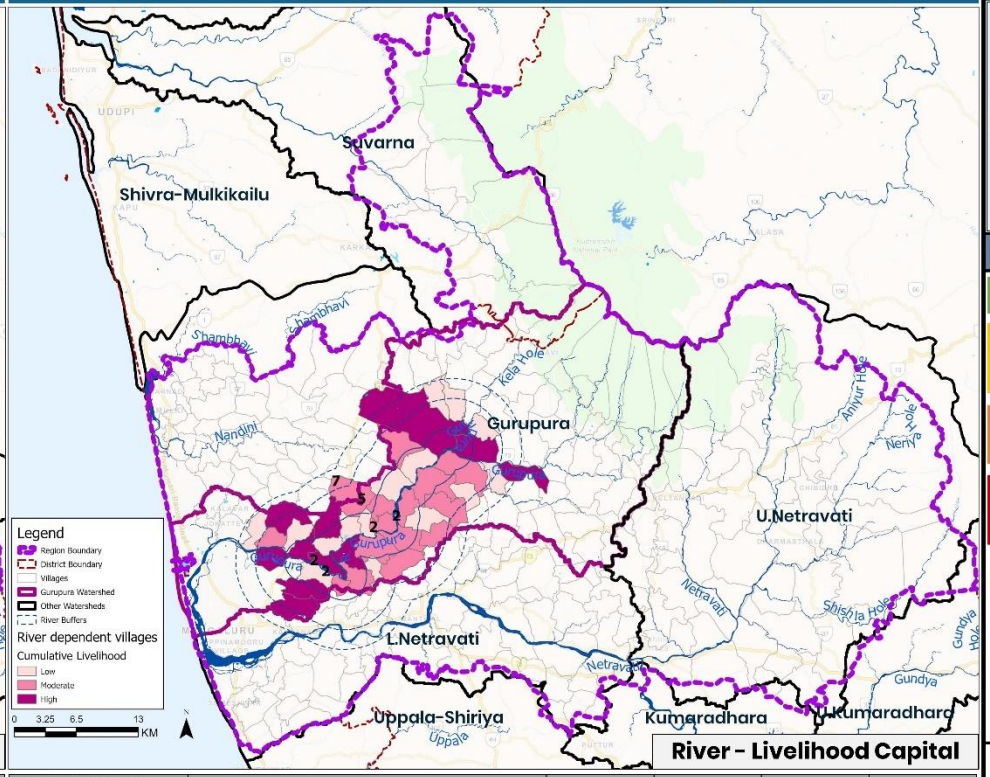
Forest – Sustainable Livelihood Analysis



Sustainable Livelihood Capital	Indicators	Core (<2 km)	2 - 5km buffer	5 - 7km buffer	7 - 10km buffer	Average
Natural Capital	Area under forest	0.40	0.21	0.06	0.08	0.19
	Area under Waterbody					
	Barren Land					
Human Capital	Literacy Rate	0.55	0.5	0.57	0.54	0.54
	Total Workers					
Physical Capital	Percentage of permanent houses	0.47	0.53	0.49	0.47	0.49
	% of tap water connection					
	% Drainage					
	% Septic Tank					
	% Improved Latrine					
	Wells & Tubewells					
	Access to road					
	Education					
	Healthcare					
Social Capital	Self-Help Groups	0.97	0.96	0.92	0.98	0.96
	Nutritional centres & Anganwadis					
	ASHA Status					
Financial Capital	Mandis	0.11	0.16	0.10	0.06	0.11
	Bank					
	Agricultural Credit Societies					
AVERAGE		0.50	0.47	0.43	0.43	0.46

- The normalized aggregate scores range between **0.06 to 0.98**, where **core area** has the **highest score** due to high **Social, physical & human capital.**
- All the zones score low in terms of **financial capital**, and high in terms of **social capital.**
- **Physical capital** is observed to be moderately developed in all the zones, least in the core zone
- The core area scores moderately for Natural capital, because of the area under waterbody and barren land, although it has **abundant forest cover.**

River - Sustainable Livelihood Analysis



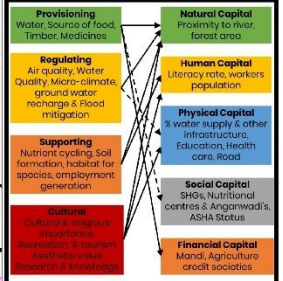
Sustainable Livelihood Capital	Indicators	Core (<2 km)	2 - 5km buffer	5 - 7km buffer	Average
Natural Capital	Distance from the river	0.32	0.24	0.12	0.23
	Area under forest				
	Area under Waterbody				
	Barren Land				
Human Capital	Literacy Rate	0.38	0.42	0.47	0.42
	Total Agricultural Workers				
	Public transport				
Physical Capital	Percentage of permanent houses	0.62	0.60	0.63	0.62
	% of tap water connection				
	% Drainage				
	% Septic Tank				
	% Improved Latrine				
	Wells & Tubewells				
	Acess to road				
	Education				
	Healthcare				
Social Capital	Self-Help Groups	0.69	0.69	0.76	0.71
	Nutritional centres & Anganwadis				
	ASHA Status				
Financial Capital	Mandis	0.27	0.24	0.38	0.30
	Bank				
	Agricultural Credit Societies				
AVERAGE		0.46	0.44	0.47	0.46

- The normalized aggregate scores range between **0 to 0.94**, where **transition zone (5-7 km buffer)** has the **highest score** due to high **Social, human & physical capital.**
- Moderately **financial capital**, and high in terms of **social capital.**
- **Physical capital** is observed to be well developed in all the zones.
- The core area scores moderately for Natural capital, because of the area under forest cover, waterbody and barren, although considering the proximity to river it scores the highest.

KEY MAP



LEGEND / INFERENCE



Linkage between Ecosystem Services & Livelihood Capital

SCALE :
1: 2,80,000

N

SHEET NO:
12

SHEET TITLE:
Sustainable Livelihood Analysis

SOURCE:
- *Observation & primary survey based*

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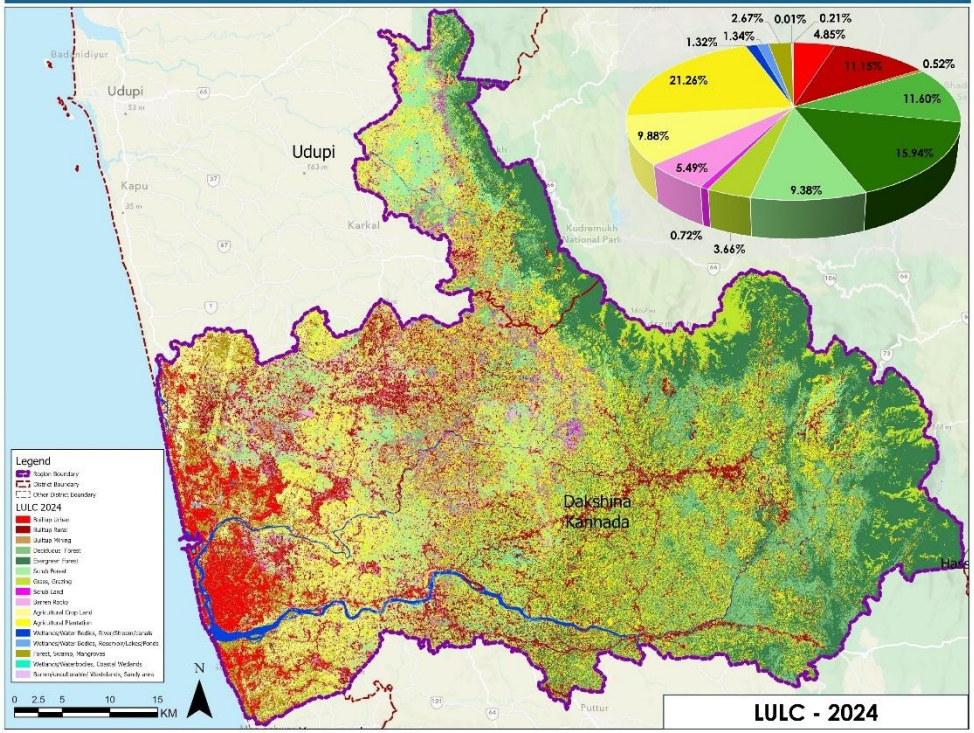
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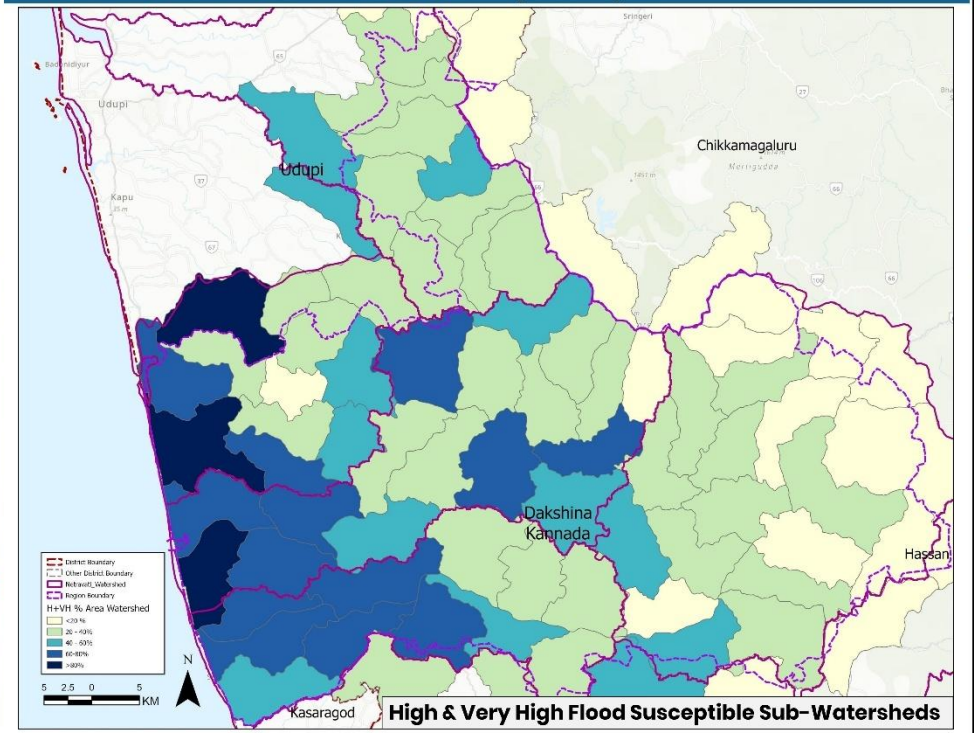


LULC



LULC - 2024

Flood Susceptibility



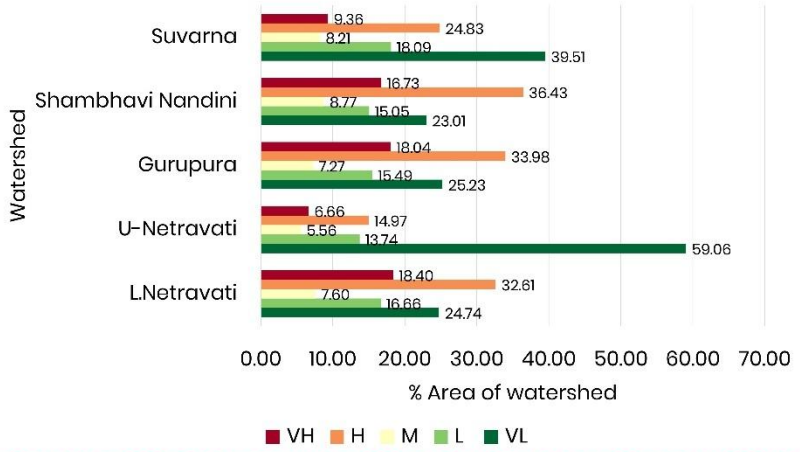
High & Very High Flood Susceptible Sub-Watersheds

Sl no	Landuse Category	Area 2015	% Area	Area 2025	% Area	Area Change	% Area Change
1	Builtup Urban	158.45	4.85	162.18	4.96	3.73	2.35
2	Builtup Rural	364.22	11.15	373.57	11.43	9.35	2.57
3	Builtup Mining	16.99	0.52	10.19	0.31	-6.80	-40.01
4	Deciduous Forest	379.15	11.60	394.92	12.09	15.78	4.16
5	Evergreen Forest	520.66	15.94	618.30	18.92	97.64	18.75
6	Scrub Forest	306.56	9.38	367.69	11.25	61.13	19.94
7	Grass, Grazing	119.74	3.66	145.14	4.44	25.40	21.21
8	Scrub Land	23.48	0.72	67.04	2.05	43.55	185.44
9	Barren Rocky	179.45	5.49	108.82	3.33	-70.63	-39.36
10	Agricultural Crop Land	322.77	9.88	265.73	8.13	-57.03	-17.67
11	Agricultural Plantation	694.51	21.26	627.68	19.21	-66.83	-9.62
12	Wetlands/Water Bodies, River/Stream/canals	43.08	1.32	43.89	1.34	0.81	1.88
13	Wetlands/Water Bodies, Reservoir/Lakes/Ponds	43.89	1.34	6.53	0.20	-37.36	-85.12
14	Forest, Swamp, Mangroves	87.18	2.67	67.20	2.06	-19.98	-22.92
15	Wetlands/Waterbodies, Coastal Wetlands	0.34	0.01	0.80	0.02	0.45	131.07
16	Barren/unculturable/ Wastelands, Sandy area	6.76	0.21	7.57	0.23	0.81	11.92
	Total	3267.25		3267.25			

Inference:

1. **Increase in Urban & Rural Built-up:** growth along the rivers -> increasing pressure on the riverbanks, leading to encroachment, pollution and altered hydrology.
2. **Decline in agricultural land:** Decline in agricultural plantation & crop land -> shift towards urban use -> increase the ground water dependency & runoff
3. **Decrease in mining area:** Reduced sedimentation & heavy metal contamination in the rivers.
4. **Increase in Forest cover:** Increase in deciduous, evergreen and scrub forest suggests improved watershed health, enhanced soil stability and reduction in erosion.
5. **Reduction in Waterbody and mangroves:** Can lead to reduced natural flood protection and affects the aquatic species

Flood susceptibility - % Area of Watersheds



Inference:

1. **Gurupura & Lower Netravati** watersheds have the highest % area of watershed under **Very high & High flood susceptibility**, followed by **Shambhavi – Nandini** Watershed
2. It can also be seen that the sub-watersheds along the coast have more than 60% & 80% sub-watershed area under High & Very High flood susceptibility.

KEY MAP



LEGEND / INFERENCE

SCALE : 1: 2,80,000

N

SHEET NO: 13

SHEET TITLE: **LULC & Flood Susceptibility**

SOURCE:

- *Landsat 8 Satellite Imagery*
- *Generated by Author*

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Stakeholder Mapping







Local Community & Tourists
Jain Festival Venur Maha masthaka-abhishekha - Once every 12 years

- Private **wells** for **Irrigation & Domestic use**
- **Tap water supply** from Gram Panchayat – **2-4 hrs/day**







Framers

Plantation workers & Framers



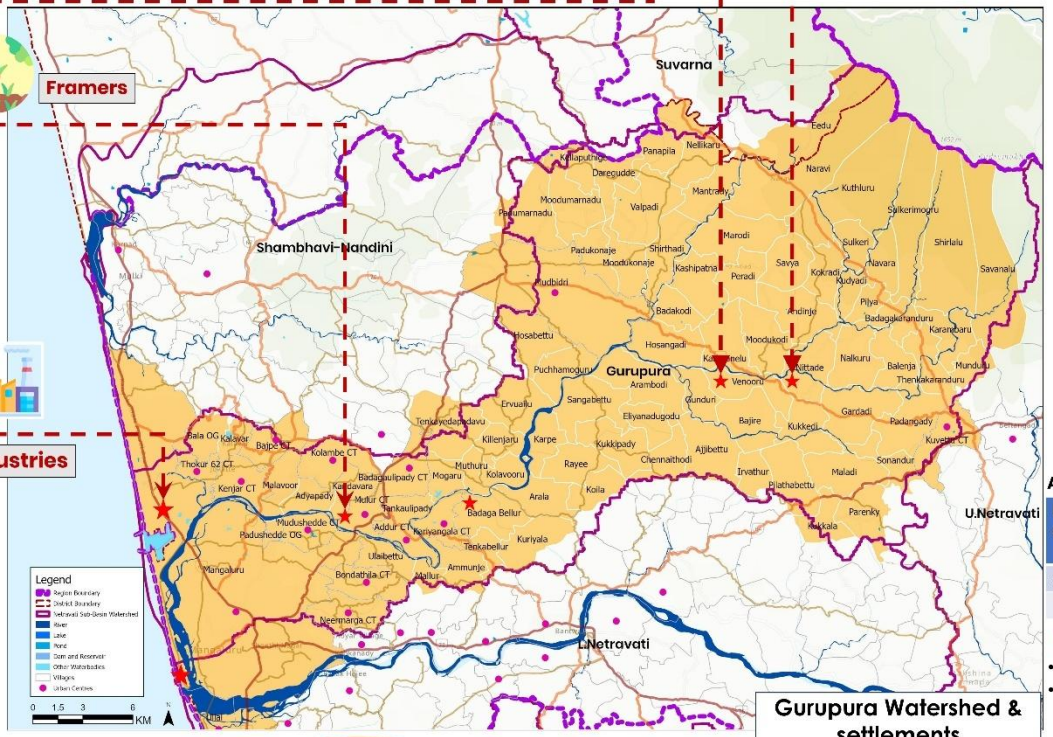


Vented dams for ground water recharge

Arecanut Plantation



Industries



Gurupura Watershed & settlements

Irrigation along river bank

- Lift Irrigation – Electricity based **Centrifugal Pumps** installed in Gurupura River
- License – Irrigation Dept.
- Capacity used – **3 to 5 HP**

Away from river bank – Ground water drawn from wells

Pump capacity	Discharge rate	Duration	Water drawn (L/day)
3 HP	11 lps	10	3,96,000
5 HP	15 lps	10	5,76,000

Drinking & other domestic use

- Private **wells**
- **Tap water supply** from Gram Panchayat – **2-4 hrs/day**

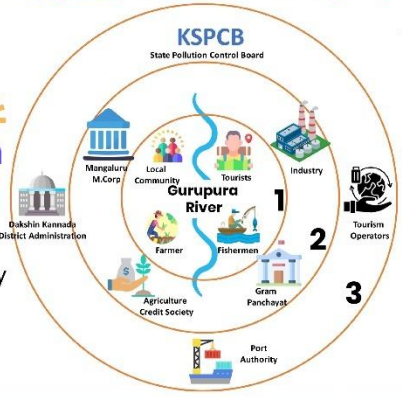
Fishermen Community

- Fishing in the estuary
- **Domestic use** – Tap water supply from M.corp





Tourists & Local Community dependent on Ferry services on the Gurupura River



1. **Innermost Circle (Direct Dependents):** These stakeholders are most vulnerable and directly dependent on the river for their daily sustenance and livelihoods.
2. **Middle Circle (Local Institutions & Economic Users):** These groups have moderate spatial proximity and play key roles in managing, governing, and utilizing the river's resources,
3. **Outer Circle (Regulators & Indirect Influencers):** These stakeholders have high influence and decision-making power over river policies despite limited direct interaction with the river.



Diagram Developed by Author

KEY MAP



LEGEND / INFERENCE

- **Urban rivers** are defined in a descriptive sense as **"Rivers that flow through cities"**, and in an analytical sense as **"those rivers that have been folded into the process of urbanization, whether flowing through urban centres or not"**
- **Rural Rivers -** that which flows predominantly through rural areas, interacts with and supports rural landscapes, livelihoods & ecosystems, remaining largely influenced by agricultural, forestry & natural processes rater than intensive urbanisation

SCALE :

N

SHEET NO: **14**

SHEET TITLE: **Stakeholder Mapping**

SOURCE:

- *Compiled by Author based on field observations*

NAME
K S ANANYA

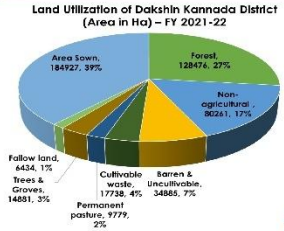
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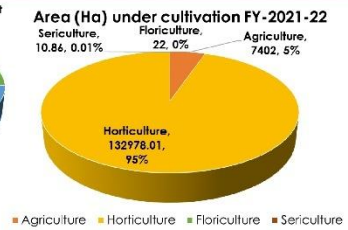
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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Economic Activates

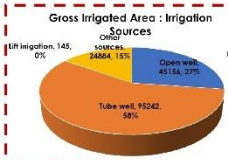
Primary Sector - Agriculture

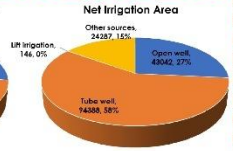




Cultivated area statistics for Dakshin Kannada District FY 2021-22

Agricultural land use	Area (Ha)
Net Irrigated area	161863
Area irrigated more than once	3564
Gross irrigated area	**165427**
Net Sown Area (NSA)	184927
Area sown more than once	4895
Gross cropped area (GCA)	**189822**
Cropping intensity (GCA/NSA*100)	**102.65 %**

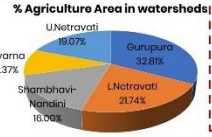




Irrigation:

- Dependent on **rainfall and groundwater.**
- Groundwater extracted through **open wells, tube wells, river water** is drawn through lift irrigation.
- Primary source of irrigation: **Tube wells**, covering **58% of** Net & gross irrigated area.

Fertilizer Type	Common Name	Amount Distributed (MT)	% in Run-off	Run-off to the river
Urea	Urea	563	25	140.75
DAP	Diammonium Phosphate	37	10	3.7
MOP	Muriate of Potash	1312	5	65.6
NPK	Nitrogen, Phosphorus, Potassium Mix	2954	15	443.1
SSP	Single Superphosphate	8	10	0.8
	Total	**4874**		**653.95 (13.42%)**



Gurupura watershed has the largest share of agriculture & plantation area – **32.81%**, assuming same % of fertilizer run-off, **≈ 87.76 MT** of fertilizer reaches the river.

Secondary Sector - Mining

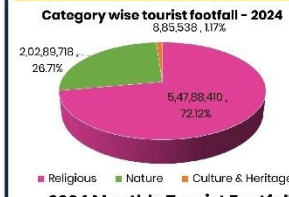
- **Major minerals -> Granite, Sillimanite, and Bauxite**,
- **Minor minerals -> Laterite, Quartz, and other Silica minerals.**

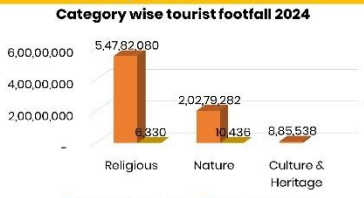
Mining Activities: Dominated by **Laterite Quarry & Sand mining**

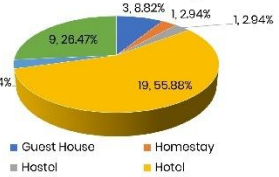
- **Quarrying:** Building stones and laterite stones
- **Sand Mining:** Non-CRZ sand block quarry -> sand extraction for construction purposes.
- **Sand bar mining** in CRZ area -> **Ordinary sand.**

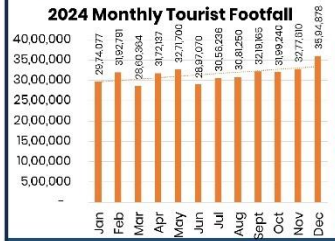
Mineral	Quantity Extracted	Year
Laterite Stone	52,214 metric tonnes	2010–2011
River Sand (non-CRZ)	75,444 metric tonnes (stock at yards)	2023
River Sand (non-CRZ)	~40,000 metric tonnes (available stock)	2024
River Sand (CRZ)	148 permits restored, 54 new issued	2022

Tertiary Sector - Tourism



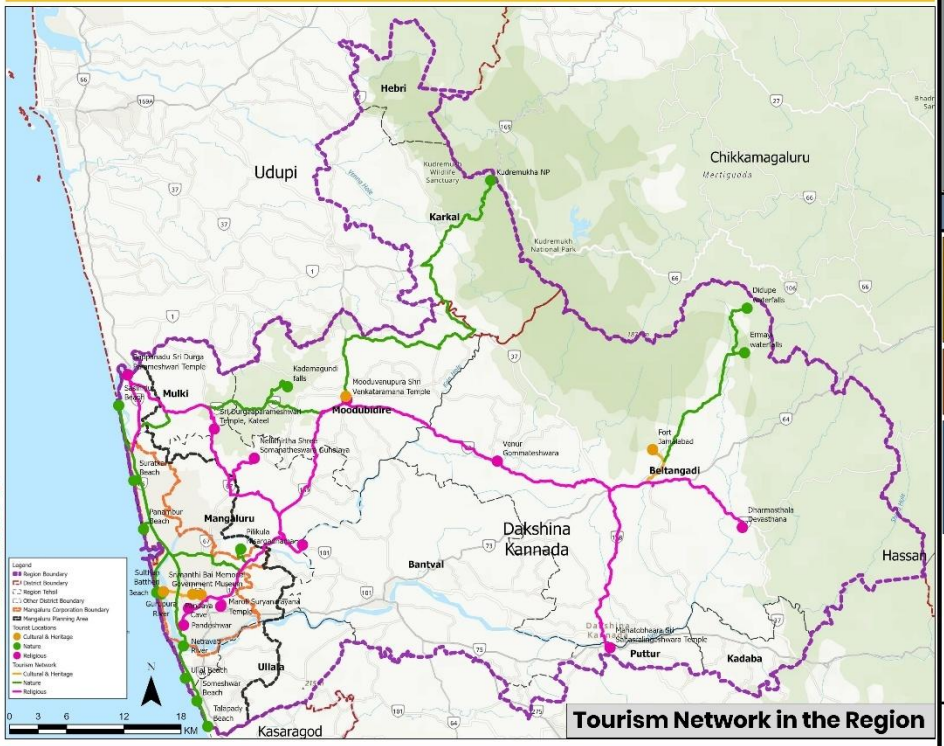






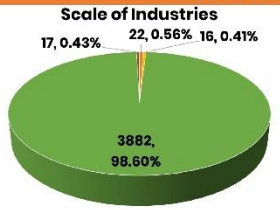
- Steady footfall throughout the year, highest in the month of December.
- **Purpose: 72.12%** -> **Nature tourism,** with the city's beaches being the key attraction.
- **Accommodation :** Concentrated in Mangaluru city & outskirts.
- 19 hotels, 1 homestays, 9 resort, 3 Guest house, 1 Hostel & 1 lodge hosting **2788** tourists in peak season.

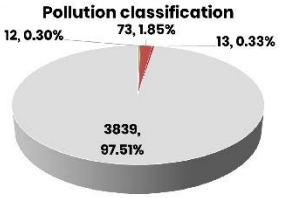
Tertiary Sector - Tourism

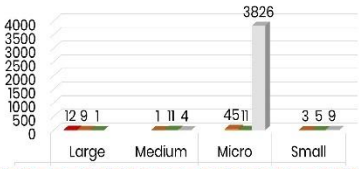


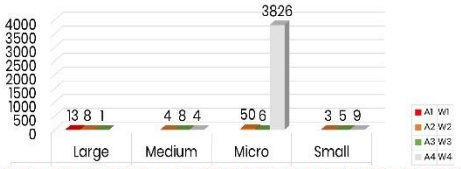
Tourism Network in the Region

Secondary Sector - Industry









- 3937 Industries in the Region (Across scale)
- **Baikampady IA** is allowed to have **Orange** category industry, other -> **Green**

Types of industries:

Agro based, Cotton textile, silk clothes, Jute, Paper, Leather based, Chemical based, Rubber, Plastic & petro based, Mineral based, Metal based (Steel Fab), & Oil refineries.

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



KEY MAP



LEGEND / INFERENCE

Region
1. Mangaluru EPIP (1970's)
2. Canara IA (1978)
3. Mangaluru SEZ & Non-SEZ (2006)

Planning Area
1. Kamad IA (1997)
2. MRPL (1988)

Mangaluru M.Corp
1. Thannirbhavi IA
2. Baikampady IA
   - Baikampady IE
   - JESCO IE

SCALE : **1: 2,80,000**

N

SHEET NO: **15**

SHEET TITLE: **Economic Activates**

SOURCE:
- *Compiled by Author*
- *District Statistical Report - 2023*

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Impact Matrix

Category	Components affected	Economic Activities: Agriculture				Industry							Mining				Tourism					
		Ploughing & flooding	Use of chemical fertilizers & pesticides	Irrigation using river water	Average	Manufacturing (chemicals, paper, food, etc.)	Use of boilers (firewood, diesel)	Effluent discharge to water bodies	Handling of produce	Solid/hazardous waste handling	Industrial transport & logistics	Average	Site clearing and material extraction	Use of diesel machinery and transport	Stockpiling and open storage of material	Average	Beach and river-based tourism (boating, recreation)	Heritage site visits & cultural festivals	Hotel and resort development	Tourist waste generation	Road transport & parking	Average
Physical Environment	Air	2	2	1	1.67	1	1	1	1	1	2	1.17	2	3	2	2.33	2	1	2	1	2	1.60
	Inland Rivers	3	3	3	3.00	1	1	1	3	1	1	1.33	2	2	3	2.33	3	1	2	3	2	2.20
	Inland waterbodies	3	3	3	3.00	1	1	1	2	1	1	1.17	1	2	1	1.33	1	1	2	2	1	1.40
	Ground water	2	3	1	2.00	1	1	1	2	1	1	1.17	2	1	2	1.67	2	1	2	2	1	1.60
	Land & Soil	3	3	2	2.67	1	1	1	1	1	1	1.00	3	2	3	2.67	2	1	3	3	2	2.20
	Micro-climate	2	1	2	1.67	1	1	1	1	1	1	1.00	1	2	1	1.33	2	1	2	1	2	1.60
Biological Aspect	Terrestrial Flora	2	3	2	2.33	1	1	1	1	1	1	1.00	3	2	2	2.33	2	1	3	2	2	2.00
	Terrestrial Fauna	2	3	2	2.33	1	1	1	1	1	1	1.00	2	2	2	2.00	2	1	2	2	2	1.80
	Aquatic Flora	1	3	3	2.33	1	1	1	1	1	1	1.00	2	1	3	2.00	3	1	2	3	2	2.20
	Aquatic Fauna	1	3	3	2.33	1	1	1	1	1	1	1.00	2	1	3	2.00	3	1	2	3	2	2.20
Socio-cultural Aspect	Livelihood	1	1	1	1.00	2	1	1	2	1	2	1.50	2	2	2	2.00	2	1	2	2	2	1.80
	Health	1	1	1	1.00	1	1	1	1	1	1	1.00	2	3	2	2.33	2	1	2	3	2	2.00
	Culture	1	2	1	1.3	1	1	1	1	1	1	1.00	1	1	1	1.00	1	2	2	1	1	1.40
Average		1.8	2.4	1.9	26.67	1.1	1.0	1.0	1.4	1.0	1.2	14.33	1.9	1.8	2.1	25.33	2.1	1.1	2.2	2.2	1.8	24.00

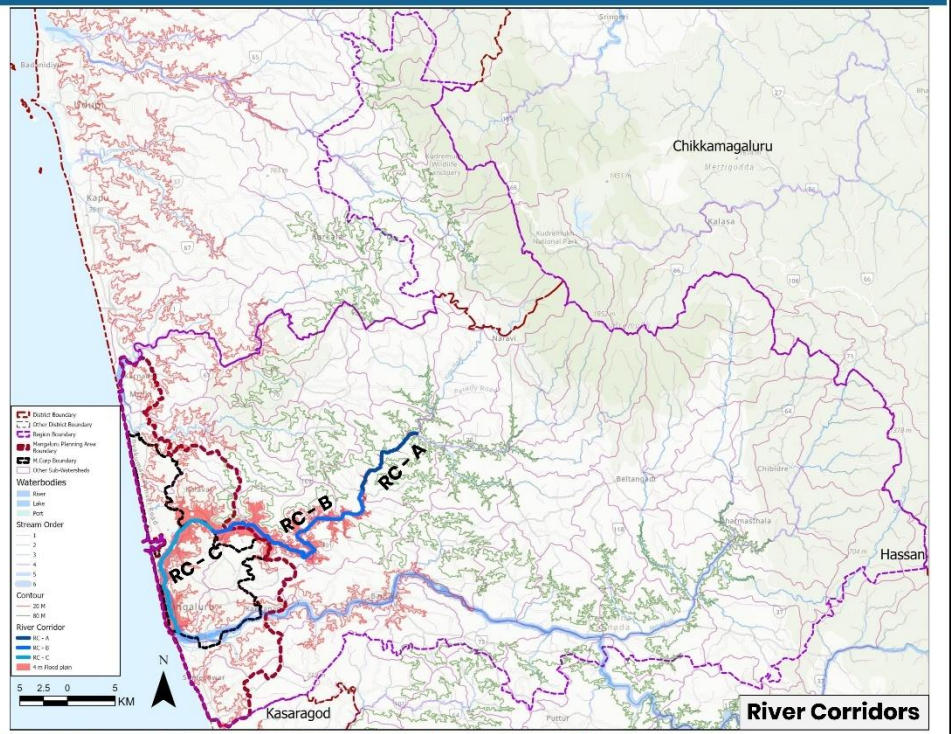
Category	Components affected	Total score	Economic Activities: Agriculture Average	Agriculture Observation	Industry Average	Industry Observation	Mining Average	Mining Observation	Tourism Average	Tourism Observation
Physical Environment	Air	6.8	1.67	The agricultural practice in the region is contaminating the surface & ground water resources, modifying river flow through irrigation & chemical use	1.17	No significant impact in the region	2.33	Mining degrades land, pollutes air and water, and slightly alters micro-climate.	1.60	Waste generation, land use changes, increased vehicular emissions, and strain on local air, water, and soil quality.
	Inland Rivers	8.9	3.00		1.33		2.33		2.20	
	Inland waterbodies	6.9	3.00		1.17		1.33		1.40	
	Ground water	6.4	2.00		1.17		1.67		1.60	
	Land & Soil	8.5	2.67		1.00		2.67		2.20	
	Micro-climate	5.6	1.67		1.00		1.33		1.60	
Biological Aspect	Terrestrial Flora	7.7	2.33	Intensive agriculture & plantation reduces biodiversity & harms non-targegt terrestrial & aquatic species & alters habitat die to chemical run-off	1.00		2.33	disturbs flora and fauna through habitat loss and sediment runoff.	2.00	Habitat disturbance from construction and tourist footfall stresses local flora and fauna, especially in sensitive riverine and coastal zones.
	Terrestrial Fauna	7.1	2.33		1.00		2.00		1.80	
	Aquatic Flora	7.5	2.33		1.00		2.00		2.20	
	Aquatic Fauna	7.5	2.33		1.00		2.00		2.20	
Socio-cultural Aspect	Livelihood	6.3	1.00	Chemical intensive farming endangers farmers & public health. The region sees a weak traditional farming knowledge which induces long term risks to sustainable rural livelihood	1.50		2.00	affects health and livelihoods moderately; cultural impact is minimal.	1.80	Boosts local income and cultural visibility but can commercialize traditions and strain infrastructure.
	Health	6.3	1.00		1.00		2.33		2.00	
	Culture	4.7	1.3		1.00		1.00		1.40	
Average			26.67		14.33		25.33		24.00	

Inference:

- Agricultural activity is observed to have highest impact.
- The most impacted aspects are Inland river (In this case, Gurupura river) from the agricultural-run-off, Land & Soil environment due to use of fertilizers & modern ploughing tools.
- This results in chemical infiltration in to ground water.

1 – 1.67	Low
1.68 – 2.33	Moderate
2.33 – 3	High

Prioritization of Watershed



Sub-watersheds	Sub-watershed code	Watershed	Area (Sq.km)	% area of watershed	Major economic Activity
Critical sub-watersheds	5A3B4P	Gurupura	55.19	5.9	Industry, Fishing
	5A3B4Q		48.38	5.2	
	5A3B1I	Netravati	34.69	6.0	
Semi-critical sub-watersheds	5A3B6S	Shambhavi-Nandini	56.76	10.4	Agriculture, Fishing
	5A3B5W		72.07	13.23	
	5A3B4N	Gurupura	46.49	4.9	Agriculture
	5A3B40		52.41	5.6	
	5A3B1G	Netravati	58.74	10.2	Agriculture, Fishing
	5A3B1J		49.85	8.7	
	5A3A7K		53.25	9.3	

Scoring the parameters

Indicators	Ecological Indicators												Demographic Indicators			
Analytical tool used	Abiotic aspect				Biotic		Basin Morphometry		Flooding		Demography & livelihood analysis					
Parameter	Rainfall		Slope		Groundwater		Mangrove	NDVI	Bifurcation ratio	Drainage density	Flow	Flood susceptibility	Population density		Urban population	
Relevance	More rainfall higher the priority		More slope, higher priority		Deeper the water table, higher the priority		Presence: High priority	Less NDVI: High priority	Higher the value, higher the flood risk	Higher the value, higher the flood risk	Higher the value, higher the flood susceptibility	Higher the value, higher the flood risk	Higher the density, higher the priority		More urban population, more the priority	
Subwatershed	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score
5A3B1I	3000 – 4000	2	Low	3	>20M	3	Present	3	Low	3	Low	1	High	3	High	3	>602k	3	>10YH	3	High	3
5A3B4P	3000 – 4000	2	Low	3	>18M	3	Present	3	Low	3	Low	1	Medium	2	High	3	>602k	3	>10YH	3	High	3
5A3B4Q	3000 – 4000	2	Low	3	>20M	3	Present	3	Low	3	Low	1	High	3	High	3	>602k	3	>10YH	3	High	3

Indicators	Socio-Economic Indicators						LULC Indicators								Institutional		
Analytical tool used	Scalogram		Dependency & Livelihood analysis		Impact Matrix		Change detection								Governance		
Parameter	Order of settlements		Ecosystem service dependency ratio		Impact of economic activities		Forest area expansion		Built-up area expansion		Waterbody		Agriculture area expansion		Master plan		Total
Relevance	More number of higher order settlements, higher the priority		More the ratio, more the priority		More the presence of economic activities more the priority		More forest area, lesser priority for development		Higher the built up, more the priority		Presence of waterbody (in this case River) is always preferred for development, high priority		More the area, more scope for population growth, more the priority		Presence of masterplan, high priority		
Subwatershed	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Score		
5A3B1I	High	3	High	3	Medium	2	Low	3	Medium	2	High	3	High	3	Low	1	3	47
5A3B4P	Medium	2	High	3	High	3	Medium	2	High	3	High	3	High	3	Medium	2	3	44
5A3B4Q	High	3	High	3	High	3	Medium	2	High	3	High	3	High	3	Low	1	1	48

- The sub-watersheds along the coast of the Gurupura Watershed score the highest and hence prioritised for further study.
- Additionally, the next set of high scoring sub-watersheds can be seen encompassing the **Mangaluru Planning Area**. These are termed **semi-critical sub-watersheds** for further reference.
- The **3 critical sub-watersheds** comprise of the Mangaluru Municipal Corporation Area.
- **Identification of River Corridors ->** based on stream order, contour & administrative boundary – All the river corridors identified for **Gurupura river** are of **Stream order 5,** & **land area up to 4m flood line** is considered
- **RC – A** between 20 – 80m contour,
- **RC – B** 20m contour to planning area boundary
- **RC – C** 20m contour within planning Area Boundary

KEY MAP



LEGEND / INFERENCE

Rural river corridor – River stretch flowing through **agricultural, forested, or sparsely populated** rural areas, where the river system predominantly interacts with **natural landscapes**, **agricultural land**, and **plantation-based livelihoods**.

Urban river corridor - River that flows through **built-up or urbanized areas**, characterized by **infrastructure**, **encroachments**, and **altered hydrology**, with complex challenges related to **pollution**, **flood risk**, and **urban interface**.

SCALE :
1: 2,80,000

N

SHEET NO:
16

SHEET TITLE:
Impact Matrix & Watershed Prioritization

SOURCE:
- *Observation & primary survey based*
- *Generated by Author*

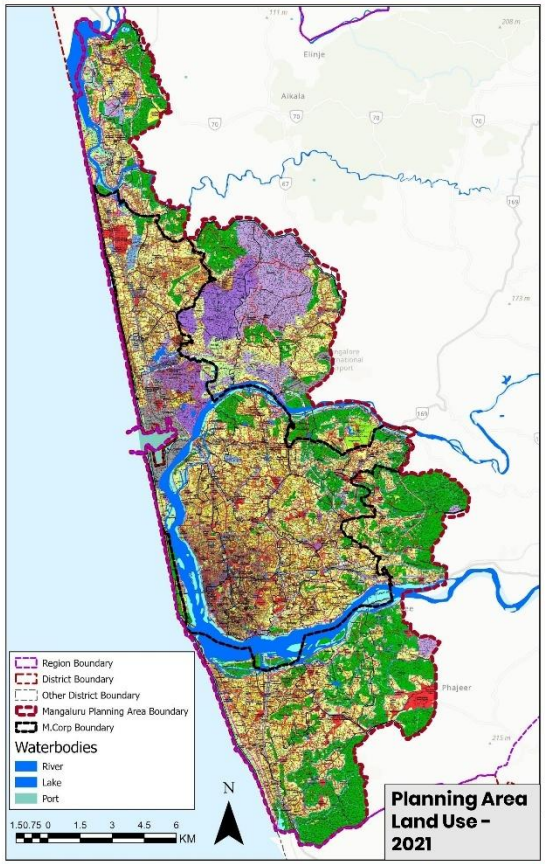
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Mangaluru Planning Area – Environmental Resources and



Planning Area Land Use – 2021

Environmental Resources

Mangaluru Planning Area **shares several broad environmental characteristics** with the larger **region**.

Environmental Resources **unique** to the Mangaluru Planning Area include

1. **Low gradient slopes:** Gradual variation in slope, forming a natural gradient from the elevated interior plateaus to the low-lying coastal fringe.
2. **River:** Confluence of the Major Rivers – **Gurupura & Netravati & Shambhavi & Nandini** with the Arabian Sea.
3. **Estuarine Complex & Mangrove:** Supports Mangroves in the Gurupura & Netravati Estuary and The Shambhavi & Nandini Estuary.
   - Currently, the mangrove area is encroached by fishermen for fish net drying – indicating mangrove degradation/ altering of river channel.



Common in both estuary



Avicennia officinalis



Rhizophora mucronata



Kandelia candel

Shambhavi & Nandini Estuary



Avicennia officinalis



Sonneratia caseolaris



Bruguiera gymnorrhiza

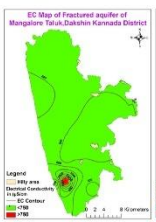


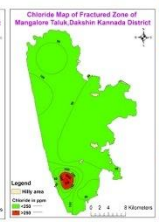
Sonneratia alba



Excoecaria agallocha

4. **Flow:** Comprises of High flow watersheds with high run-off, contributing to seasonal fluvial flooding
5. **Ground Water Levels:** Water table ranges beween **10 to 58.4m** below sea level, **high levels of EC & Chloride** levels in one village (Ullal Area) **->** indicator of high salinity levels due to sea water intrusion.
6. Stage of ground water withdrawal is **49.51%** & is in **safe** category





	2020				2022			
	GW Availability (ham)	GW Availability	GW Draft	Stage of GW withdrawal	GW Availability	GW Draft	Stage of GW withdrawal
	3598	9750.13	3232.94	**33.16**	10242.29	5071.78	**49.51**

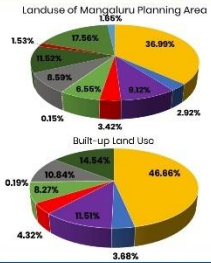
Demography & Socio-economics

Aspects	Villages	Urban Centres	Total
Number	16	17	33
Population	42,772	700917	7,43,689
Male population	21,334	3,48,778	3,70,112
Female Population	21,438	3,54,434	3,75,872
Population Density (Avg)	8.40	17.98	13.19
Sex Ratio (Avg)	1,002	1,013	1007.5
Literacy Rate (Avg)	88.25	90.11	89.18
WFPR (Avg)	45.17	44.52	44.84

Mangaluru Planning area has **1 M.Corp (Mangaluru), 1 TMC (Mulki), 1 TP (Ullal), and 14 Census Towns**

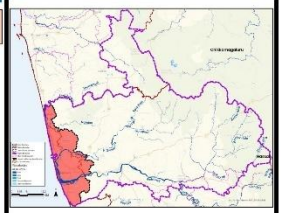
Land use and Development Plan Analysis

Landuse	Area in Ha
Residential	11317.59
Commercial	892.97
Industrial	2790.71
PSP	1047.64
Recreation	2005.74
Public utility	45.8
Transport	2629.48
Urban Agriculture + Waterbodies	3525.8
Total Built up	**24255.73**
Spotted developments	468.06
Agriculture	5372.62
Waterbodies	503.59
Grand total	**30600**



Sector	Spatial Planning Proposals	Non-Spatial Proposals	Implications on Gurupura River & Urban River Management
Industrial Areas	- SEZ in Kalavar, Bala, Kenjar, Permude, Bajpe - Ancillary units near Harekala, Marakada, etc.	- IT Park support by KIADB (e.g., Infosys expansion)	May contribute to effluent discharge; proximity to Gurupura increases risk of water pollution. Need for buffer zones.
Solid Waste	- Landfills: Kudupu, Pachnadi, Ullal, Mulki	- MCC manages disposal; landfill sites planned for 30-year horizon	Landfills near river catchments could leach into groundwater or Gurupura unless protected with liners/leachate systems.
Water Supply	- Based on intake from Nethravathi (Thumbe)	- Integration with KUIDFC project (ADB assisted)	Over-extraction from Nethravathi may stress basin recharge, indirectly affecting Gurupura.
Sewage / Stormwater	- Existing UGD coverage 20–25% only - Kavoor and Jeppinamogaru STPs	- ₹157 cr ADB-funded sewer network upgrade	Direct sewage outfall into Gurupura at unserved areas; delay in STP upgrades may worsen pollution.
Green Zones	- 2005.74 Ha of open space (9.68% of development area)	- CMZ and CRZ-based protection measures	Buffer function for Gurupura banks; needs stricter encroachment control.
Blue-Green Network	- CRZ I–III zones along Gurupura identified - Buffer lands proposed	- Based on MoEF notifications; regulated by local authority	Strengthens flood resilience and pollution buffering; implementation and enforcement remain key.
Development Control Regulations (FAR/FSI)	- Maximum FAR varies by area and road width: • **Intense urban areas (Area A)**: Up to **3.25 (Permissible 2.5 + Premium 0.75)** for >6000 m² sites • **Organizable plots** (non-residential >6000 m²): Up to **4.0** with 30m roads • **Integrated townships**: FAR up to **4.0**, coverage 45% (for 45m roads) • **Flatted factories**: Max FAR **1.75**, based on road width • **CRZ-I & II** (coastal/river adjacent zones): Height restrictions, typically G+1 permitted; stricter land use control; FAR severely restricted	- Premium FAR allowed with 50% mandatory TDR - CRZ rules apply within 500m of high tide line; no new development in CRZ-I	FAR relaxations in flood-prone zones can cause high-density urbanization near rivers, increasing runoff and encroachments. CRZ areas near Gurupura must maintain low-density use to safeguard the river ecosystem.

KEY MAP



LEGEND / INFERENCE

Area of Mangaluru Local Planning Extent = 30600 Ha

Landuse

- Residential
- Industrial
- Recreation
- Transport
- Spotted developments
- Waterbodies
- Commercial
- PSP
- Public utility
- Urban Agriculture + Wa
- Agriculture

SCALE : **1: 1,25,000**

N

SHEET NO: **17**

SHEET TITLE: **Mangaluru Planning Area – Introduction & Development Plan Analysis**

SOURCE:

- *Census of India, 2011*
- *Mangaluru Planning Area Master Plan, 2021*

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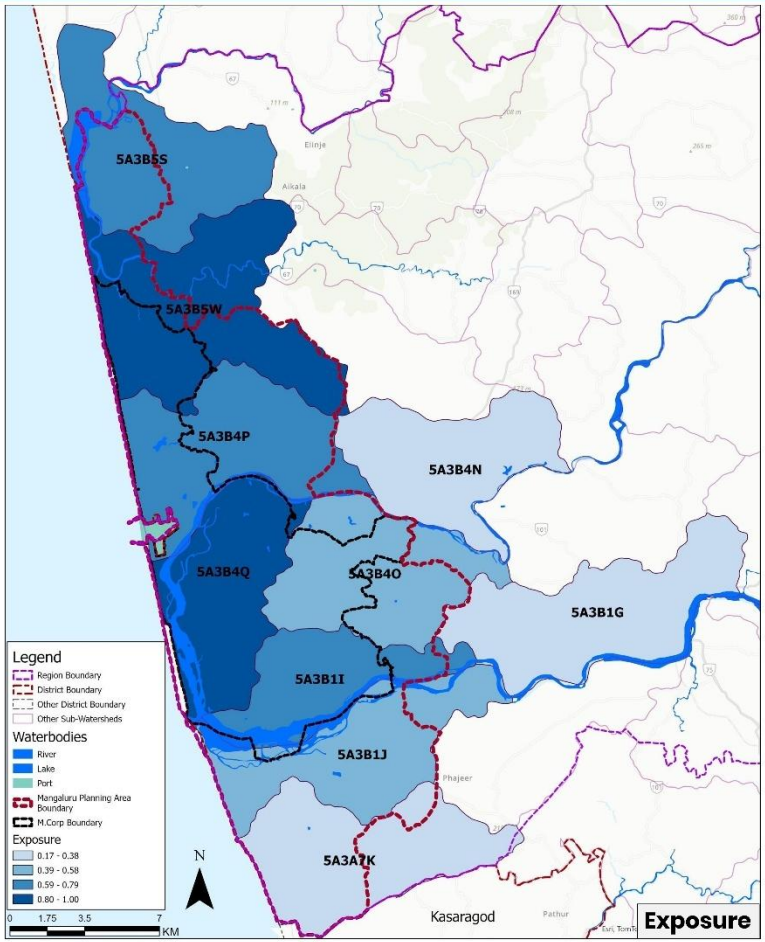
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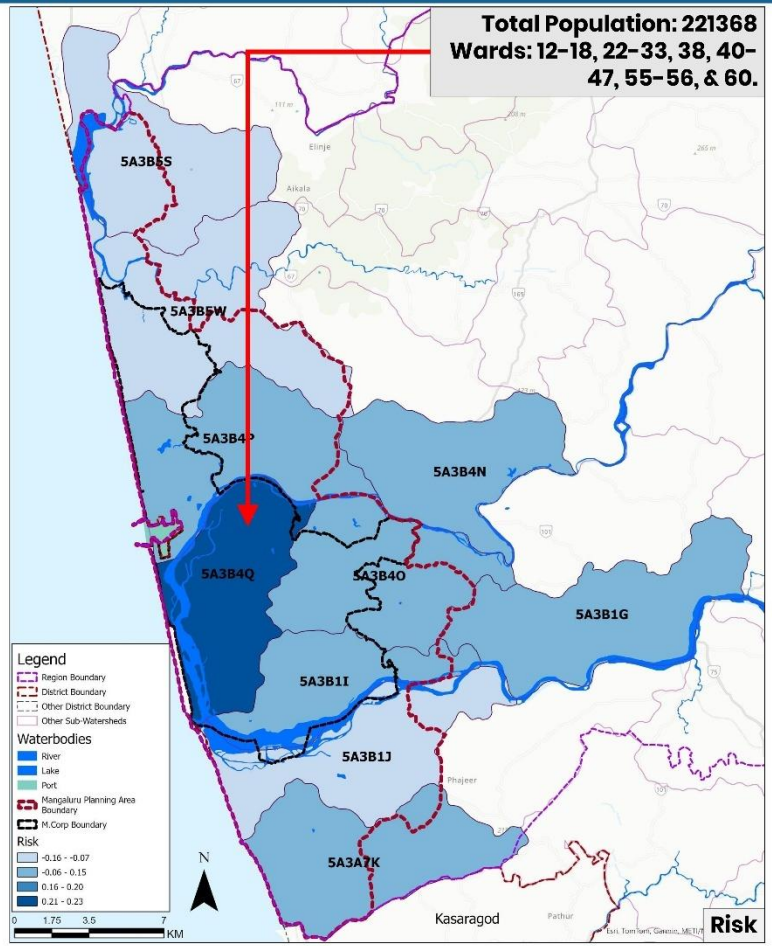
Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



Fluvial Flood Risk



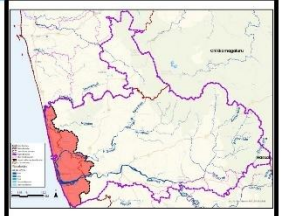
Exposure



Risk

Sub-Watershed Code	Sensitivity						Adaptive Capacity Parameters							Exposure		Hazard		Average Sensitivity (A)	Average Adaptive capacity (B)	Vulnerability (C = A-B)	Exposure (D)	Hazard (E)	Flood Risk (C*D*E)
	Flood	Demography & socio-cultural indicators			Infrastructure and development indicators		Ecological Indicators			Demography & socio-cultural indicators	Infrastructure and development indicators		Institutional Indicator	Demography	CRZ	Flood	CRZ						
	Run-off	Population density	SC & ST population	Agricultural workers population	Number of 3rd & 4th order settlements	Access to wells & drainage system	High infiltration potential of soil	% Forest Area	Presence of Mangrove	Literacy rate	HH with tap water access	SHG	Masterplan	Population	High Flood Line	Flood susceptibility	Hazard Line						
5A3A7K	0.04	0.12	0.00	0.28	0.00	0.62	1.00	0.20	0.50	1.00	1.00	0.00	0.50	0.23	0.33	0.00	0.33	0.18	0.60	-0.42	0.17	0.17	-0.01
5A3B1G	0.07	0.04	0.15	0.35	0.29	0.50	0.00	1.00	0.00	0.47	0.72	0.00	0.00	0.19	0.33	0.16	0.33	0.23	0.31	-0.08	0.24	0.24	0.00
5A3B1I	0.35	0.62	1.00	0.40	0.43	0.98	0.50	0.00	0.50	0.09	0.63	1.00	1.00	0.50	1.00	0.57	1.00	0.63	0.53	0.10	0.78	0.78	0.06
5A3B1J	0.02	0.16	0.04	0.00	0.00	0.72	1.00	0.15	0.50	0.93	0.91	0.00	1.00	0.34	1.00	0.16	1.00	0.16	0.64	-0.49	0.58	0.58	-0.16
5A3B4N	0.00	0.00	0.32	0.75	0.43	0.21	0.50	0.83	0.00	0.85	0.62	0.00	0.00	0.00	0.00	0.59	0.00	0.28	0.40	-0.12	0.30	0.30	-0.01
5A3B4O	0.03	0.17	0.20	0.65	0.14	0.77	0.00	0.16	0.00	0.98	0.85	0.00	1.00	0.25	0.33	0.52	0.33	0.33	0.43	-0.10	0.43	0.43	-0.02
5A3B4P	0.70	0.55	0.81	0.40	0.29	1.00	0.50	0.02	0.50	0.00	0.62	0.00	1.00	0.23	1.00	0.49	1.00	0.63	0.38	0.25	0.74	0.74	0.14
5A3B4Q	0.59	1.00	0.73	1.00	1.00	0.98	0.00	0.05	1.00	0.64	0.89	1.00	1.00	1.00	1.00	1.00	1.00	0.88	0.66	0.23	1.00	1.00	0.23
5A3B5S	0.06	0.00	0.81	0.70	0.43	0.22	1.00	0.38	1.00	0.98	0.18	0.00	0.50	0.03	1.00	0.34	1.00	0.37	0.58	-0.21	0.67	0.67	-0.09
5A3B5W	1.00	0.13	0.47	0.40	0.86	0.00	1.00	0.79	0.50	0.96	0.00	1.00	0.50	0.30	1.00	0.75	1.00	0.48	0.68	-0.20	0.87	0.87	-0.15

KEY MAP



LEGEND / INFERENCE

Sub-watershed **5A3B4Q** has high **Flood Risk.**

Vulnerability = Sensitivity – Adaptive Capacity

Risk = Vulnerability x Exposure x Hazard

SCALE : **1: 1,25,000**

N

SHEET NO: **18**

SHEET TITLE: **Flood Risk**

SOURCE:
- *Author*

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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Mangaluru Municipal Corporation – Introduction

Multi-framework Approach for Urban River Management

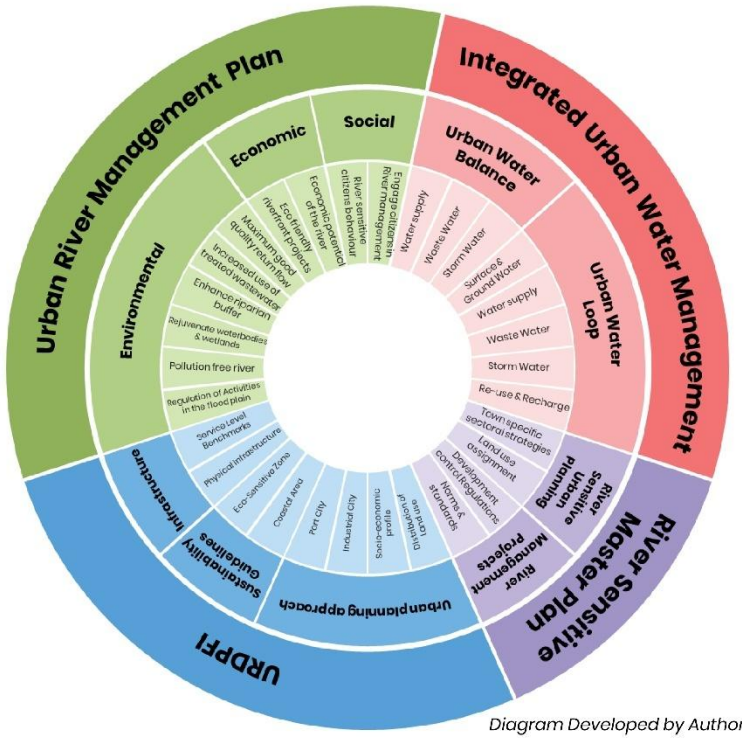


Diagram Developed by Author

Evolution of the Mangaluru City


Gurupura River


Old Port

- Mangalore's physical landscape—undulating terrain with coastal area and hillocks — naturally guided how the city expanded in the **inter-fluvial zone** of **Gurupura & Netravati.**
- The **old town** core developed around Bunder (the old port) in the low-lying area within **20m elevation**. Early settlements grew in a ribbon - like pattern along: **Trading routes, Coastal lines,** facilitating Access to rivers for trade and transport.

14th Cen. — **Historic Core and Old Port**
Bunder developed as a **trade-based port**; settlement grew around it due to river and coastal trade access.

1956 — **1st Water Supply Scheme Commissioned**
Organized piped water supply from Thumbe (Nethravathi)

1970s — **Development of Baikampady Industrial Area**
Industrial estate established north of Mangalore city

1974 — **New Mangalore Port (NMPT) Commissioned**
Major modern port at Panambur opened, for large-scale cargo trade

77–78 — **Urban Expansion Along Highways**
Notable ribbon development along NH-66.

1980s — **MRPL (MRPL)**
Established MRPL near NMPT catalyzed industrial cluster formation and employment rise.

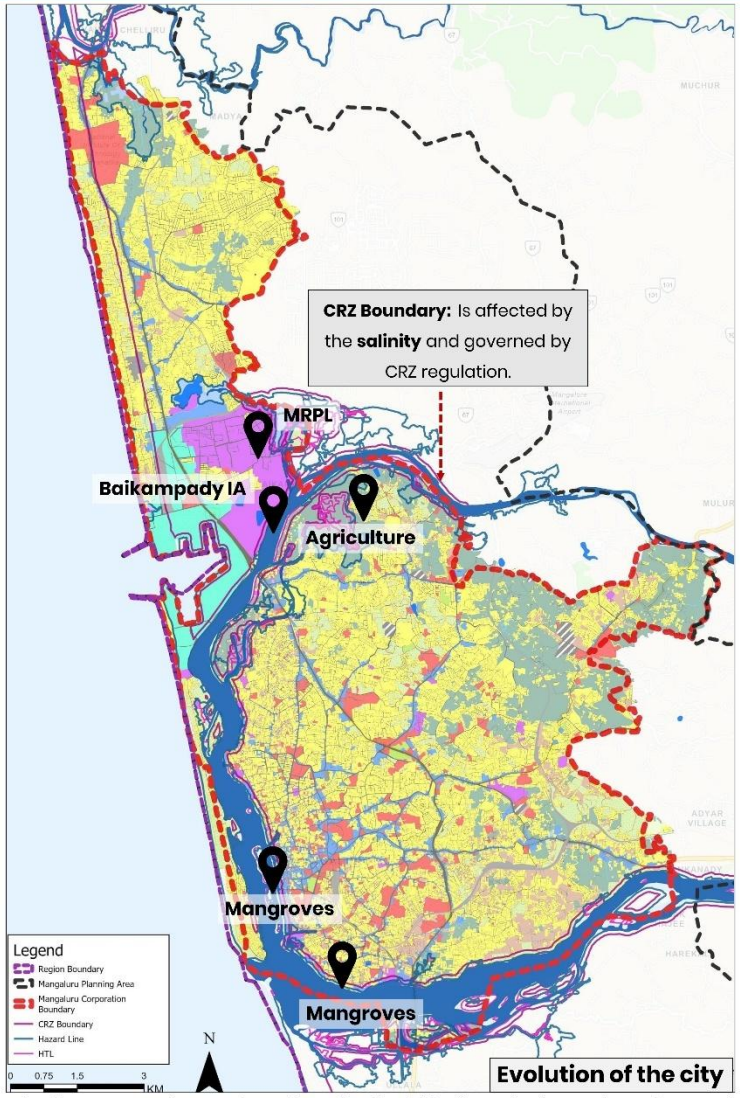
1984 — **Formation of Mangalore City Corporation (MCC)**
Unified governance for city services, sanitation, water, roads, urban regulation officially established.

1988 — **First Master Plan Prepared**
Formal introduction of zoning laws, land use control, road network hierarchy and planned urban expansion.

1991 — **Coastal Regulation Zone (CRZ) Enforced**
Coastal and riverbank construction regulations established to protect the rivers and coastlines.

2001 — **Second Master Plan (Revision-I) and SEZ Initiation**
Planned suburban growth (Suratkal, Ullal), SEZ notified to promote IT, petrochemicals, and service industries.

2021 — **Master plan revised – II Finalized**
Compact urban growth model adopted; focus on blue-green corridors, river and floodplain protection (Gurupura, Netravathi).



- As Gurupura river enters the city, it shifts from being primarily rural life-support systems → **strategic urban infrastructure assets.**
- **Flow[1]:** Consistent high flow, with an annual rainfall of 4100 mm, dependable flows exceeding **70%** reliability (Q70) indicating availability throughout the year.
- Supports the industrial activity by carrying its effluent & as a source of water, transport activity through ferry services, and sustains fishermen's livelihood.
- **High sediment load[2]** - Sand, Silt, Clay, Organic Carbon due to run-off and tidal action – high in monsoon.

KEY MAP



LEGEND / INFERENCE

Sources:

1. *Evaluation of Satellite Precipitation Products in Simulating Streamflow in a Humid Tropical Catchment of India' (Sharannya et al., 2020)*
2. *Water and sediment quality parameters of the restored mangrove ecosystem of Gurupura River and natural mangrove ecosystem of Shambhavi River in Dakshina Kannada, India*

SCALE : **1: 1,25,000**

N

SHEET NO: **19**

SHEET TITLE: **Mangaluru M.Corp Environmental Resources**

SOURCE:
- *Revise Master Plan for Mangaluru Planning Area 2021*
- *Generated by Author*

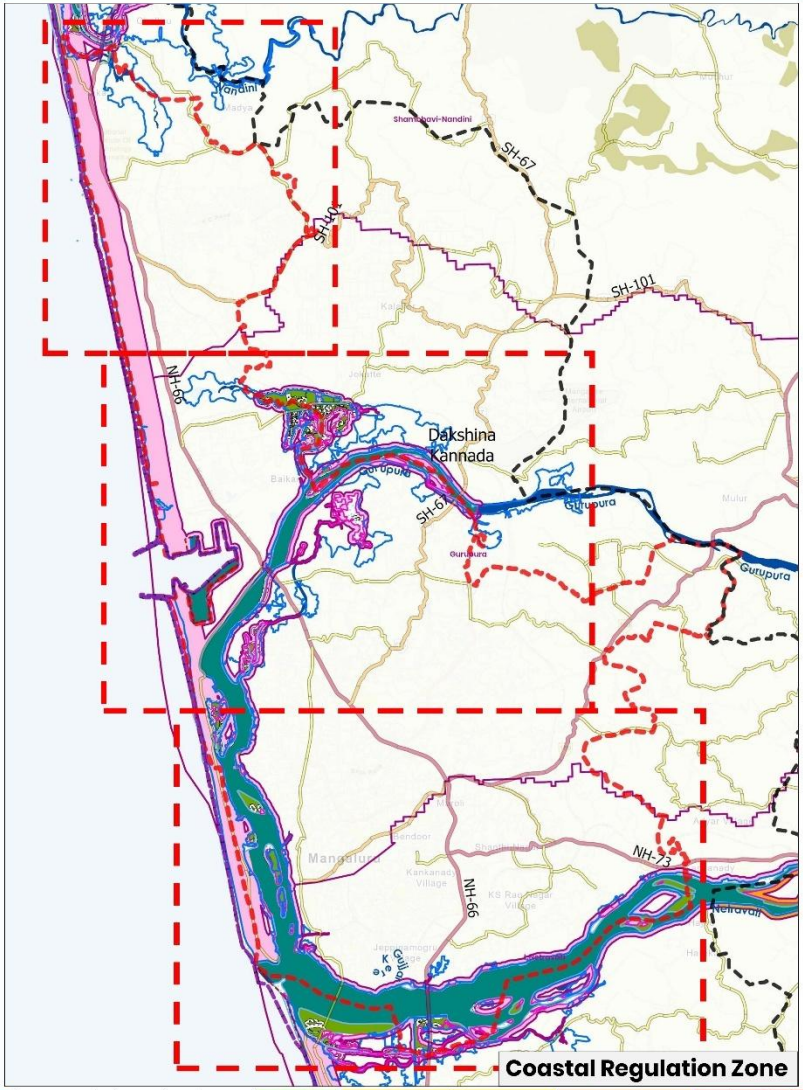
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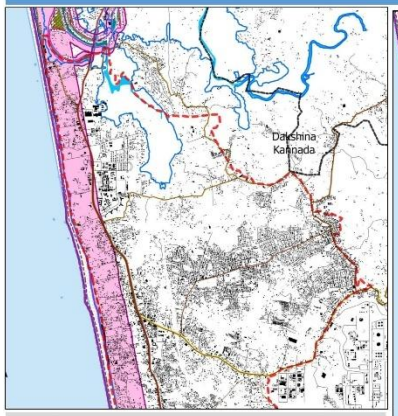
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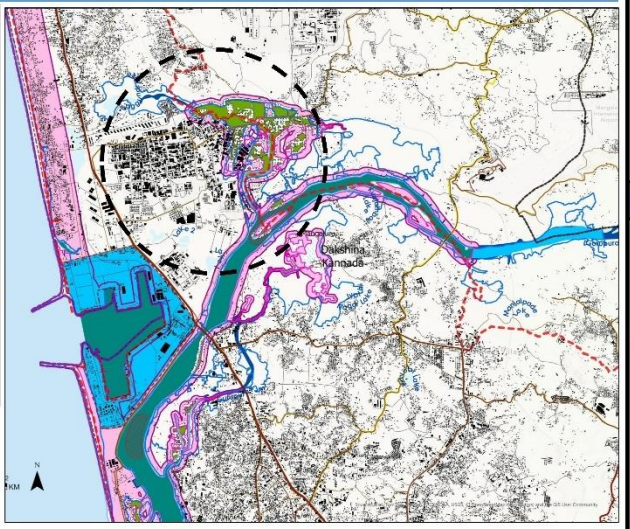
Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Mangrove Ecosystem Services & CRZ



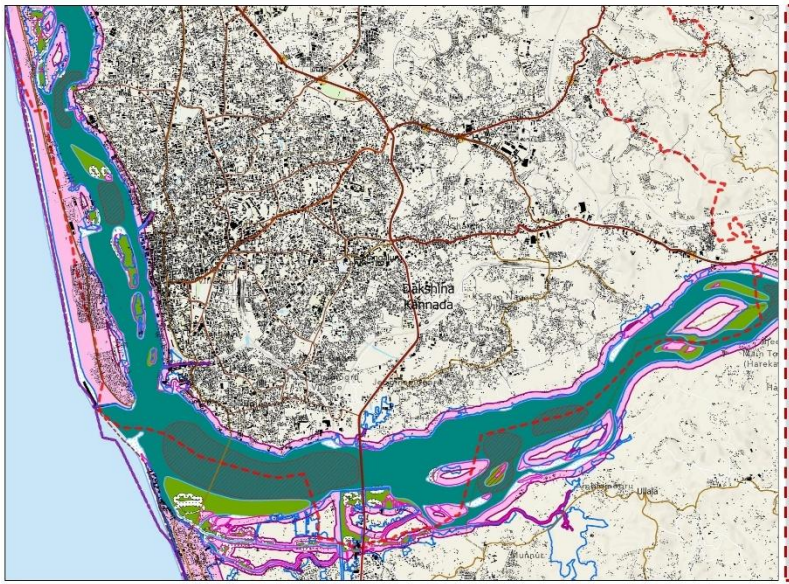
Coastal Regulation Zone





CRZ is a part of **24** of the **60** Wards within the Mangaluru Municipal Corporation limits.

The wards include: 1,2, 7, 9 to 14, 16, 25 to 27, 43 to 45, 50, 52 to 55, 57, 58 & 60, with **1,92,775** people living within these wards.



Area of Scoped Region: 3161.92 Sq.km

- Total CRZ area within scoped region: **57.75 Sq.km (1.8%)**

Area of Mangaluru Planning Area: 318 Sq.Km

- Total CRZ Area within Mangaluru Planning Area: **51.72 Sq.Km (16.3%)**

Area of Mangaluru Municipal Corporation: 136.44 Sq.km

- Total CRZ Area within Corporation limits: **27.1 Sq.km (19.84)**

Industries in CRZ II: Includes **Food processing, Oil, Alcohol based, Plywood and Fish processing industries.**

- These have come up before the notification and hence continue their operations. These industries can undergo modernization & expansion provided they comply with environmental norms & acquire clearance from regulatory authority.
- Setting up of new industries in CRZ II is prohibited with exceptions for non polluting industries, service industries related to waterfront activities – such as fishing, coastal tourism, ports and harbours, and renewable energy projects.

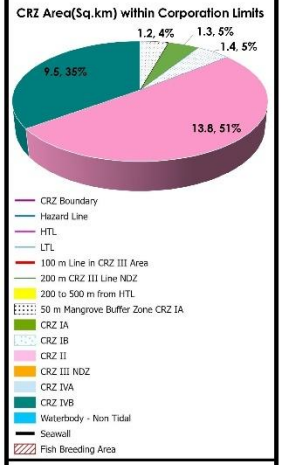
Mangrove Ecosystem Services

Zones	No. of wards	Total Population	2X: No. of wards with < 8000 population	1X: No. of wards with > 8000 population	Provision: Food	Provision: Fibre, Timber, Fuel	Provision: Medicinal resources	Provision: Total	Regulating: Erosion regulation	Regulating: Water quality maintenance	Regulating: Carbon sequestration	Regulating: Flood mitigation	Regulating: Micro-climate regulation	Regulating: Ground water rejuvenation	Regulating: Total	Supporting: Nutrient cycling formation and soil formation	Supporting: Habitat provision	Supporting: Employment generation	Supporting: Total	Cultural: Cultural & religious significance	Cultural: Recreation & Tourism	Cultural: Aesthetics	Cultural: Education & Research value	Cultural: Total	Grand Total
Core Area 1 - Upto 2 km (3X)	29	2,31,795	14	15	9	6	6		6	9	6	9	6	6		6	9	9		3	3	9	9		
Total								21							42				24					24	111
Core Area 2 - 2-5km Buffer (2X)	24	1,99,481	14	10	8	4	4		4	8	4	8	4	4		4	4	8		4	4	4	4		
Total								16							32				16					16	80
Transition Area - Beyond 5km (1X)	7	57,692	4	3	4	2	2		2	2	2	2	2	2		2	2	2		2	2	2	2		
Total								8							12				6					8	34
Grand Total					21	12	12	45	12	19	12	19	12	12	86	12	15	19	46	9	9	15	15	48	

KEY MAP



LEGEND / INFERENCE



SCALE : **1: 60,000**

N

SHEET NO: **20**

SHEET TITLE: **Mangaluru M.Corp Environmental Resources**

SOURCE:

- *Generated by Author*

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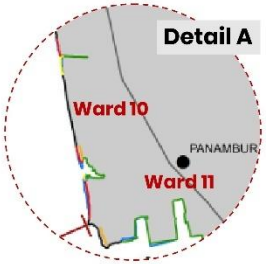
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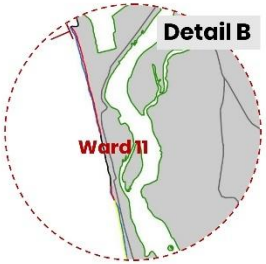
Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

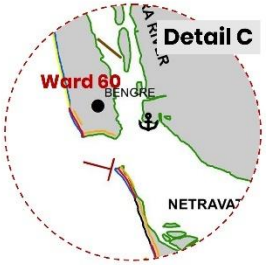
Coastal Hazard – Shoreline Erosion

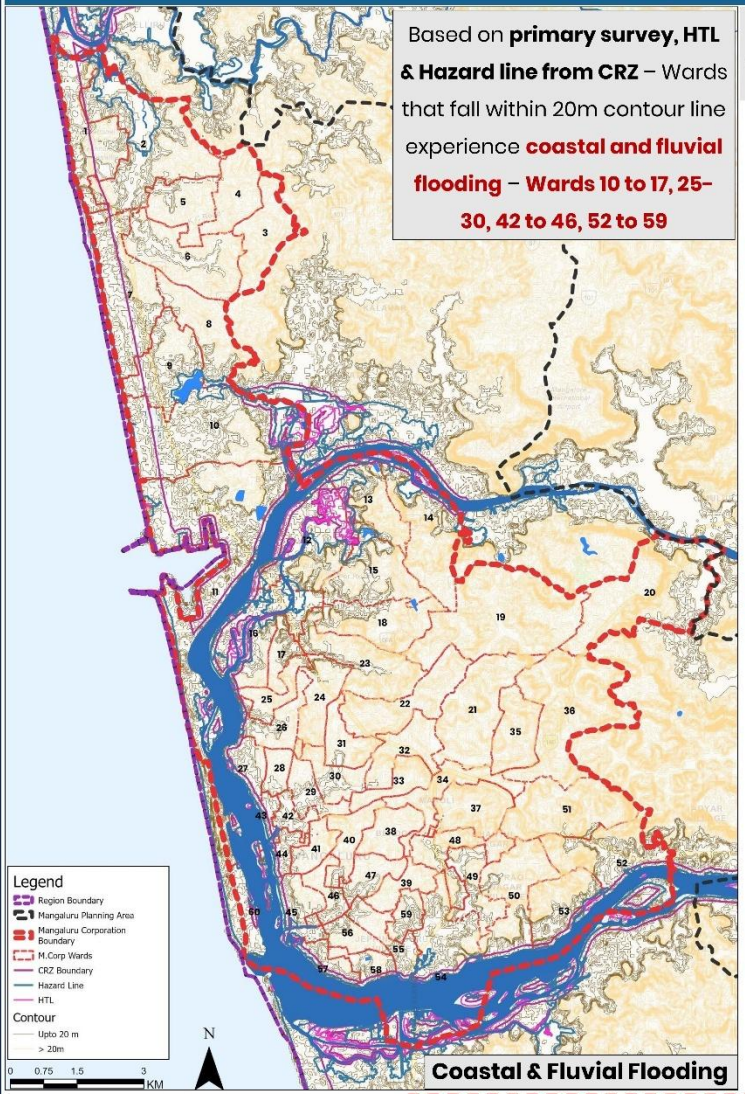
Based on **primary survey, HTL & Hazard line from CRZ** – Wards that fall within 20m contour line experience **coastal and fluvial flooding** – **Wards 10 to 17, 25-30, 42 to 46, 52 to 59**

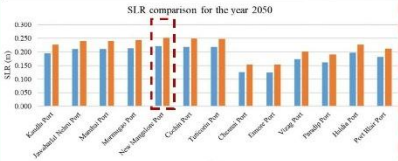
Shoreline change map – ISRO & Centra Water Commission (IRS LISS4 IMAGES OF 2004-06 & 2014-16)

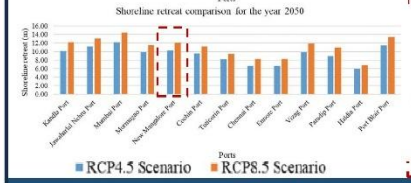












Highest Rate of Sea Level Rise (SLR): New Mangalore Port to experience the maximum absolute SLR among Indian ports:

- **5.16 mm/year** under RCP 4.5 (moderate scenario)
- **7.20 mm/year** under RCP 8.5 (worst-case scenario)

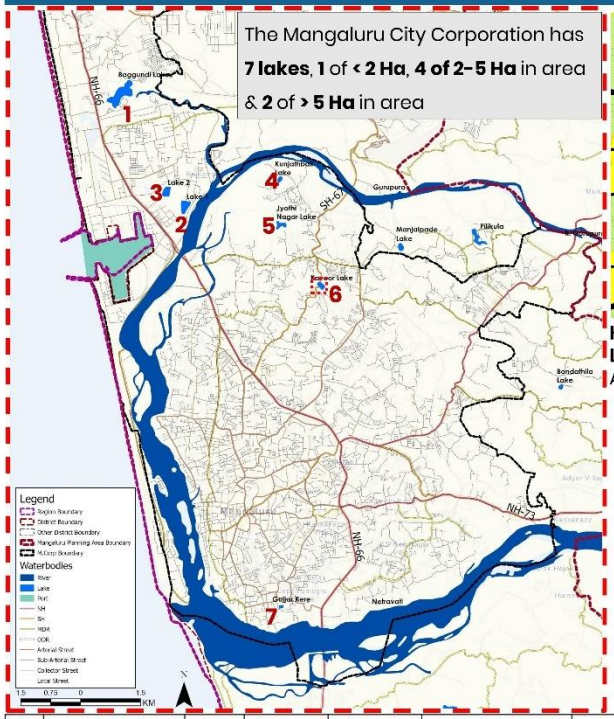
Shoreline Retreat Estimates

- **10.21 m** by 2050
- **24.04 m** by 2100 under RCP 4.5
- **Ward 10, 11 & 60** face shoreline erosion

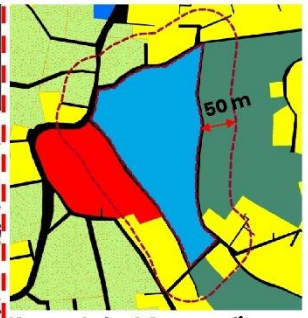
Beach Inundation Risk near New Mangalore Port

- **34.4%** by 2050
- **81.0%** by 2100, signaling significant coastal vulnerability

Waterbodies



The Mangaluru City Corporation has **7 lakes**, **1** of **< 2 Ha**, **4 of 2-5 Ha** in area & **2** of **> 5 Ha** in area



Kavoor Lake & Surrounding Landuse
Agriculture, Residential, Temple

Post-monsoon



Pre-monsoon



The lake dries up in Summer & eutrophication is an issue due to agricultural run-off.

Sl.no	Name	Area (Ha)	Catchment area (Ha)	Shoreline Density Index (L/2√Πa)	Biotic Environment	Use/Activity	Ecosystem Sevices
1	Baggundi Lake	18.66	394.85	1.53	Cat fish **Condition:** Eutrophication	-	Supporting : Habitat Regulating : microclimate
2	Lake 1 (Near MCFL)	5.74	876.61	1.17	Cat fish, Catla	-	Supporting : Habitat Regulating : microclimate
3	Lake 2 (Near MCFL)	4.24		1.11	Eutrophication	-	Regulating : microclimate
4	Kunjathbail Lake	2.03	599.21	1.21	Eutrophication	-	Regulating : microclimate
5	Jyothi Nagar Lake	3.08	515.32	1.43	Encroached - Agricultural Land	-	Regulating : microclimate
6	Kavoor Lake	2.34	456.81	1.35	small minnows, barbs, Cyprinus carpio, Oreochromis mossambicus, and Poecilia reticulata **Condition: Eutrophication**	Irrigation, Temple, Walking track, Recreational	Provisioning : Water for irrigation Supporting : Habitat Regulating : microclimate Cultural : Temple, Recreational
7	Gujjar Kere	0.90	1094.64	1.15	Catla, Labeo	Walking track, Play area, Recreational	Supporting : Habitat Regulating : microclimate Cultural : Recreational

Maximum depth of the **Kavoor Lake** is **50m.**The catchment has majorly **agricultural landuse**



Area = 2.34 ha = 23,400 m²
Average Depth = 25 m
Volume=23,400 m²×25 m =585,000 m³
Estimated Capacity = 0.585 million m³

Watershed Area = 456.81 ha
= 4,568,100 m²
Rainfall = 4.1 m/year
Runoff Coefficient (C) = 0.35
Runoff = Runoff Coefficient (C) x Rainfall (R) × Watershed Area (A) = 0.35m x 4.1 m × 4,568,100 m
Total Run-off = 6.56 million m³

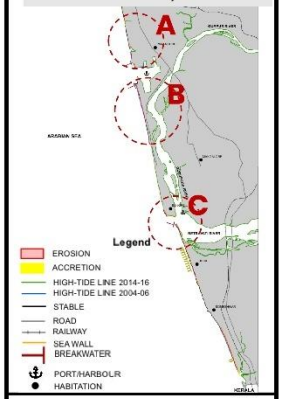
Kavoor Lake holds 8.91% of the catchment's total run-off

KEY MAP



LEGEND / INFERENCE

Shoreline change map – ISRO & Centra Water Commission (IRS LISS4 IMAGES OF 2004-06 & 2014-16)



SCALE : **1: 60,000**

N

SHEET NO: **21**

SHEET TITLE:
Mangaluru M.Corp Environmental Resources

SOURCE:
- *Compiled by Author*

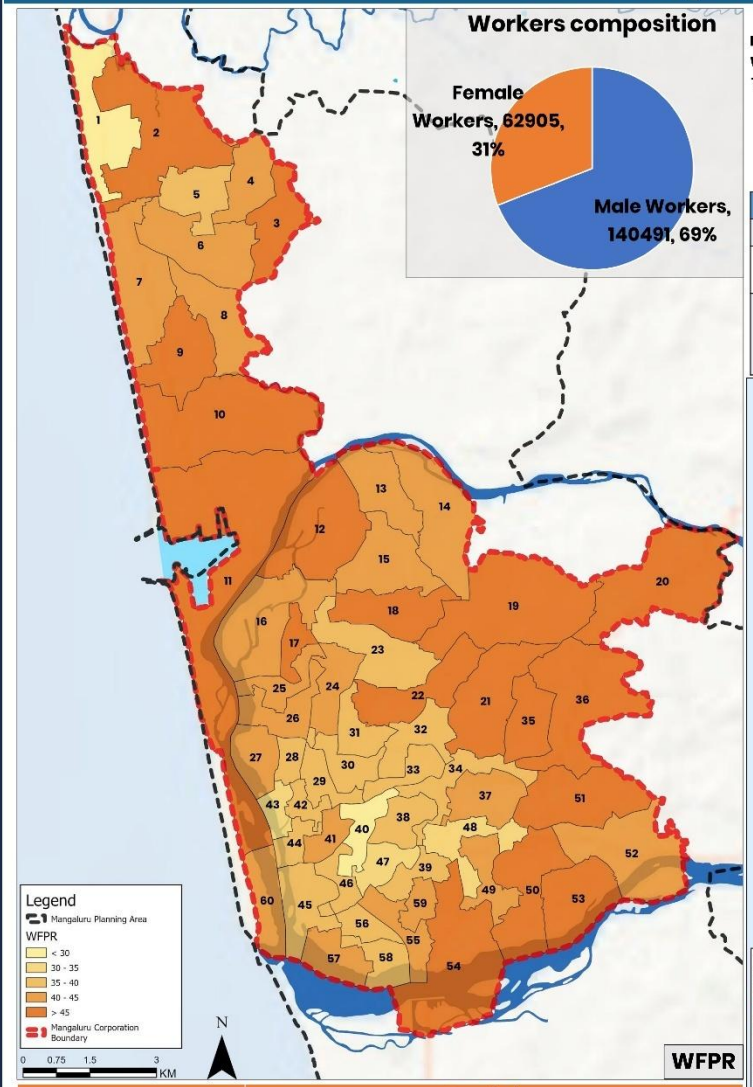
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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Mangaluru Municipal Corporation – Demography

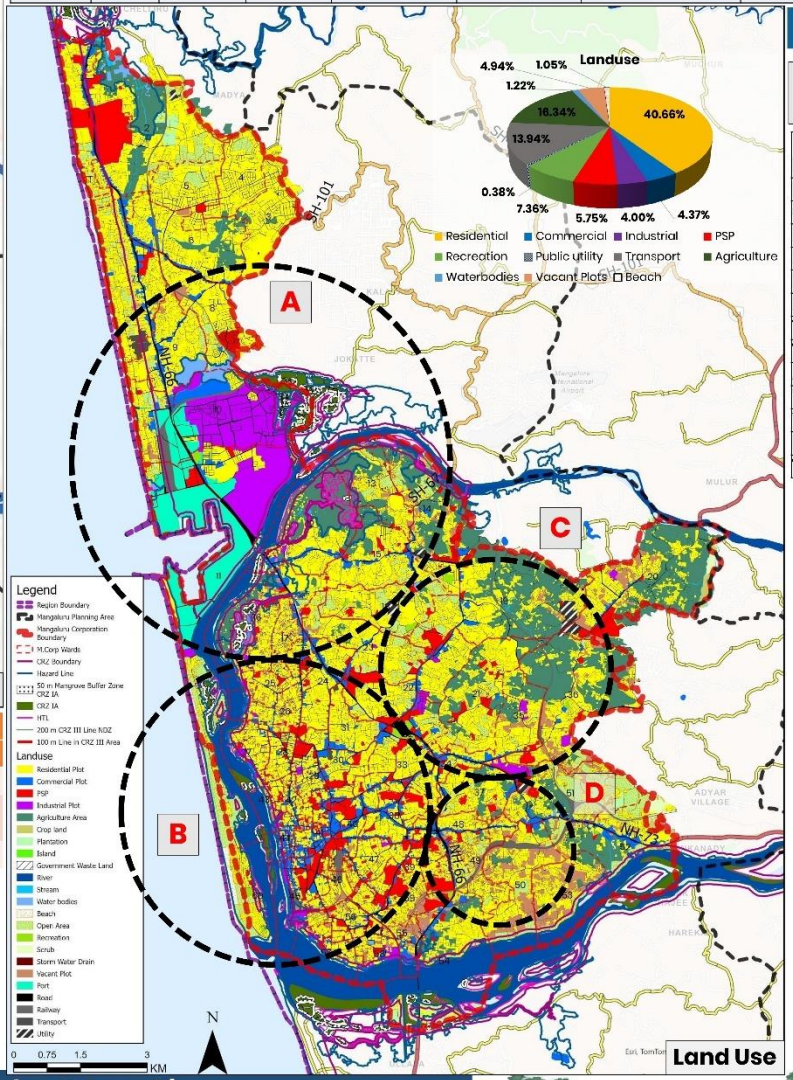




- **WFPR** is **40.7%** lower than state & higher than district averages.
- **93%** of the Workforce are **main workers**
- **93.46%** of the main workers fall in other workers category.
- Occupational pattern in district suggest **50%** of other **main workers** are engaged in **Manufacturing sector** (c).

Mangaluru Municipal Corporation

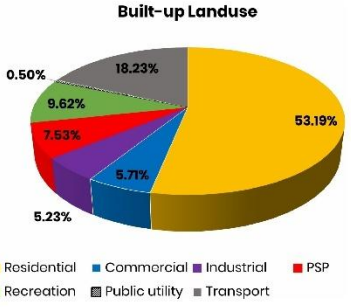
Population				Estimation Methods				Estimated population	
1981	1991	2001	2011	Method	Estimated 2011	Difference form normal	Absolute Error %	Estimate Population 2021	Estimate Population 2025
1,93,699	2,81,161	3,99,565	4,99,487	Geometric	5,01,959	2,472	0.5	6,02,421	6,43,852
				Arithmetic	4,98,844	-643	0.1		
				Incremental	4,84,371	-15,116	3.0		



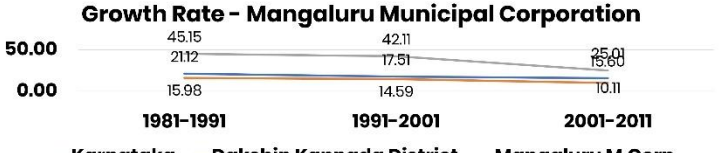
Land Use

M.Corp – 42.13% of the Mangaluru Planning Area

Landuse	Area in Ha	% of built-up
Residential	5,386.06	53.19
Commercial	578.197	5.71
Industrial	529.165	5.23
PSP	762.22	7.53
Recreation	974.482	9.62
Public utility	50.1436	0.50
Transport	1,846.50	18.23
Total Built up	**10126.78**	**100.00**
Agriculture	2,164.00	
Waterbodies	161.916	
Vacant Plots	653.894	
Beach	138.414	
Total Area	**13245**	



Area	Population			
	1981	1991	2001	2011
Karnataka	3,71,35,714	4,49,77,000	5,28,50,562	6,10,95,297
Dakshin Kannada District	14,28,028	16,56,165	18,97,730	20,89,649
Mangaluru M.Corp	193699	281161	399565	499487



KEY MAP



LEGEND / INFERENCE

Area of Mangaluru Municipal Corporation = 132.45 Sq.km

- **Wards with high population (> 10,000):** 9, 17, 18, 23, 22
- **Wards with population density > 60 PPH :** Low-lying core area up to **20 m** ASL have high density Sex Ratio: **1025,** higher than state & lower than district.
- Literacy Rate: **93.84% ,** higher than both state & district
- **SC & ST** Population lower than state & district average
- Male Work force: **69%**

SCALE : **1: 1,25,000**

N

SHEET NO: **22**

SHEET TITLE: **Demography & Land Use**

SOURCE:
- *Compiled by Author*

NAME
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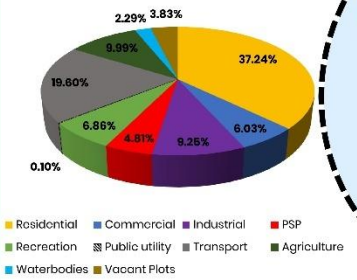
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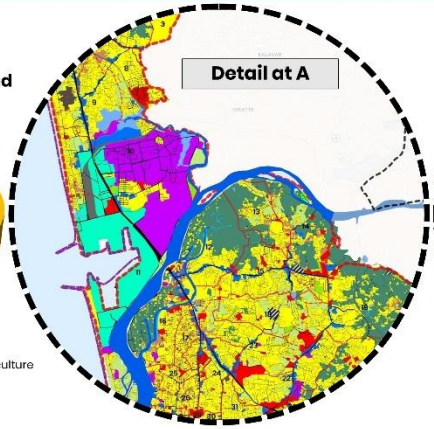
SCHOOL OF PLANNING AND ARCHITECTURE, NEW DELHI

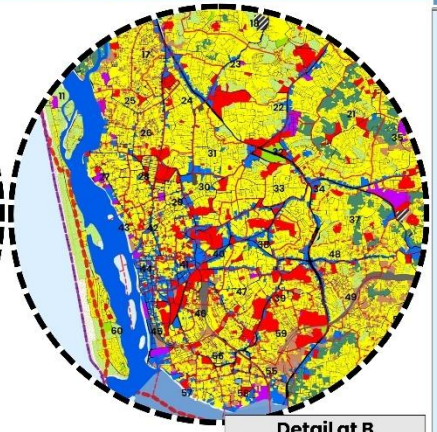
Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Land Use & Water Quality

Landuse of micro-watersheds within 2 km buffer of Urban Gurupura – Core Area

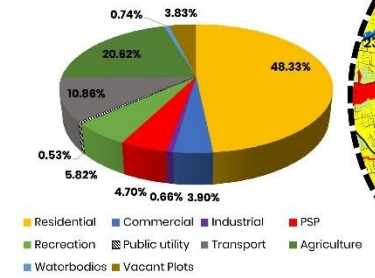


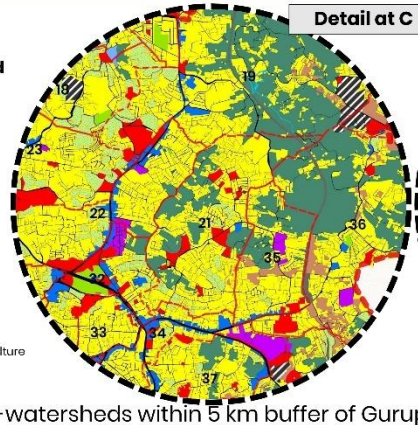


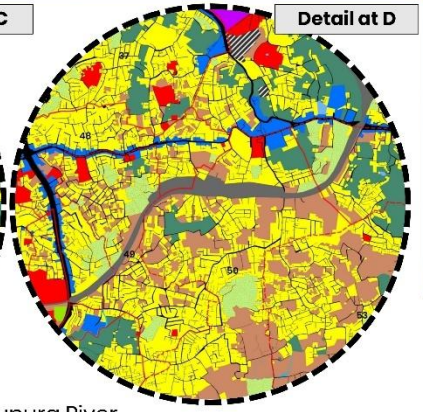


- There are **29 wards** in the micro-watersheds within 2 km buffer of Gurupura River.
- **37.24 %** of the land area is under residential use, followed by **19.6%** under **Transport** sector which includes **ports** along with the **Road & Railway network.**
- **Agricultural use** occupies **10%** of the land area, concentrated on the southern banks of the Gurupura
- **9.25 %** of the land area is under **Industrial use**, this includes the Baikampady Industrial area on the northern banks of Gurupura, identified as critically polluted industrial area with a CEPI score of **73.68** as of 2018. **Commercial and PSP** use concentrated along the lower stretches of the river.
- Drains joining the river from these areas carry **industrial effluents, agricultural run-off and domestic waste water** into the Gurupura river.

Landuse of micro-watersheds within 5 km buffer of Urban Gurupura – Transition Area

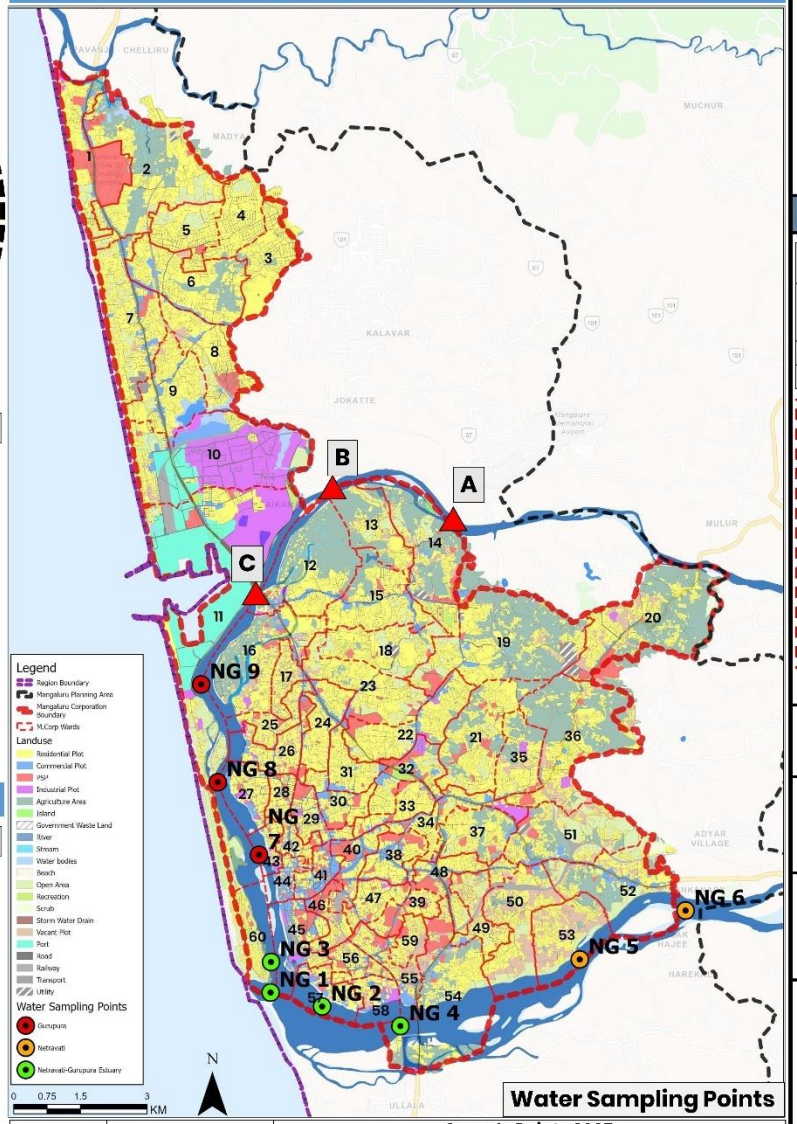






- There are **24 wards** in micro-watersheds within 5 km buffer of Gurupura River.
- This transition zone includes **48.33%** of land under Residential use, followed by **20.62%** area under Agricultural use.
- The **MCC solid waste management plant** occupies **0.53%** of the land area.
- The run-off from this zone includes domestic wate water, and agricultural field-run off.

Water Sampling Points



Parameter	Standard	Sample Points 2025 A	B	C
BOD	≤ 2.0 mg/L (Class A) ≤ 3.0 mg/L (Class B/C)	3.5	5	6.5
DO	≥ 6.0 mg/L (Class A) ≥ 5.0 mg/L (Class B/C)	6.5	5.5	4.8
COD	< 20–30 mg/L (BIS)	23	42	55
		Nutrient runoff present, but still fairly healthy ecosystem	Mixed impacts; moderate pollution and some oxygen depletion	High organic and chemical pollution; oxygen stress on aquatic life
Designated Best Use (DBU)		D	D	D

KEY MAP



LEGEND / INFERENCE

Sample Point	DO	BOD	PO_4	DBU Class
NG 7				Class D (fisheries only)
NG 8				Class D
NG 9				Class D/E

Probable sources of pollution for Gurupura River

- Waste water form Domestic, Commercial & Public-semi public Landuse
- Industries
- Agricultural run-off
- Untreated sewerage from STP's
- Slums

SCALE : **1: 60,000**

N

SHEET NO: **23**

SHEET TITLE: **Land use & Water Quality**

SOURCE:

- *Revised Master Plan for Mangaluru Planning Area 2021*
- *Sample tester by Author*
- *2022 Water quality of Gurupura river – Research Paper*

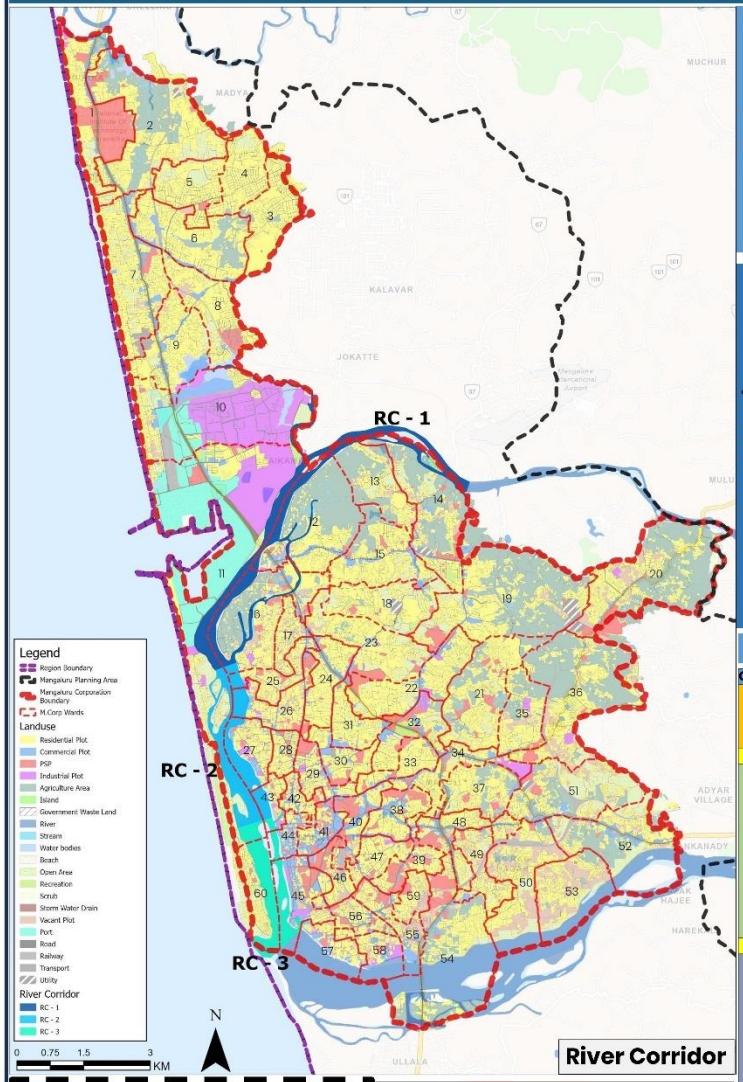
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Economic Activities



Port

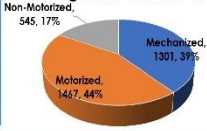


Basic Areas and Facilities

- Berths for handling cargos
- Storage facilities: open storage yards, covered warehouses, & liquid storage tanks
- Cargo handling equipment: cranes, conveyor systems, & mobile harbor cranes
- Navigational channel & turning circle for large vessels
- Breakwaters to protect the harbor from rough sea conditions
- Port railway & internal roads
- **18 Berths** with total cap. of **737 MMT**
- **Major imports:** Crude oil & POL products, Coal, Fertilizers & LPD
- **Major exports:** Iron ore fines, Coffee, Cashews, Spices, Granite & Mineral products

Fishing

Gurupura & Netravati Estuary species: Catfish, Sillago, Platycephalus, Indian Mackerel, Salmon, Sardines, Mullets, Flounder, Bass, Barbels, Eels, & Shads.



- **83%** of the boats used in marine fisheries operate on **diesel**.
- **Primary concern: Diesel leaks**

Impact Matrix

Affected Aspect		Total Score	Economic Activities											
			Agriculture		Fishing		Industry		Port		Built-up		Tourism	
Category	Components affected		Avg	Observation	Avg	Observation	Avg	Observation	Avg	Observation	Avg	Observation	Avg	Observation
Physical Environment	Air	11.0	1.7	Ground water-based irrigation is impacting DTWL, fertilizers affecting river quality	1.8	Mechanized operations & waste handling is polluting the water & generating noise	2.5	Air & Water pollution is significant. CEPI Area with73.68 score in 2018	1.8	Port operations & expansion has led to altered coastal landform though dredging & reclamation	1.5	untreated sewage inflow, solid waste dumping, and altered stormwater pathways, degrading the Gurupura's water	1.75	Waste generation, land use changes, increased vehicular emissions, and strain on local air, water, and soil quality.
	Costal waterbody & Estuarian	13.2	1.7		2.8		2.7		1.6		2.25		2.25	
	Inland Rivers	14.4	2.0		2		2.5		1.4		2		2.5	
	Inland waterbodies	10.1	2.0		1.4		1.5		1.2		2.5		1.5	
	Ground water	11.3	2.3		1.2		2.2		1.8		2		1.75	
	Land & Soil	12.4	2.3		1.8		1.8		2.2		1.75		2.5	
	Micro-climate	9.0	1.7		1.2		1.5		1.4		1.5		1.75	
Biological	Terrestrial Flora	12.0	2.3	Intensive agriculture reduces biodiversity & harms terrestrial & aquatic species & alters habitat die to chemical run-off	1.4	Mechanized trawling, pollution is degrading the habitat, reduced fish population is an issue	1.8	Chemical & effluent discharge impacts aquatic flora & fauna. Reduced mangrove area & fish deaths.	2.4	Dredging, spillage during handling & shoreline modification has impacted the biodiversity	1.75	Encroachment & pollution from built-up areas reduce mangroves, disturb aquatic life, and fragment riparian habitats.	2.25	Habitat disturbance from construction and tourist footfall stresses local flora and fauna, especially in sensitive riverine and coastal zones.
	Terrestrial Fauna	11.7	2.3		1.4		1.8		2.4		1.75		2	
	Aquatic Flora	12.8	1.7		1.8		2.0		2.6		2.25		2.5	
	Aquatic Fauna	13.0	1.7		2		2.0		2.6		2.25		2.5	
Socio-cultural	Livelihood	9.4	1.0	No significant impact noticed	1.8	No significant impact noticed	2.2	No significant impact noticed	2.4	Exposes workers to health hazards	1	No significant impact observed	1	Boosts local income and cultural visibility but can commercialize traditions and strain infrastructure.
	Health	8.3	1.3		1		1		1.4		1.25		1.25	
	Culture	8.9	1.0		1.8		1.7		2.2		1		1.25	
Average			25.0		24.6		29.0		29.4		25.8		28.8	

GIDC Sustainability Standards Assessment

Quality criteria	Sub-criteria	Weighted value
Economic Quality	Investment & Revenue	8.8
	Employment	12.5
	Competitiveness	13
	Investment Safety & branding	14
	Sub-Total	**48.3**
Environmetal Quality	Cleaner production & resource efficiency in individual	0.4
	Water preservation measures	2.1
	Storm water management	0
	Waste water management	2.3
	Waste management	4
	Emissions & air pollution	1.8
	Resource efficiency	1
	Climate change mitigation and adaptation	1.5
	Biodiversity preservation	4
	Disaster risks management/ preparedness	2
	Sub-Total	**19.1**
Infrastructure Quality	Location suitability	5
	Site master plan	7
	Logistic support provision	6
	Art and architecture	3
	Building design	2
	Mobility infrastructure	21
	Environment friendly transport	0
	Power and Energy Systems	2.1
	Plantation & landscaping	3
	Common infrastructure	5
	Sub-Total	**54.1**
Social Quality	Social management systems	11.9
	Social infrastructure	15
	Gender equity	6.3
	Local community well-being and community outreach	11.9
	Sub-Total	**45.1**
Management Quality	Administrative & management infrastructure	14.4
	Application of standards	0
	Quality assurance & monitoring	0
	Environmental stewardship	5
	Sub-Total	**19.4**
	Grand Total	**37.2**

Quality Criteria	Value	Sub-criterial	Weightage	Indicators	Weightage (A)	Value (0 to 100 out of 100) (B)	Weighted Value (A*B/100)	Weighted Value
Environmental Quality	100	Cleaner production and resource efficiency in individual	10	Cleaner production processes	20	0	0	0.4
				Waste/waste water recycling by industries	20	20	4	
				Industrial symbiosis and synergies	20	0	0	
				Circular economy by industries	20	0	0	
				Sustainable procurement by industries	20	0	0	
		Water preservation measures in the	10	Sustainable water supply	40	30	12	2.1
				Limited ground water extraction	30	10	3	
				Water preservation	30	20	6	
		Storm water Management	10	Storm water management system	100	0	0	0.0
		Wastewater management	10	Sewerage network	10	0	0	2.3
				Conveyance systems	10	0	0	
				Sewage treatment	15	20	3	
				Waste water treatment	15	30	4.5	
				Safe disposal	10	30	3	
				Treated wastewater recycling/reuse	10	25	2.5	
				Non-potable water	10	30	3	
				Skilled personnel	10	40	4	
				Waste water monitoring systems	10	30	3	
		Waste management	10	Hazardoud waste management	25	40	10	4.0
				Industrial solid waste management	25	40	10	
				Municipal/domestic solid waste management	25	80	20	
				Minimised use of non recyclable goods/materials	25	0	0	
		Emissions and air pollution control	10	Air pollution control systems	70	0	0	1.8
				Air pollution monitoring systems	30	60	18	
		Resource efficiency	10	Energy efficiency	50	0	0	1.0
				Resource saving infrastructure	50	20	10	
		Climate change mitigation and	10	Minimisation of GHGs	50	0	0	1.5
				CCA adaptation measures	50	30	15	
		Biodiversity preservation	10	Biodiversity preservation	100	40	40	4.0
		Disaster risks management/	10	Natural disasters	50	0	0	2.0
				Industrial disasters	50	40	20	
Sub-total			100	Sub-total				19.1

GIDC Sustainability Standards:

- Assesses the quality criteria for Economic Environmental, Infrastructure, Social, & Management aspects.
- Baikampady Industrial Area scores the least for **environmental quality** due to lack of cleaner production, storm water & waste water management & resource efficiency
- Total sustainability score is **37.2** (<55 -> needs improvement)



Category	Red	Orange	Green	Total
Small	7	78	137	**222**
Medium	1	4	4	**9**
Large	14	10	3	**27**
Total	**22**	**92**	**144**	**258**

- MSEZ includes Baikampady & MRPL outside the M.Corp limits)
- As of CEPI 2019 Report, 258 industries are present
- CEPI Score is 73.68 (2018)
- **22 Red category industries**, & **4 of 17 category industries** which include:
  - MRPL
  - BASF
  - Mangalore Chemicals & Fertilizers
  - Solara active pharma science ltd.

Landuse
Water Quality
Economic Activities

- **RC – 1 - High Impact Stretch:** Covers the agricultural & industrial belt -> Class D (DBU) indicating high pollution & limited use.
- **RC – 2 - Moderate Impact Stretch :** Passes through residential areas -> Class D
- **RC – 3 - Low Impact Stretch:** Located near the estuary, surrounded by commercial, residential, & PSP land use, with water quality is in desirable limits, suggesting lower cumulative impact.

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



KEY MAP



LEGEND / INFERENCE

Impact Matrix:

- **The Inland river (Gurupura), Coastal waterbodies & Estuary** are most impacted components, followed by aquatic flora & fauna.
- **Reason:** Industrial pollution, agricultural run-off and use of mechanized boats for fishing

GIIDC Sustainability Score

Score Range	Rating
85 – 100	Platinum
70 – 84.99	Silver
55 – 69.99	Bronze
< 55	Needs Improvement

SCALE : **1: 60,000**

N

SHEET NO: **24**

SHEET TITLE: **Land use & Development Plan Analysis**

SOURCE:

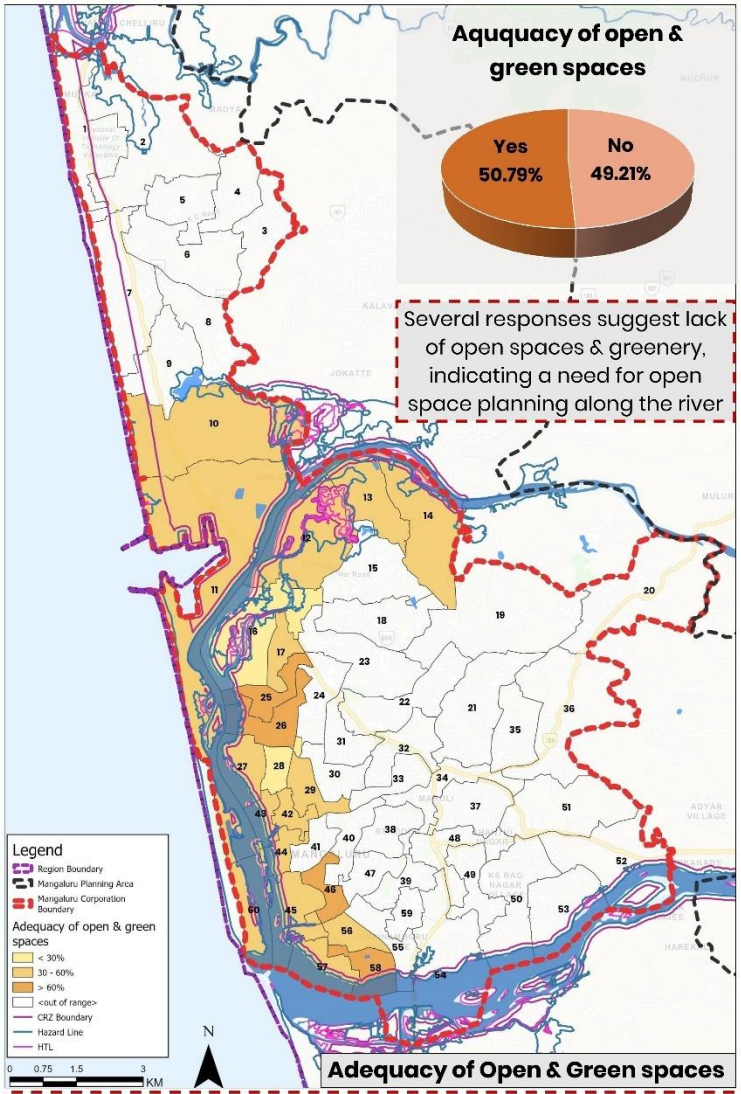
- *SUSTAINABILITY STANDARDS for Planning and Retrofitting of Industrial Estates in Gujarat – GIDC*
- *Fisheries department*

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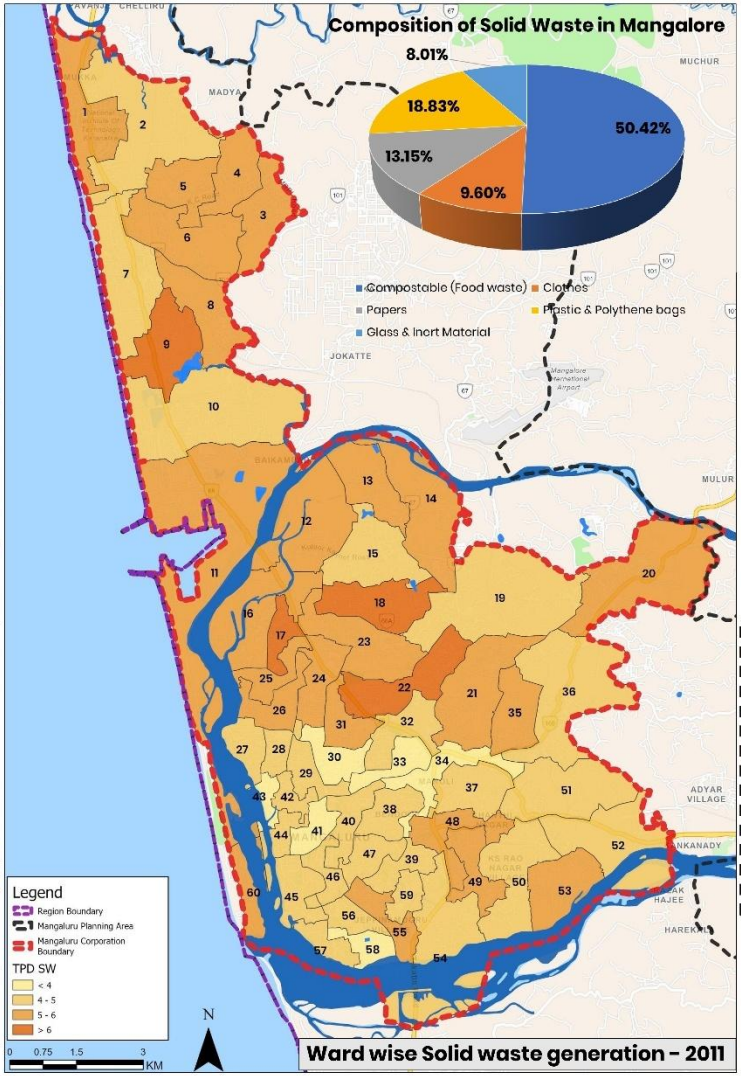
Primary Survey



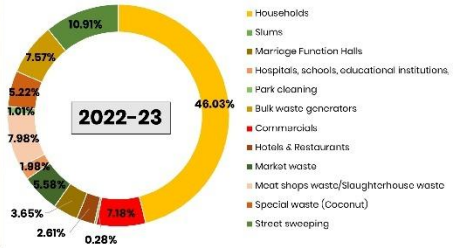
Adequacy of Open & Green spaces

- **Water Supply:** Mix of tap and bore water, tap more common in core areas.
- Daily or alternate day supply for **1–4 hours**. Tanker supply used in summer.
- **Sanitation:** Septic tanks common in the core wards; sewer network coverage is partial.
- **Waste Management :** Door-to-door collection is dominant; daily in most wards.
- **Drainage & Flooding:** Water logging occurs but usually clears within a day. **Solid waste in drains is reported**; maintenance is irregular.
- **Open Spaces :** Lack of parks and greenery noted in several wards.

Housing & Solid Waste

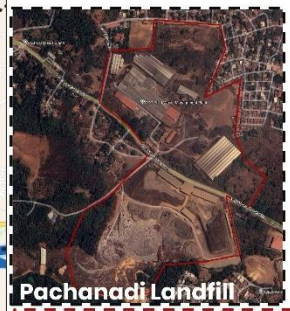


Ward wise Solid waste generation - 2011



46.03% of the city's waste is generated by **Households**, followed by 10.91% from slums, 7.98% from meat shops, 7.18% from commercial shops

- Current per capita waste generation is **608 grams/day**
- **Primary Collection**: Door-to-door using Jeep tippers
- **Secondary Collection :**Via compact trucks, tippers, & compactors
- **Frequency:** Wet waste: Daily, Dry waste: Once in 3 days



- Site area: **77.93 acres** (2009)

Facilities:

- Vermicompost pits
- Windrow composting
- Sanitary landfill
- Leachate collection & treatment

- Poor waste segregation at source.
- Inefficient collection and manual handling.
- Sanitary landfill issues: leachate during monsoon, legacy waste.
- No facility for C&D waste management.

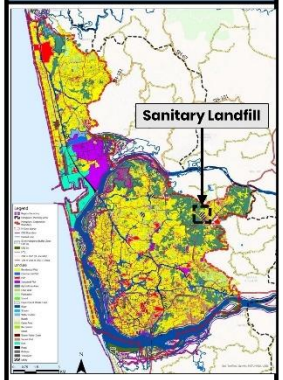
Housing

- **Predominantly Planned Housing:** 55.89% -> indicating a formal urban development trend.
- **Significant Organic and Unplanned Areas:** A combined 44.11% of housing is organic **(34.43%)** and unplanned **(9.68%),** suggesting mixed development patterns.
- **Slums Concentrated Along River and Coast:** Slums are mainly located along the Gurupura River and coastal areas, indicating exposure to environmental risks.
- Wards on the western banks of the Gurupura river have more than **2% House holds** living **in temporary housing**, while the wards along the eastern banks of the Gurupura river have **> 15% households** living in **semi-permanent housing.**

KEY MAP



LEGEND / INFERENCE



SCALE :
1: 60,000

N

SHEET NO:
25

SHEET TITLE:
Primary Survey, Housing & Solid Waste

SOURCE:

- *Primary Survey*
- *Census of India, 2011*
- *Mangaluru Municipal Corporation*

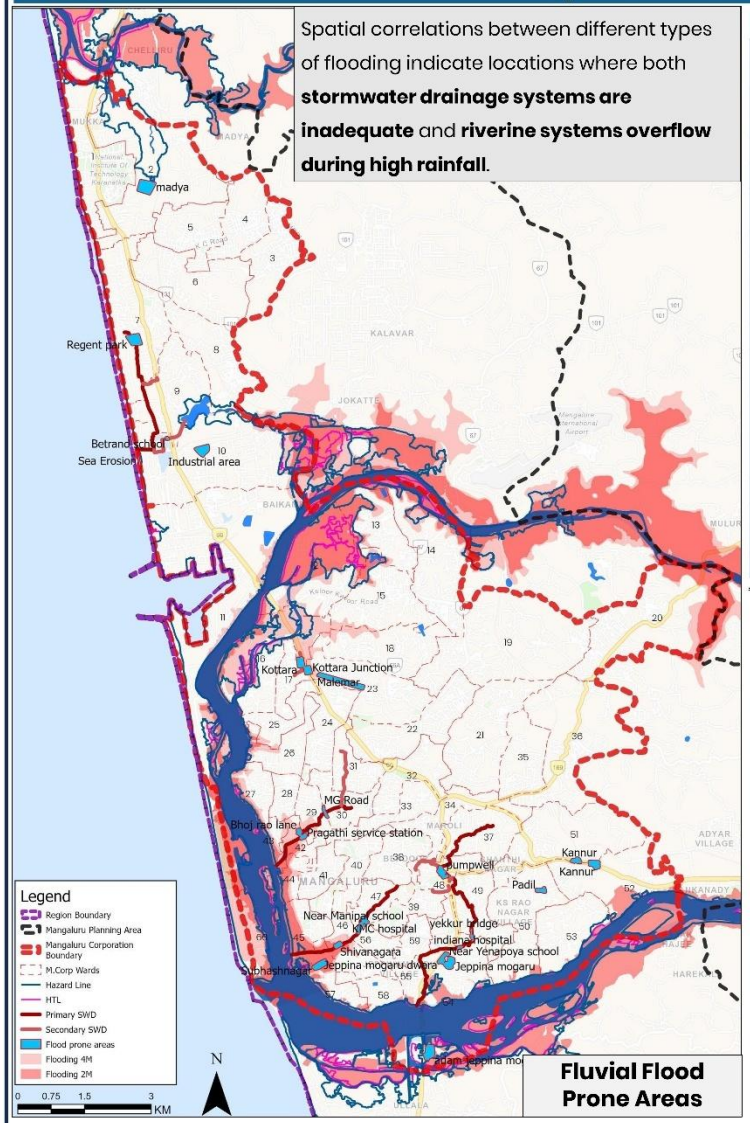
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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Physical Infrastructure – Water Supply, Sewerage, Storm water



Fluvial Flood Prone Areas

Water Supply

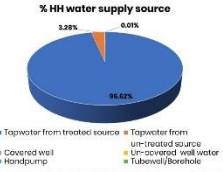
	2023	2025	Remark
Population	623136	643852	
Demand			
Domestic (135 LPCD)	84.12	86.92	As per CPHEEO Standard
Non-Domestic	27.78	29.25	Source: MCC (Commercial & Tourism)
Fire demand	2.39	2.60	Source: MCC
Bulk Demand	20.30	20.30	Includes NITK Surathkal, KIADB, Industrial & NMPA
Total demand	**134.59**	**139.07**	
20 % Loss	**26.92**	**27.81**	Non-Revenue water (NRW)
Total demand + 20% Loss	**161.51**	**166.88**	
Source			**Thumbe Dam (MLD)**
Mangaluru WSS 1st Stage, 1965	10	10	Replaced with new 20MLD WTP under AMRUT (10 MLD to Villages)
Mangaluru WSS 2nd Stage, 1971	81.7	81.7	Discontinued
Mangaluru WSS 3rd Stage, 2012	80	80	
			Adyar Dam (MLD)
Proposed 24/7 WSS			Designed to supply water upto 2046
Total Water Supply	**171.7**	**171.7**	
Gap	**+ 10.19**	**+ 4.82**	Water surplus

WSS – Water Supply Scheme

Water Supply : Thumbe Dam built across Netravati River (22 km away).
The city receives water for **12 hours per day** (Gap 12 hrs).
3 water supply Zones

1. **Panamboor** –Industrial Area, NITK Suratkal, NMPA, 12 wards in the northern part of the city.
2. **Padil** –26 wards in the Eastern parts of the city
3. **Bendoor** –Includes 22 Wards

Sl No	MBR	Pump House	GLSR	OHT
1	Padil	5	6	17
2	Bendoor	4	3	11
3	Panambur	3	1	14
Total		**12**	**10**	**42**



- **97%** Households have access to tap-water from treated source
- The city has water surplus & no shortage is observed
- **Ground water** allotted for **domestic use** is **7 MLD**
- **KIADB Industrial area** has permissions to directly draw **57 MLD** water from Gurupura & Netravati River & additional **38 MLD** treated waste water from STPs in the city

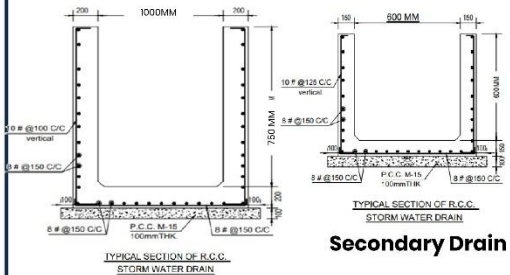
Sewerage

	2025
Population	643852
Total demand + 20% Loss	**166.88**
Waste water generated	133.51
STP	**Existing Capacity (MLD)**
Surathkal STP	16.5
Kavoor	43.5
Pachanady	8.75
Bajal	20
Total	**88.75**
Gap	**-44.76**

- Area Covered under Sewerage network: **~184.85 sq. km, 360 km** of sewer lines laid
- **No Sewerage System in Wards**: 10 (Baikampady), 11, 12, 13, 60 (Bengre)
- Major problems: Choked lines, overflowing manholes, structural failures, final discharge not compliant to CPCB Standards and polluting the Gurupura River.
- 2 of STP's (Pachanady & Bajal) discharge quality does not subscribe to CPCB standards

Storm Water

Type of Drain	Width (m)	Depth (m)	Total Length (KM)	Shape	Material	Remarks
Main SWD	1.0	0.75	12	Rectangular	Concrete	Carries runoff from large catchments to rivers or sea (e.g., near Bunder, Kulur)
Secondary SWD	0.6	0.6	3.8	Rectangular	Concrete	Collects runoff from wards or sub-catchments



Primary Drain | **Secondary Drain**

Design Capacity

- Main Storm water drain : **50mm/hr**
- Secondary drains designed : **30 mm/hr**

Maximum rainfall intensity received is **40mm/hr**
Total Run-off in Mangaluru City limits = **485.179 M.m³**

Parameter	Primary Drain	Secondary Drain
Discharge Q (m³/s)	0.82	0.30
Annual run-off (L x Q x 60 x 60 x 24 x 365) Million Metric Cube	**309**	**36**
% of total run-off	**63.77**	**7.40**

SWD Flooding Locations – Malemar (W-17) , Kotekara (W-23), Kannur (W – 51 & 52), MG Road (W – 29 & 30), Jeppina Mogaru (W – 54), Near KMC Hospital (W – 46 & 59), Padil (W-50)



- Issues: Solid waste dumping in SWD -> Pluvial flooding.
- In 2022, **3.5 tons** of plastic waste was collected through clean up of SWD & River banks in the city.
- Heavy rainfall -> Flooding
- The peripheral wards has **> 40%** house holds that are not connected to the drains, indicating run-off from roof tops and courtyards are not directed into the SWDs.

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE

- To estimate the stormwater flow velocity, assess the drain capacity & demonstrate the pluvial fludding Manning's equation is used.
- **Manning's Equation:** $Q = 1/n \times A \times R^{2/3} \times S^{1/2}$
- Q = Discarge (Flow velocity) , n = co-efficient, A = Area, P = Wetted perimeter, R = Hydaulic radius, S = Slope

SCALE : **1: 60,000**

N

SHEET NO: **26**

SHEET TITLE: **Physical Infrastructure**

SOURCE:

- *Census of India, 2011*
- *Mangaluru Municipal Corporation*

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Water Stress & Balance

Apect	Indicator	1 (Good)	2 (Moderate)	3 (Poor)
Water quality	Average BOD Levels (mg/l)	1-2 mg/L	3-5 mg/L	>5 mg/L
	Average Turbidity Levels (NTU)	0-5 NTU	6-15 NTU	>15 NTU
	% Wards in STP Command Area	>80%	50-80%	<50%
	% Industries with ETP	>80%	50-80%	<50%
Environmnetal Flow	E-Flow Gurupura (m^3/s)	> 40% of average lean season flow	20 - 30% average lean season flow	< 20% of average lean season flow
	E-Flow Netravati (m^3/s)	> 40% of average lean season flow	20 - 30% average lean season flow	< 20% of average lean season flow
Volumetric Availability	Total Renewable Water Available (Surface+Ground)	>150 LPCD	135 - 150 LPCD	<135 LPCD
	Annual Water Demand	135 - 150 LPCD	150 - 200 LPCD	> 200 LPCD
	Water Stress Index (Demand/Availability)	<0.4	0.4-0.8	>0.8
Accessibility	% HH with access to treated tap water	>90%	70-90%	<70%
	Hours of water supply per day (hours)	>20 hours	12-20 hours	<12 hours
	% of water supplied through Water tankers	<5%	5-15%	>15%
	% Use of recycled / reused water in Industry	<80%	50-80%	<50%

Domestic Sector – Water Stress

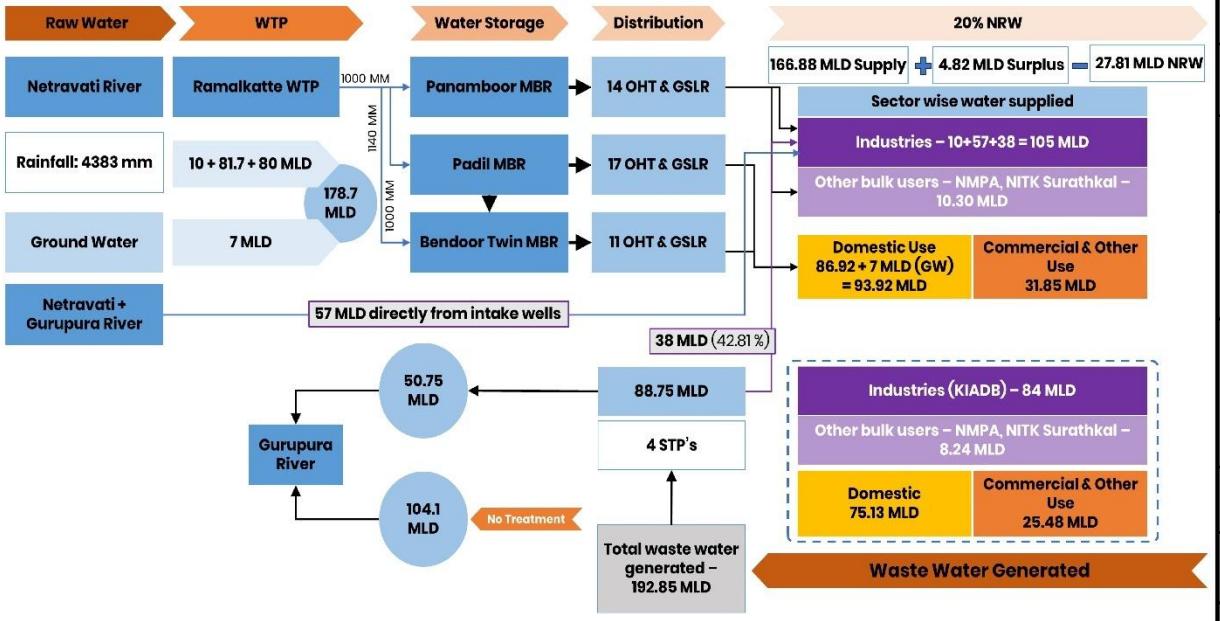
Aspect	Indicator	Absolute value	Score	Normalized	Average	Remark
Water quality	Average BOD Levels (mg/l)	3.66	2	0.50	0.5	
	Average Turbidity Levels (NTU)	70.10	3	1.00		
	% Industries with ETP	93.33	1	0.00		
Environmnetal Flow	E-Flow Gurupura	351.30	2	0.50	0.5	
	E-Flow Netravati	368.42	2	0.50		
Volumetric Availability	Total Renewable Water Available (Surface+Ground) (MLD)	93.92	2	0.50	0.50	145.87 LPCD
	Annual Water Demand (MLD)	86.92	1	0.00		135 LPCD
	Water Stress Index (Demand/Availability)	**0.93**	3	1.00		
Accessibility	% HH with access to treated tap water	96.62	1	0.00	0.17	
	Hours of water supply per day (hours)	12	2	0.50		
	% of water supplied through Water tankers (1.4 MLD)	1.61	1	0.00		

Industry Sector – Water Stress

Aspect	Indicator	Absolute value	Score	Normalized	Average
Water quality	Average BOD Levels (mg/l)	3.66	2	0.50	0.67
	Average Turbidity Levels (NTU)	70.1	3	1.00	
	% Industries with ETP	> 50% & < 80%	2	0.50	
Environmnetal Flow	E-Flow Gurupura	351.3	2	0.50	0.5
	E-Flow Netravati	368.418	2	0.50	
Volumetric Availability	Total Renewable Water Available (Surface+Ground)(MLD)	105	1	0.00	0.67
	Annual Water Demand (MLD)	20.3	3	1.00	
	Water Stress Index (Demand/Availability)	0.19	3	1.00	
Accessibility	Hours of water supply per day (hours)	12	2	0.50	0.75
	% Use of recycled / reused water in Industry	19.70%	3	1.00	

- The average of the normalized average of each of the four aspects of water stress in domestic & Industrial sector is 0.42 & 0.65 respectively, indicating Moderate water stress in the city of Mangaluru City.
- Despite moderate water stress, Water stress index in residential sector is 0.93, & values closer to 1 indicated water scarcity.

Water Balance

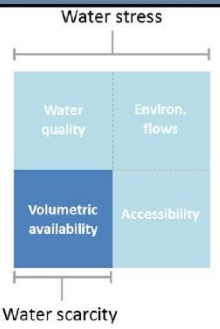


- The industrial supply reuses 38 MLD treated water from the STP in the city
- **46%** of waste water generated is treated while the remaining **54%** is discharged in the river

KEY MAP



LEGEND / INFERENCE



Average Value	Water Stress
0 – 0.33	Low
0.33 – 0.66	**Moderate**
0.66 – 1.00	High

SCALE :

N

SHEET NO: **27**

SHEET TITLE: **Water Stress & Water Balance**

SOURCE:

- *Driving Harmonization of Water Stress, Scarcity, and Risk Terminology – The CEO Water Mandate*
- *Mangaluru Municipal Corporation*
- *Author*

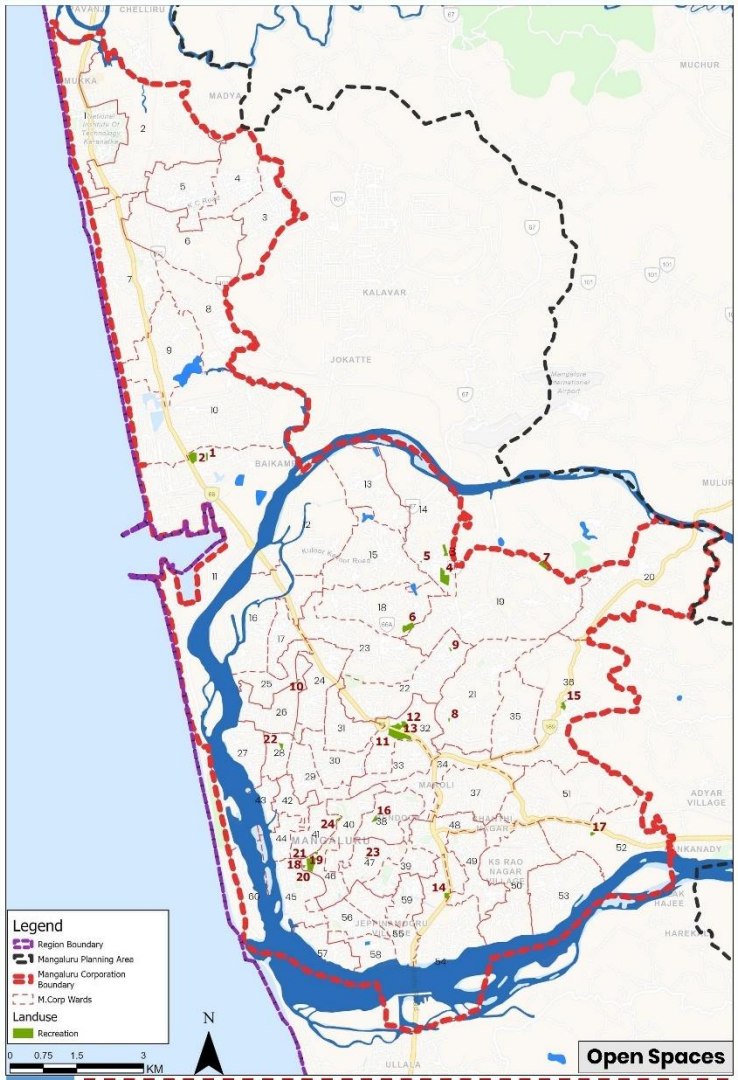
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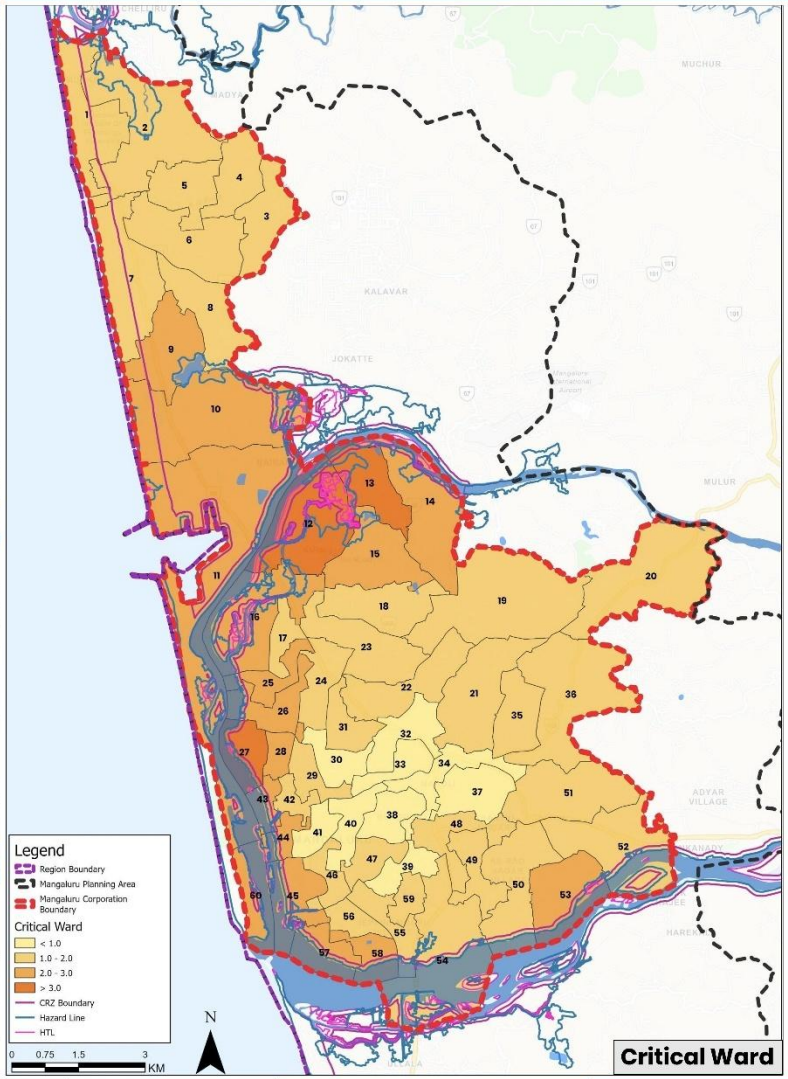
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Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

Social Infrastructure



Identification of Critical Wards



- Indicators for **Physical infrastructure, Flood risk, Coastal hazard, water stress & Land use** are considered for identification of critical wards – Absolute values are normalized for each of the 5 parameters and added for the final score
- **Ward 11, 12, 13 and 27** are identified as critical wards.
- **Ward 13 and 27** score the highest, and hence chosen for further study

Education & Health care

Mangalore has adequate higher education & tertiary healthcare facilities, with minor gaps in colleges & nursing home facility, indicating a well-developed urban social infrastructure.

Open Spaces: Norms for Organised Green for Plain Areas - URDPFI Guidelines

Category	Population Served per unit area	Area Requirement (Ha)	Number of Open Spaces	Existing Area (Ha)	Required Area (Ha)	Gap
Housing Area Park	5000	0.5	6	4.42	64.39	59.97
Neighbourhood Park	15,000	1	9	21.57	42.92	21.35
Community Park	1,00,000	5	2	12.39	79.77	67.38
District Park	5,00,000	25	0	0	32.19	32.19
Sub-City Park	10,00,000	100	0	0	NA	NA

- Estimated 2025 population = **6,43,852**
- URDPFI Guidelines: **10–12 m² / person**.
- Existing : **17,83,940 m²** (including beach)
- Per capita open space = **2.77 m²**
- Gap: **8.23 m²**

Ward No	Physical Infrastructure			Flood Risk				Coastal Hazard			Water Stress	Land Use			Total
	Solid waste	Storm water drainage	Avg	Pluvial Flooding	Fluvial Flooding	Coastal Flooding	Avg	Sea level rise	Coastal Erosion	Avg	Primary Survey (Use of tanker supply)	Water intensive activities	Water quality	Avg	
1	0.76	1.00	0.88	0.00	0.00	1.00	0.33	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.30
7	0.63	1.00	0.82	0.00	0.00	0.50	0.17	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.07
9	0.89	1.00	0.94	0.00	0.50	0.50	0.33	1.00	0.67	0.83	0.00	0.50	0.00	0.25	2.36
10	0.16	1.00	0.58	0.00	0.00	0.50	0.17	0.50	1.00	0.75	0.23	1.00	1.00	1.00	2.73
11	0.00	1.00	0.50	0.00	0.00	0.50	0.17	1.00	1.00	1.00	0.25	1.00	1.00	1.00	2.91
12	0.68	0.50	0.59	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.56	1.00	1.00	1.00	2.82
13	0.69	1.00	0.84	0.00	1.00	0.50	0.50	0.00	0.00	0.00	0.56	1.00	1.00	1.00	2.91
16	0.66	0.50	0.58	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.56	1.00	0.00	0.50	2.31
17	0.86	0.00	0.43	1.00	0.50	0.50	0.67	0.00	0.00	0.00	0.71	0.50	0.00	0.25	2.06
27	0.54	1.00	0.77	0.00	1.00	1.00	0.67	0.00	0.00	0.00	0.85	0.50	1.00	0.75	3.04

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



KEY MAP



LEGEND / INFERENCE

SCALE : **1: 60,000**

N

SHEET NO: **28**

SHEET TITLE: **Social Infrastructure & Critical Ward Identification**

SOURCE:
- *URDPFI*
- *Author*

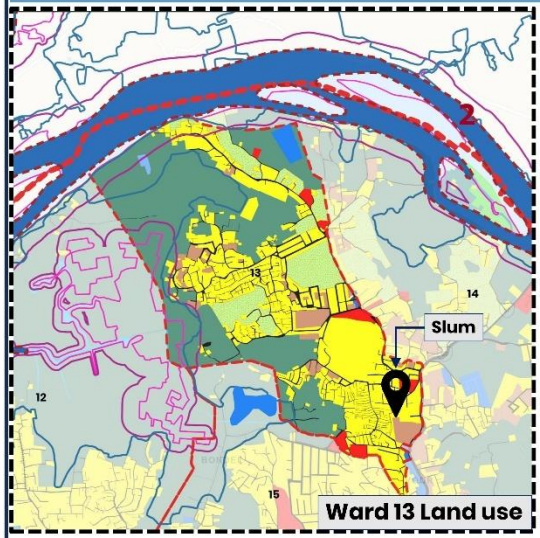
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Critical Ward Analysis

Ward 13

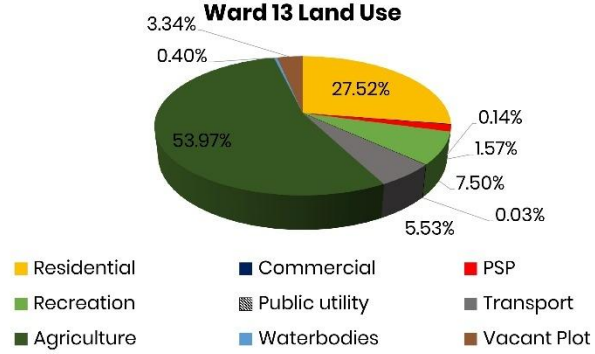


Area – 2.46 Sq.km
Average Elevation: 35 M
Soil type - Sandy Clay Loam
Population – 8615 (Census 2011)
Population density – 35.16
Number of Households – 1988
WFPR – 44%
Agricultural workers = 18

Economic activity: Largely Agricultural, irrigation via Ground water

Socio-economic aspect:
Jyoti Nagar Slum: current population > **5000.**

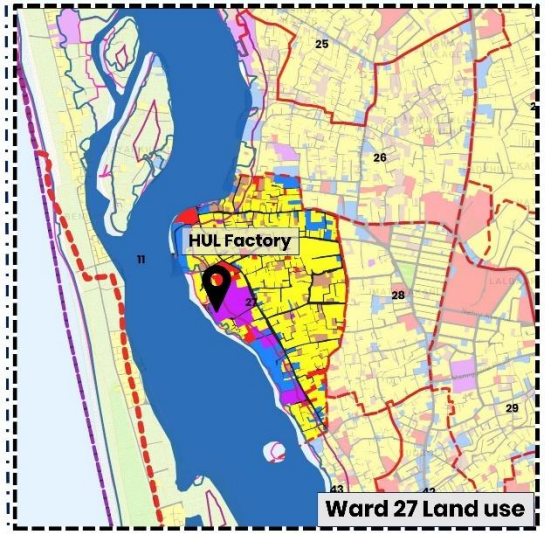
Ward 13	
Landuse	**Area Sq.Km**
Residential	0.68
Commercial	0.00
PSP	0.04
Recreation	0.18
Public utility	0.00
Transport	0.14
Agriculture	1.33
Waterbodies	0.01
Vacant Plot	0.08
Total	**2.46**



Issues

1. **Physical infrastructure:** No sewerage network in the ward
   - Inadequate infrastructure in the slum – water supply, sanitation facilities, sewerage network and storm water drains
2. **Water Quality:** The water quality of **Gurupura River stretch** adjacent to ward 13 has **exceeding levels of BOD (5 mg/l) & COD (42 mg/l)** and falls **in DBU class D**, suitable for propagation or wildlife & fisheries.
   - This is caused by the agricultural run-off, and organic pollution – Inlet of sewage
3. **Water Logging:** Water Logging is a concern as per primary house hold survey conducted – agricultural field inundate during monsoon – crop damage, soil erosion & economic loss.

Ward 27

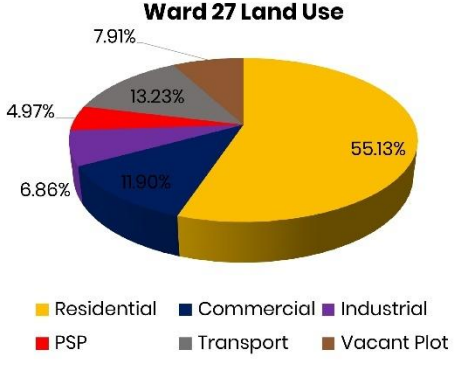


Area – 0.90 Sq.km
Average Elevation: 15 M
Soil type - Sandy Loam
Population – 7077
Population density – 52.03
Number of Households – 1664
WFPR – 44.4%

Economic aspect: HUL Manufacturing unit – **ZLD from March 2024**

Socio-economic aspect: Largely residential area, with MIG housing

Ward 27	
Landuse	**Area SqKm**
Residential	0.49
Commercial	0.10
Industrial	0.06
PSP	0.04
Transport	0.11
Vacant Plot	0.07
Total	**0.90**



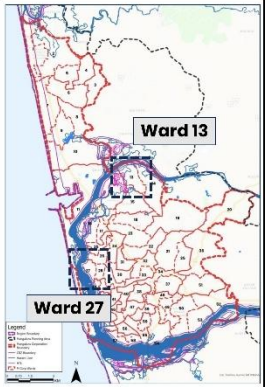
Issues

1. **Physical infrastructure:** The stormwater network in the ward gets blocked with solid waste leading to fluvial flooding in the ward
2. **Water Quality:** The water quality of **Gurupura River stretch** adjacent to ward 27 has **exceeding levels of BOD (5.1 mg/l), and high Turbidity level** and falls **in DBU class D**, suitable for propagation or wildlife & fisheries.
   - This is caused by the agricultural run-off, and sewerage inlet, industrial effluents from Baikampady industrial are.
3. **Water Logging:** Water Logging due to fluvial & pluvial flooding is a concern in the ward as per primary house hold survey.

KEY MAP



LEGEND / INFERENCE



SCALE : **1: 15,000**

N

SHEET NO: **29**

SHEET TITLE: **Critical Ward Analysis**

SOURCE:
- *Author*

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Case Study of Gurupura River in the Coastal City of Mangaluru

Urban River Resilience Index

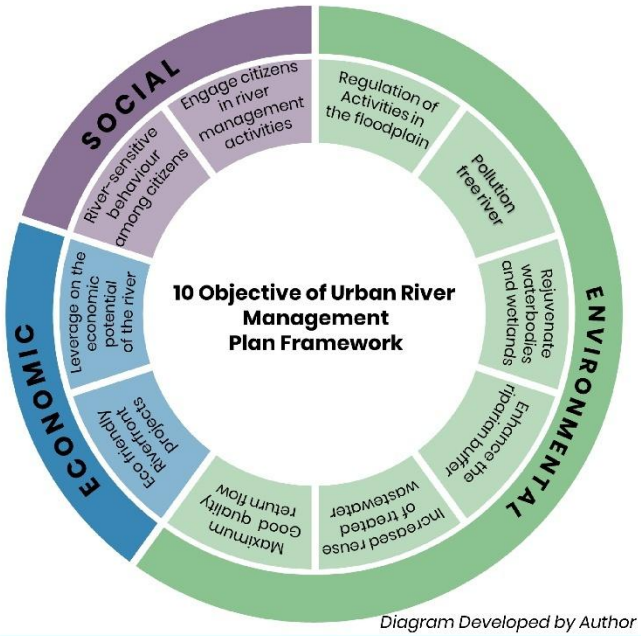


Diagram Developed by Author

The **URM Index** is used to quantitatively assess and align the river's current status with the thematic indicators of the URMP, for targeted and structured planning interventions.

URMP Monitoring Indicators		
No	**Indicator**	**Score**
1	Floodplain Management Score	1
2	Net Dissolved Oxygen Score	5
3	Water Body Revival Score	1
4	Riparian Buffer Score	2
5	Wastewater reuse score	1
6	Return flow score	4
7	Eco-friendly riverfront score	3
8	River economy score	5
9	Citizen sensitization score	1
10	Citizen engagement score	4
	URM_{index}	**2.7**

URM_{index}	Interpretation	What it means
<1.5	Poor level of urban river management	The city is incapable of meeting the basic requirements for effective urban river management. The river is neglected and used indiscriminately without proper planning and management. There are serious concerns for all dimensions of urban river management.
1.6-2.5	Elementary level urban river management	Basic actions required to ensure urban river management are evident. However, there are still major gaps and serious concerns with regards to almost all dimensions of urban river management.
2.6-3.5	**Average level of urban river management**	**The city has a satisfactory urban river management system. However, some dimensions of urban river management are still a cause of concern.**
3.6-4.5	High level of urban river management	The city is well-placed with most of the dimensions of urban river management. The dimensions may not be at par with each other, but the overall situation is still nonetheless satisfactory.
4.6-5.0	Ideal level of urban river management	The city is an ideal example of urban river management. There are evidences of exemplary actions against every dimension of urban river management, suggesting that the plans and policies in regards to urban river management are working well.

Proposed Indicators for Urban River Resilience Index

Proposed Indicator 11: CRZ Compliance Score

No	Desirable feature	Fixed Score	Points earned
1	All CRZ-I areas (like mangroves, salt marshes) are strictly protected with no violations	30	30
2	All permitted activities in CRZ-II (urbanized areas) have obtained necessary CRZ clearances	20	0
3	No unauthorized construction in CRZ-III	20	0
4	Presence of updated CRZ maps integrated into local planning documents	15	15
5	Citizen sensitization efforts on CRZ norms (signage, awareness drives)	15	0
	Total	**100**	**45**
	CRZ Compliance points = 40 - 59		**CRZ Compliance Score = 3**

Proposed Indicator 12: Mangrove and Estuarine Habitat Health Score

No	Desirable feature	Fixed Score	Points earned
1	No net loss in mangrove area (year-on-year)	35	0
2	Presence of >75% native species among estuarine vegetation	15	15
3	Visible signs of healthy biodiversity (bird nesting, juvenile fish presence)	15	0
4	No solid waste or oil contamination in estuary	20	0
5	Community initiatives for mangrove conservation	15	0
	Total	**100**	**15**
	Mangrove and Estuarine Habitat Health Points < 20		**Mangrove and Estuarine Habitat Health Score = 1**

Proposed Indicator 13: Urban Flood Resilience score

No	Desirable feature	Fixed Score	Points earned
1	Flood forecasting system and early warning systems	30	30
2	Flood protection infrastructure (Levees, flood walls, etc)	20	0
3	100% coverage of storm water drains and sewerage	20	0
4	Flood insurance and financial support mechanism for recovery	15	0
5	Mapping of vulnerable population (Low-income communities, elderly, children and people with disabilities)	10	0
	Total	**100**	**30**
	Urban Flood Resilience points 20 -39		**Urban Flood Resilience score = 2**

Proposed indicators for URRI		
No	**Indicator**	**Score**
11	CRZ Compliance Score	3
12	Mangrove and Estuarine Habitat Health Score	1
13	Urban Flood Resilience score	2
	$URRI_{index}$ (Along with URM_{index})	**2.5**

$URRI_{index}$	Interpretation	What it means
<1.5	Poor resilience of the urban river	The river ecosystem is highly vulnerable to environmental and climate-related stressors. There is minimal or no adaptive infrastructure or planning in place. Communities and biodiversity around the river are at risk.
1.6-2.5	**Low resilience of the urban river**	**Some preliminary efforts toward resilience are evident, but systemic gaps remain. Flood risk, pollution, and ecological degradation persist without long-term mitigation strategies.**
2.6-3.5	Moderate resilience of the urban river	The river shows signs of resilience with functioning infrastructure in some areas. However, inconsistencies exist in governance, ecosystem health, and flood resilience
3.6-4.5	High resilience of the urban river	The river is generally resilient with integrated risk management systems. Ecosystems are protected or restored, and urban systems show readiness for future stressors. However, occasional vulnerabilities remain.
4.6-5.0	Ideal resilience of the urban river	The river and its urban context are fully climate-adaptive and ecologically stable. Nature-based solutions are implemented, stakeholders are engaged, and disaster preparedness and response systems are robust and proactive.

Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru



KEY MAP



LEGEND / INFERENCE

- Resilience is critical when managing coastal urban rivers, as they face climate-induced risks like flooding, salinity intrusion, and sea level rise.
- The existing URM framework covers 10 indicators but lacks a focus on resilience, ecosystem health, and community preparedness.
- 3 indicators—on flood resilience, ecosystem health, and CRZ Compliance—the framework can be enhanced into **the Urban River Resilience Index (URRI)**

SCALE :

N

SHEET NO: **30**

SHEET TITLE: **Urban River Resilience Index (URRI)**

SOURCE:
- *Urban River Management Plan, NIUA*
- *Author*

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Governance

INTERNATIONAL

- Ramsar Convention (For Wetland protection)
- Convention on Biological Diversity (CBD)
- Sustainable Development Goals (SDG's)
- International Waters Treaties

NATIONAL

Ministry of Jal Shakti				MoEFCC			Ministry of Housing & Urban Affairs				
CWC	CGWB	National Water Board	National Water Resource Council	CPCB	NGT	National River Conservation Directorate	NIUA	CPHEEO	TCPO	AMRUT Directorate	Smart Cities Directorate
River Boards Act (1956)	Composite water Management Index, 2019	National Water Policy, 2012	River boards act, 1956	Jal Shakthi Abhiyan, 2019	Water (Protection & Control of Pollution) Act, 1974	Wetlands (Conservation & Management) Rules, 2017	National urban water mission, 2015	AMRUT guidelines, 2015	CPHEEO Manual, 2013		
					Forest Act	Biodiversity Act	Environment (Protection) Act, 1986	Model Building Bye-laws, 2016	Smart cities mission guidelines, 2015		

KARNATAKA STATE

Forest Department	Water Resource Department	Karnataka Urban Water Supply & Drainage Board (KUWSDB)	Irrigation Department	Karnataka Watershed Development (KAWAD)	Fisheries Department	Agriculture Department	Geology & Mining Department	Tourism Department
Karnataka State Pollution Control Board (KSPCB)	Karnataka Industrial Area Development Board (KIADB)	Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC)		Karnataka State Disaster Management Authority (KSDMA)			Karnataka State Wetland Authority	
Karnataka Forest Act, 1963	Karnataka Industrial Policy, 2020-2025	Karnataka State Water Policy, 2002		Karnataka State Action Plan for Climate Change, 2015			Karnataka Urban Drinking Water Policy, 2011	

SCOPED REGION

- Mangalore Division
- Kundapur Division
- Kudremukh Wild Life Division

Udupi District

Taluks: Hebri, Karkala

Dakshin Kannada District

Taluks: Mulki, Mangaluru, Ullal, Belthangady, Puttur, Bantwal

- Mulki Town Panchayat
- Mangaluru UDA
- Mangaluru M. Corp
- Ullal TMC

SWOC Analysis

REGION

S – Strength

- Rich Biodiversity with presence of **Forest, Riverine and Coastal** ecosystem
- **High literacy** rate and well-developed **social capital**
- Availability of Surface and Ground water for Irrigation - **High ground water table**
- **65% perennial streams**, High flow in the Gurupura watershed, indicating availability of water throughout the season

W – Weakness

- High dependency on **ground water for Irrigation and domestic** use despite tap water supply for domestic use
- **Complex governance** due to varied topography
- **High flow watersheds** carrying **agricultural run-off & sediments** as the region is susceptible to erosion
- **Moderate flood risk** and possibility of flash flood as identified in Basin Morphometry analysis

O – Opportunity

- Enhancement of **watershed-based agriculture & farming**
- Diversification of livelihood through **sustainable agriculture and nature-based tourism**
- **Eco-labeling** and certification for Arecanut, Coconut and cashew providing better farming practices and market value for farmers
- **Promotion of NBS** - river bank stabilization, riparian buffer zones

C – Challenges

- Pressures from land-use change, plantation expansion and infrastructure development
- **Encroachment** and **pollution** from plantation field run-off
- Lack of real-time water quality, sediment load, and flow data hinders evidence-based planning for river health monitoring.

MANGALURU CITY

S – Strength

- Strategic **coastal & Riverine location** - Natural advantage for trade, fisheries and tourism
- **High literacy and institutional capacity**, & municipal governance capable of implementing integrated rive and coastal management
- **CRZ regulations in place** – a tool to protect ecologically sensitive zones, encroachment & manage flood risk
- Established economic base with river linkages

W – Weakness

- **High Pollution Load** on river and estuary - direct discharge of untreated sewage, grey water and industrial effluents
- **Encroachment** in CRZ zones
- Poor integration of river systems in Urban planning
- **Fragmented infrastructure** systems
- **Saline water intrusion** in Ground water along the low-lying areas due to upstream over extraction and tidal impact

O – Opportunity

- Potential to **increase mangrove cover,** restore wetlands and riparian zones along the river
- Opportunity for **river-based sectors**: eco-tourism, water transport
- Leverage **Smart city and AMRUT** missions to fund river sensitive infrastructure, waste water treatment and urban resilience interventions
- Potential for **ground water recharge and Nature based solutions**

C – Challenges

- Despite CRZ regulations, **lack of real time monitoring**, limited penalties can weaken the implementation
- Combined risk of **Coastal, fluvial, pluvial flooding,** due to in adequate infrastructure, and climate change posing a risk for riverfront settlements
- **Stakeholder conflict** - between urban developers, fishing communities, industries and ULB's

KEY MAP



LEGEND / INFERENCE

SCALE :

N

SHEET NO: 31

SHEET TITLE: **Governance & SWOC**

SOURCE:
- *Author*

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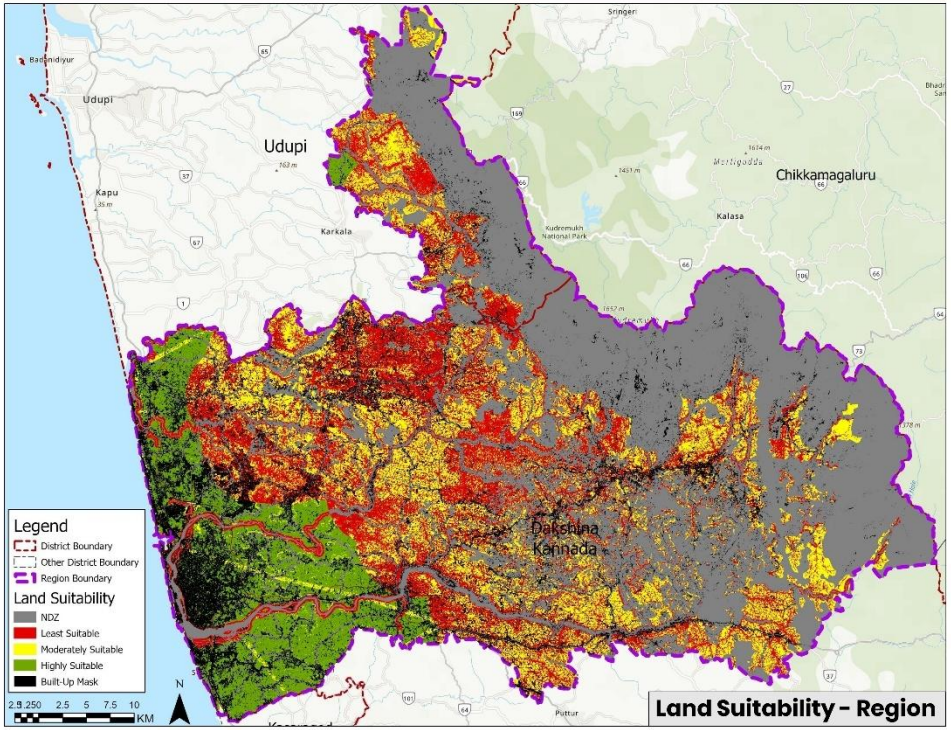
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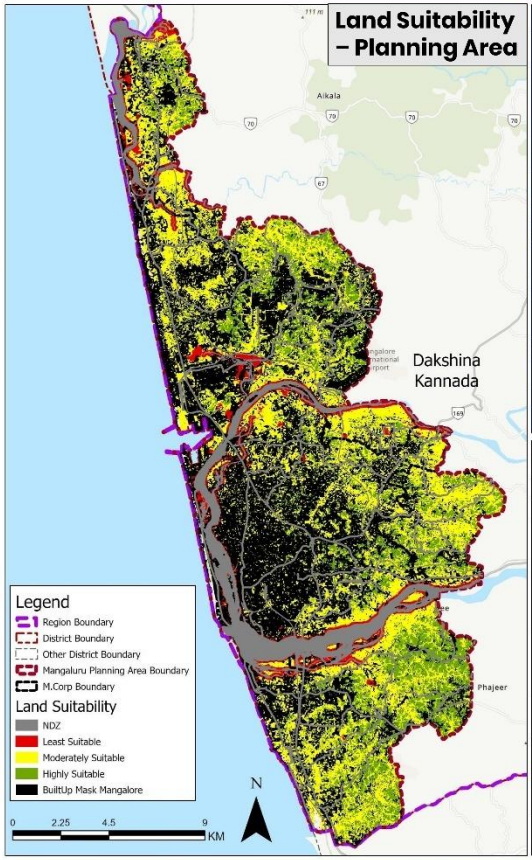


Land Suitability & Population Projection

Region



Planning Area



Pair wise matrix – Normalised scores

Parameters	Rivers	Waterbody	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Weighted average
Rivers	0.27	0.37	0.29	0.31	0.26	0.25	0.22	0.21	28
Waterbody	0.14	0.18	0.29	0.21	0.18	0.19	0.16	0.17	19
CRZ	0.14	0.09	0.14	0.21	0.18	0.19	0.16	0.17	16
Flood Susceptibility	0.14	0.09	0.07	0.10	0.18	0.13	0.16	0.13	12
Faults & Lineaments	0.09	0.09	0.07	0.05	0.09	0.13	0.11	0.13	9
Slope %	0.09	0.06	0.05	0.05	0.04	0.06	0.11	0.08	7
Major Roads	0.07	0.06	0.05	0.03	0.04	0.03	0.05	0.08	5
Railways	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.04	4
							Total	100.00	

Parameter	Suitability			
	NDZ	Least	Moderate	High
Rivers	100 m	200 m	500m	> 500m
Waterbody	50 m	65 m	95 m	> 95 m
CRZ	CRZ III NDZ, CRZ IA & 50 m Mangrove buffer, CRZ IB, CRZ IV B	CRZ III A & B	CRZ II	Areas outside CRZ boundary
Flood Susceptibility (FS)	Very high & High FS zones	Moderate FS Zones	Low FS Zone	Very Low FS Zone
Faults & Lineaments	< 100 m	100 - 200 m	200 - 300 m	> 300 m
Slope percentage	> 30 %	20 - 30%	10 - 20%	< 10%
Major Roads	50 m	50 - 150M	150 - 300 M	> 300 M
Railways	50 m	50 - 100 m	100 - 150 m	> 150 m

Pair wise matrix – Normalised scores

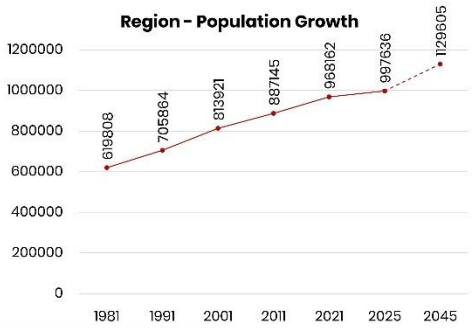
Parameter	Forest	Rivers	CRZ	Flood Susceptibility	Faults & Lineaments	Slope %	Major Roads	Railways	Weighted average
Forest	0.33	0.39	0.38	0.31	0.32	0.25	0.26	0.21	31
Rivers	0.16	0.19	0.25	0.21	0.16	0.19	0.15	0.17	19
CRZ	0.11	0.10	0.13	0.21	0.16	0.19	0.15	0.17	15
Flood Susceptibility	0.11	0.10	0.06	0.10	0.16	0.13	0.15	0.13	12
Faults & Lineaments	0.08	0.06	0.06	0.05	0.08	0.13	0.10	0.13	9
Slope %	0.08	0.06	0.04	0.05	0.04	0.06	0.10	0.08	7
Major Roads	0.07	0.05	0.04	0.03	0.04	0.03	0.05	0.08	5
Railways	0.07	0.05	0.03	0.03	0.03	0.03	0.03	0.04	4
								Total	100.00

Parameter	Suitability			
	NDZ	Least	Moderate	High
Forest	1 KM	5 KM	10 KM	> 10 KM
Rivers	100 m	200 m	500m	> 500m
CRZ	CRZ III NDZ, CRZ IA & 50 m Mangrove buffer, CRZ IB, CRZ IV B	CRZ III A & B	CRZ II	Areas outside CRZ boundary
Flood Susceptibility (FS)	Very high & High FS zones	Moderate FS Zones	Low FS Zone	Very Low FS Zone
Faults & Lineaments	< 100 m	100 - 200 m	200 - 300 m	> 300 m
Slope percentage	> 30 %	20 - 30%	10 - 20%	< 10%
Major Roads	50 m	50 - 150M	150 - 300 M	> 300 M
Railways	50 m	50 - 100 m	100 - 150 m	> 150 m

Population Projection

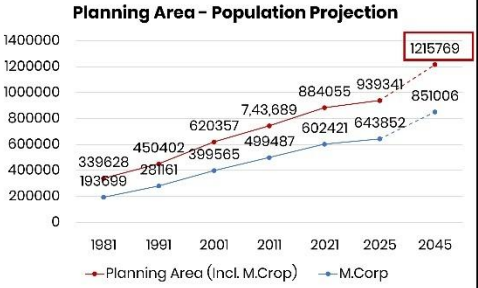
REGION

The population in the **region** has grown in a Geometric trend, & projected population for the year **2045** is **11,29,605**



Mangaluru Planning Area

The population in the **Planning & Municipal Area** is observed to have a linear growth, therefore, **Arithmetic growth** method is used for Projections.



Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE

SCALE :

N

SHEET NO: 32

SHEET TITLE: **Land Suitability & Population Projections**

SOURCE:
- *Author*

NAME
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Proposals

REGION

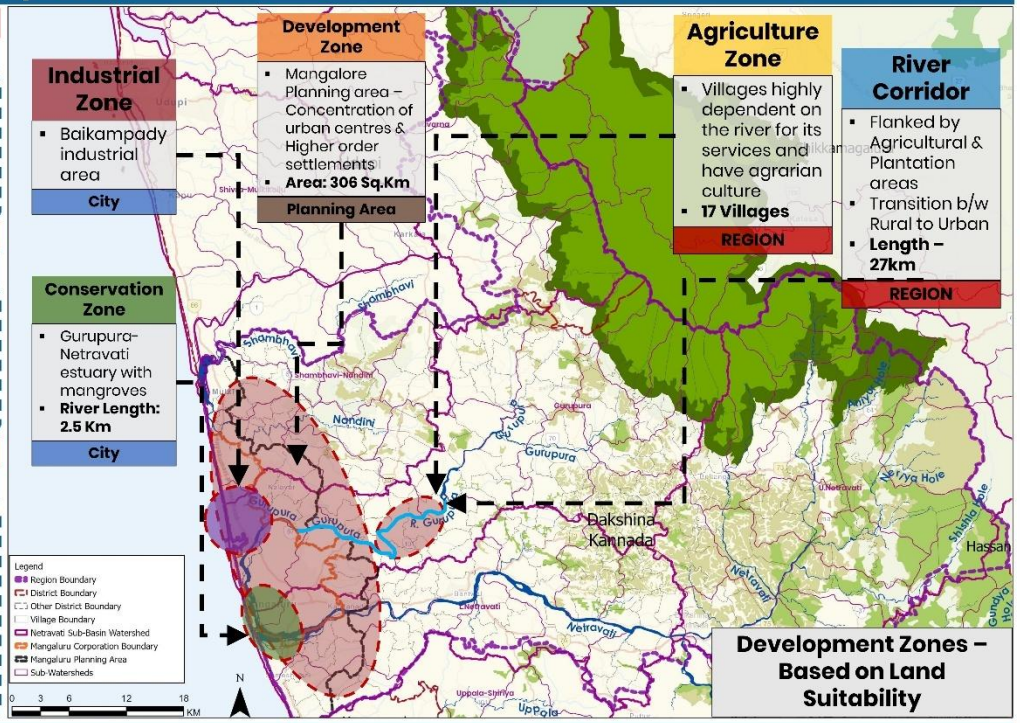
POLICY	PLANNING	MANAGEMENT
▪ Integrate eco-village guidelines into district rural development schemes. ▪ Mandate buffer zones along the river corridor (zoning restrictions for, agriculture, and construction).	▪ Develop eco-villages with water conservation, regenerative agriculture, & decentralized sanitation. ▪ Delineate & protect river corridor - land use plans & buffer zones.	▪ Implement riverbank vegetation restoration using native species. ▪ Support training for panchayat members on river monitoring and waste management.

PLANNING AREA

POLICY	PLANNING	MANAGEMENT
▪ Restrict land use changes in flood-prone zones near the river. ▪ Introduce riverbank buffer guidelines in census towns' development controls.	▪ Prepare a **Watershed Management Plan** for integrated surface water and groundwater coordination. ▪ Development control regulations in flood prone areas.	▪ Map vulnerable areas and implement localized flood mitigation works. ▪ Decentralize greywater treatment and runoff management in towns.

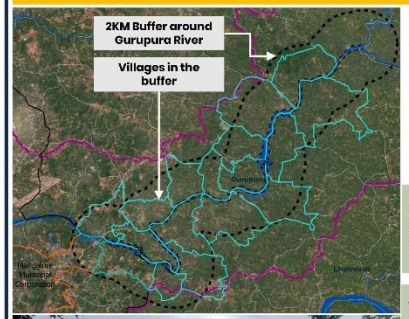
CITY

POLICY	PLANNING	MANAGEMENT
▪ Designate Critical Wards for focused interventions: pollution control, infrastructure upgrades, and eviction prevention. ▪ Enforce strict penalties for illegal discharges and encroachments near riverbanks.	▪ Restore mangrove patches and estuary edges to improve river health. ▪ Plan for riverfront open spaces in dense urban stretches with setback areas. ▪ Regulate industrial land use in river-adjacent zones with green buffers and effluent safeguards.	▪ Monitor & penalize industrial effluent discharge from Baikampady. ▪ Upgrade/expand sewerage networks and STPs to stop direct sewage disposal. ▪ Clear stormwater drains blocked by solid waste to reduce pluvial flooding.



Proposals - Region

Agricultural Zone





Intercropping brinjal and tomato seedlings on gunny-based soil columns in water-logged rice field

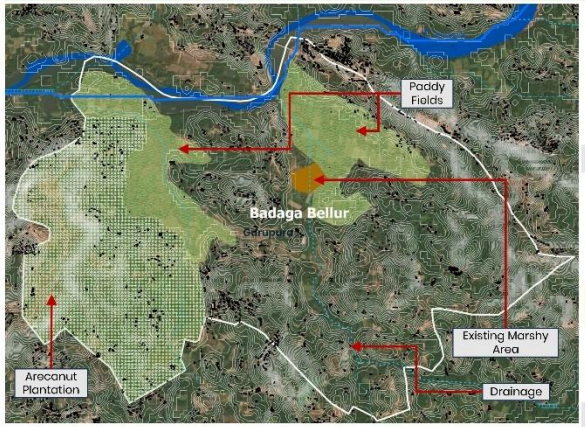
REGENERATIVE AGRICULTURE



	KEEP SOIL COVERED	MINIMIZE SOIL DISTURBANCE	INCREASE PLANT DIVERSITY	MAINTAIN LIVING ROOTS	INTEGRATE LIVESTOCK
HOW	-Organic Mulches -Cover crops	-No or low till -Manual & Shallow tool	-Intercrop -Native Variety	-Cover crop -Intercrop -Mulching	-Planned grazing -Organic fertilizer
BENEFITS	-Reduced sediment run-off	-Reduces erosion -Ground water recharge	-Ecological balance -reduced pollution	-Nutrient cycling -Carbon sequestration	-Reduced chemical fertilizer -Nutrient cycling

RIVER			
0 – 30 M 30 – 100 M	Riparian buffer	Perennial or seasonal cover cropping zones, No till & mulching	Flood inundated or seasonally water-logged
100 – 300 M	Intermediate Buffer	Intercropping & living root system	Flood prone Transition zone – riparian to agriculture
	Agriculture Buffer	Minimal tillage Agro-forestry	Lesser flood risk Suitable for agriculture
> 300 M	Community pasture	Planned grazing & managed manure collection for compost	Shared open land Buffer to high traffic areas

RIVER SENSITIVE ECO-VILLAGE MODEL



Village – Baga Bellur
Population - 3874
Population Density - 4.8
III Order Village

Natural Capital

Existing **paddy fields** can transition to **Regenerative Agriculture**

Riparian Buffer – native species (Madhuca insignis, Ochreinauclea missionis, Carallia brachiata, Euonymus indica, Homonoia riparia, & Rotula aquatic)

Physical Capital

Clustered Ground water recharge Trenches – Plantation areas

Roof top rainwater harvesting in the settlement area

Ground water recharge pits in the settlement area & **well-conservation**

Constructed wetland in the existing marshy area

Social Capital

Community managed **Seed Banks**

Plantation Tourism

Local guided & River based **Eco-tourism**

Solar Water ATM – Treated Ground & Rain water



Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE

SCALE :

N

SHEET NO: 33

SHEET TITLE: Proposals

SOURCE:
- *Author*

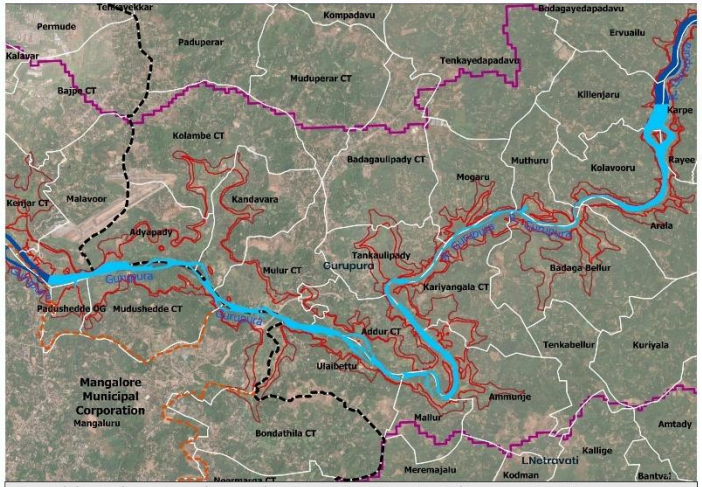
NAME
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Proposals - Region

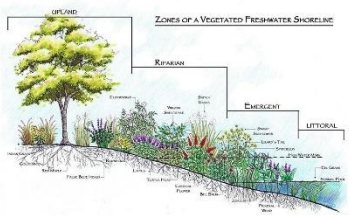
River Corridor



Identified River Corridor with 2M & 4M flood plains marked by Karnataka Government & Surrounding Villages

Planning Level	Objective	Intervention
Corridor-wide (macro)	Sustain ecological continuity and hydrological functions across the stretch	- Delineate **ecological zones** (riparian forests, wetlands, floodplains)- Map threats and sensitive zones- Set broad **land use controls and buffers**
Cluster/Village-level (meso)	Integrate river into rural livelihoods and eco-village design	- Develop **eco-sensitive land use** (wetlands, eco-tourism, buffer farming)- Site recharge zones
Parcel/Micro-sites (micro)	Implement tangible interventions for resilience	- Constructed wetlands- Riverfront greens- Community interpretation trails- Bio-fencing and native replantation

Corridor Wide (Macro)



20 – 100m width depending on the slope & use

Land-use Control

No built-up development to prevent runoff, erosion, and habitat disturbance.

Dense & Native Riparian Species – stabilizes banks against erosion via deep-rooted vegetation.

Cluster/Village – Level (Meso)

Bio-swales & Phytoremediation

At nala or drainage discharge points into river to filter greywater, controls village runoff pollution entering the river.

Development control regulations

Use of local material – **Laterite blocks and Mangalore tile roof** – No concrete structure.

Traditional water harvesting technique





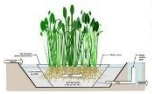
Farm ponds – stores rainwater for irrigation & ground water recharge

Kattas – Temporary structure made of mud and stones, built post monsoon– slows the flow for recharge purpose, disintegrates by arrival of next monsoon

Parcel/Micro Sites (Micro)



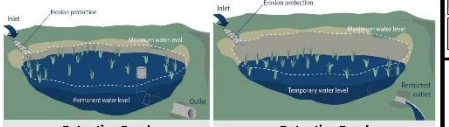
Bio-fencing: Along all buffer zones of the river, wetland periphery, cluster perimeters – prevents encroachment and livestock intrusion



Constructed wetlands: Decentralised waste water treatment in areas that lack drainage networks

Decentralised Storm water Management Retention & Detention Ponds :

In Plantation zones along the river bank - Captures excess rain, supports seasonal water availability, reuse & holds excess water to avoid floods



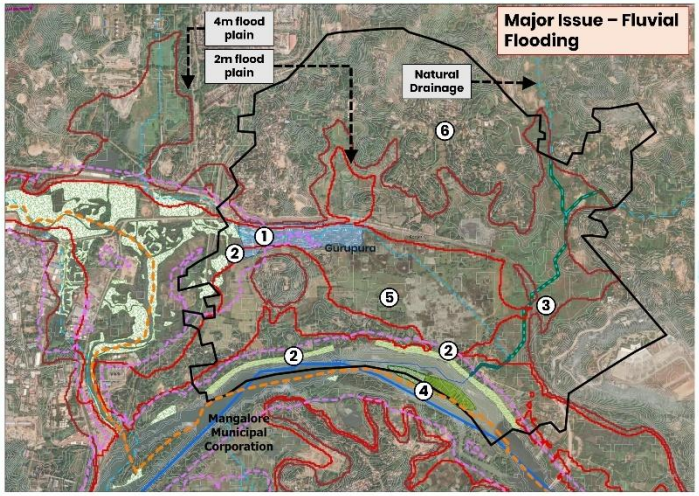
Retention Pond | Detention Pond

Commonly found Riparian species in the region



Ochlandra travancorica | Holigarna arnottiana | Homonoia riparia | Rotula aquatic

Proposals - Planning Area



Area: 6.68 Sq.km **Population: 5338**

Town Name: Kenajr CT **Population Density: 8 PPH**

1. Brackish Aquaculture Zone for Livelihood

Tidal Fish Ponds - integrated species like shrimp, milkfish, or mud crabs – Managed by local farmers & fishermen

2. Mangrove Flood Buffer

Conserve existing Mangroves and plant native mangrove species for flood mitigation

3. Eco-Drainage Trails Linking Uplands to River

Bio-swale along the existing natural drainage creating green infrastructure that filters the pollution and rejuvenates ground water

Linear Park to prevent encroachment of the natural drains and link upland areas with the river

4. Tidal Wetland Park

Mangrove plantation & conservation zone in the existing river islets.

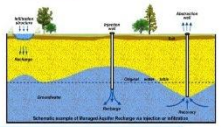


Wetland Park – Access to public – bamboo boards for trails, Bird-watch tower and interpretation center for knowledge & awareness. Managed by local communities and SHG's

5. Saline-prone Land Use Regulation

No conventional agriculture in salinity-intrusion belts

Pilot agro lab with collaboration from local Krishi Vigyan Kendra (KVK) or NITK Surathkal. Demonstrate **salt-tolerant paddy, millet varieties, medicinal halophytes.**

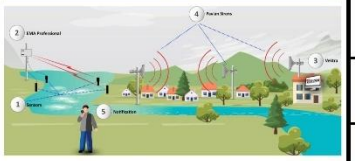


Shallow dug wells & Manager Aquifer Recharge for Irrigation - No deep borewells for irrigation

6. Drainage & Sewerage Network

100% coverage of **drainage and sewerage** network in the town

7. Early warning System



- Install warning sirens, SMS alert systems, and flood gauges
- Place signage with flood levels and safe evacuation routes

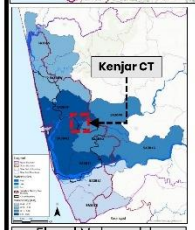
Environmental Planning Strategies for Urban River : Case Study of Gurupura River in the Coastal City of Mangaluru

KEY MAP



LEGEND / INFERENCE





Flood Vulnerable Watersheds

SCALE :

N

SHEET NO: **34**

SHEET TITLE: **Proposals**

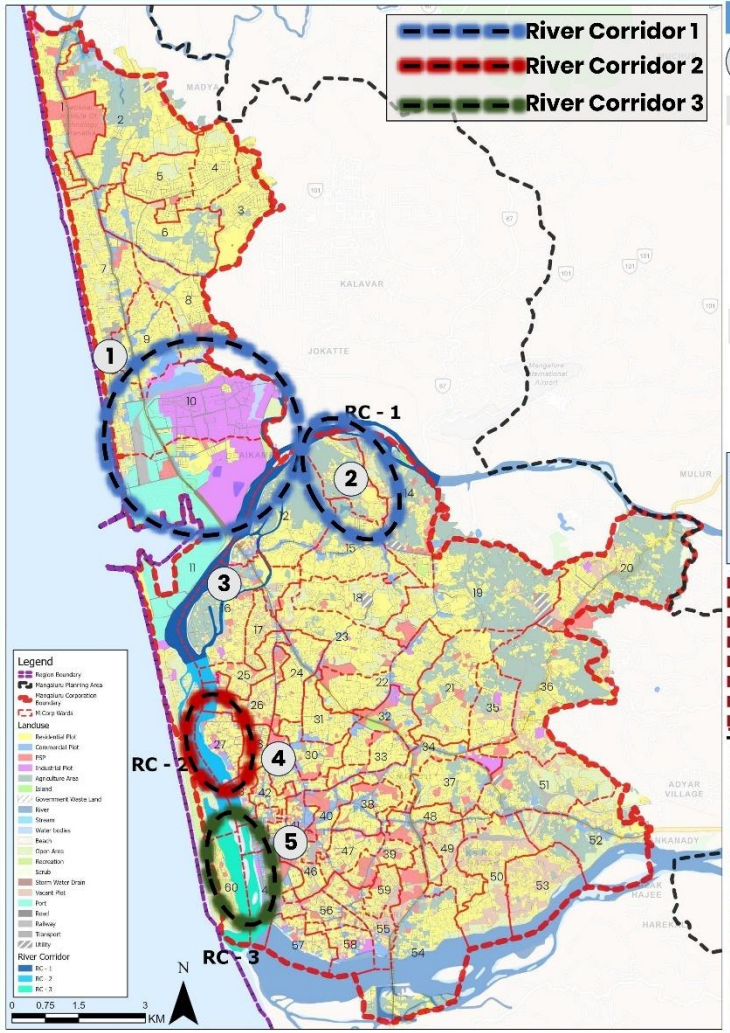
SOURCE:
- *Author*

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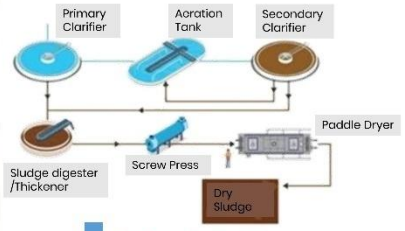
Proposals – Mangaluru City



River Corridor – 1

1 Industrial Area Proposals

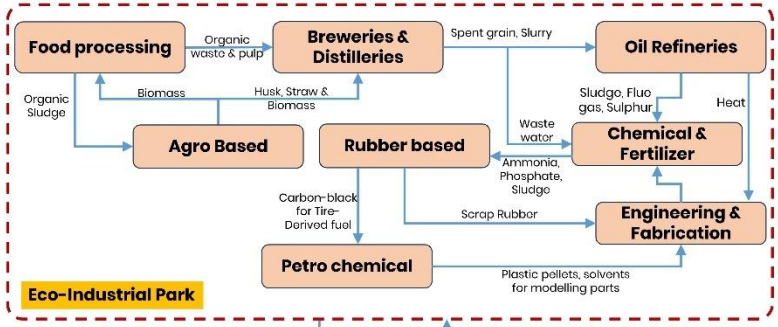
CETP (MBBR) with Paddle dryer – 3 MLD

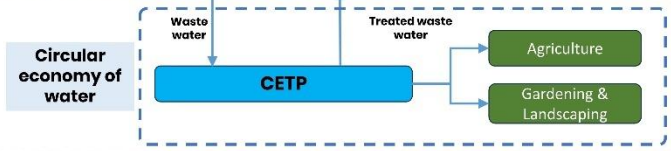


Integrated with reuse mechanism

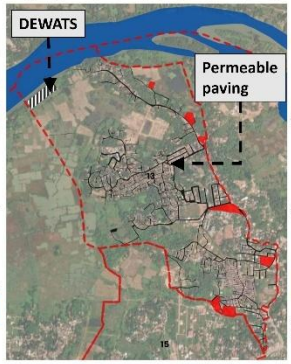
1. **Treated water storage tank**
2. **Dual piping system** -> Cooling towers, Floor washing, Gardening/ Landscaping
3. **Water Metering** – Monitor reused quantity

Eco-Industrial Park – Industrial Symbiosis



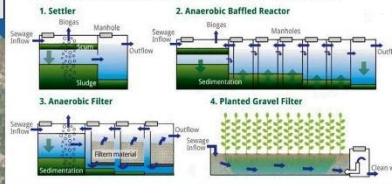


- The establishment of any new industries in Baikampady must adhere to the **Zoning Atlas approach** for environmentally sound industrial siting.
- KIADB currently permits the operation of **Orange category industries** in the area, future industrial development should be restricted to **Green, Yellow, White, or Blue category industries**.
- This is essential to prevent the introduction of additional polluting units and to safeguard the **ecologically sensitive Gurupura River ecosystem**.



2 Proposals for Ward 13

DEWATS module for wastewater treatment



Infrastructure & Flood Management

- **Total DEWATS area**: ~**5–7 m² per KLD** (including Settler, ABR, PGF, and polishing pond)
- Wastewater generation norms: **100–135 LPCD**
- 8615 people × 120 L/day = 10,338,000 L/day ≈ **10338 KLD**
- 10338 KLD × 5 m² = 51,690 m² (5.1Ha), DEWATS can be designed up to **1 MLD capacity, Area: 0.7 Ha**

Permeable Paving in the internal roads

Rainwater Harvesting in public buildings

Slum Upgradation

Sewerage & Drainage network

Plinth: 0.5 – 0.8m above flood level

Livelihood

- **Nursery Management**
- **Mangrove & Green belt maintenance**

River Corridor – 2

4 Proposals for Ward 27

Rainwater Harvesting in public buildings, industries, & group housing

Bio-swales along road medians & sidewalks, & public spaces with impervious surfaces

Green & biodiverse roof

System build-up
Steeply Pitched Green Roof



Reduced run-off & urban flooding

How?

- **Tax rebates** for properties with green roofs
- Include in local building bye-laws, PMAY housing guidelines
- Financial & technical assistance from ULB or Urban Development Authority

3 Zoning Strategy for Agricultural Area

RIVER			
0 – 20 M	Phytoremediation buffer	Wetland plants,	Plants that can uptake excess nutrients and tolerate waterlogging.
20 – 30 M	Intermediate Buffer	Mixed native tree species + understory plants	Recharges soil, adds biodiversity
Agricultural Zone	Agriculture Zone	Regenerative agriculture	Salt tolerant crops, reduced chemical usage

Native Trees: Terminalia arjuna (Arjun tree), Syzygium cumini (Jamun), Azadirachta indica (Neem), Ficus benghalensis (Banyan)
Shrubs & Grasses: Lemon grass, Vetiver, Lantana camera (controlled), Cassia spp.

Soil Type: Clayey -> poor drainage and low aeration

Suitable plants that can grow in the buffer areas include

Phytoremediation remediation belt in clayey soil:

Plant	Suitability
Vetiver grass	Deep roots adapt to heavy soils
Canna indica	Good for nutrient-rich runoff
Typha angustifolia	Tolerates waterlogging & clayey substrate
Ipomoea carnea	Fast-growing and flood-tolerant
Bamboo species	Grows in compact soil

KEY MAP



LEGEND / INFERENCE

- DEWATS proposed in Least & Moderately suitable area for residential development.

SCALE :

N

SHEET NO: **35**

SHEET TITLE: **Proposals**

SOURCE:

- *Decentralised Wastewater Treatment Systems (DEWATS) – A Technical Guidebook*
- *A review on decentralized wastewater treatment systems in India*
- *Author*

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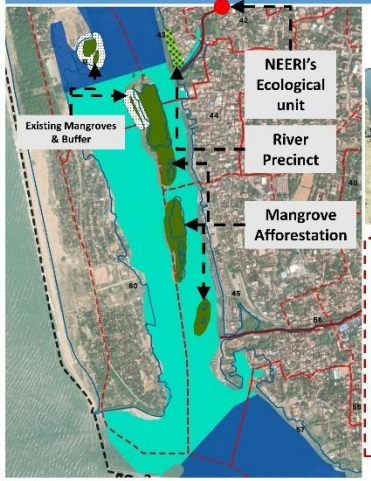
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Proposals – Mangaluru City

River Corridor - 3



5 Eco-restoration Strategies



Strategies to prevent Pluvial Flooding

NEERI's Ecological units: In-situ cleaning treatment for storm water drains

Screen & grit trap	Traps solid waste
Sedimentation	Settling of solid particles
Phytotrap & Biomat	Bacterial Growth that traps suspended organic matter, breakdown of pollutants
Wetland Plants	Controls unwanted vegetation & algae, maintaining ecological balance

Mangrove Conservation & Afforestation

Conservation Strategies

- Removal of artificially created island in the river
- Ban on Fish net drying
- No Plastic Zone
- Ban on operation of motorized boats

Afforestation Strategies

1. Community based eco-restoration of Mangroves
2. Mangrove Afforestation
   - Soil remediation
   - Local mangrove species
   - Community engagement in plantation (Bengre fishermen community & slum residents)
   - **NGO's & SHG's** involvement with ULB's and other funding agencies
   - Incentivize communities for maintenance


Avicennia officinalis


Rhizophora mucronata


Kandelia candel


Sonneratia caseolaris

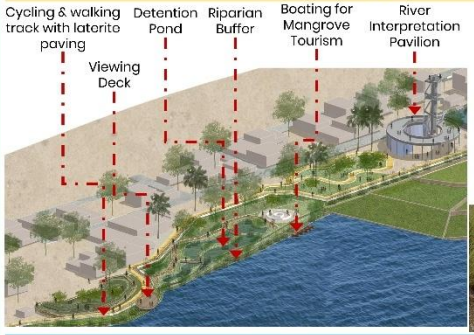

Bruguiera gymnorrhiza


Sonneratia alba

3. **Mangrove Tourism**
   Board walks in afforested area
   Observation decks for birdwatching & tidal ecology



River Precinct



Area: **2 Ha**

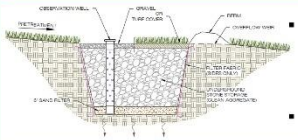
Riparian buffer:

Native grasses – Vetiver Grass, Napier Grass, & Bermuda Grass



City Wide Strategies

Ground Water Recharge Strategies – Infiltration Trenches

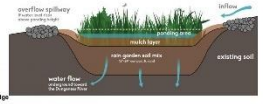


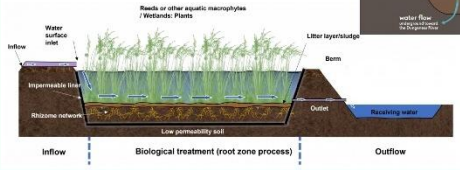
- **Shallow trenches** (1–2 m deep, 0.5–1 m wide), filled with layers of coarse sand, gravel, and pebbles.
- Along edges of parks and sidewalks.

Revival of Water bodies

50m Green buffer to be maintained around all the lakes

Rain gardens in green buffer to soak excess run-off and allow infiltration





Constructed wetland for inflow channels draining into lakes

City Wide Strategies

WATER SUPPLY

	2045	Remark
Population	851006	
Demand		
Domestic (135 LPCD)	114.89	CPHEEO Standard
Non-Domestic	36.01	Source: MCC
Fire demand	3.36	Source: MCC
Bulk Demand	20.30	Source: MCC
Total demand	**174.56**	
20 % Loss	**34.91**	NRW
Total demand + 20% Loss	**209.47**	
Source	**Thumbe Dam (MLD)**	
Mangaluru WSS 1st Stage, 1965	10	
Mangaluru WSS 3rd Stage, 2012	80	
Source	**Adyar Dam (MLD)**	
Proposed 24/7 WSS	125	Up to 2046
Total Water Supply	**215**	
Gap	**+ 5.53**	Water surplus

Strategies to reduce NRW

- Conduct Water **Audit & Leak Detection**.
- **Infrastructure Upgrades:** Replace aging or leaking pipelines, introduce pressure management systems
- **Institutional Measures:** Build capacity in the ULB for NRW management, incentivize leak reporting, ensure metering & billing compliance.
- **Outcome:** Reducing NRW from **20% to 10%**

WASTE WATER TREATMENT

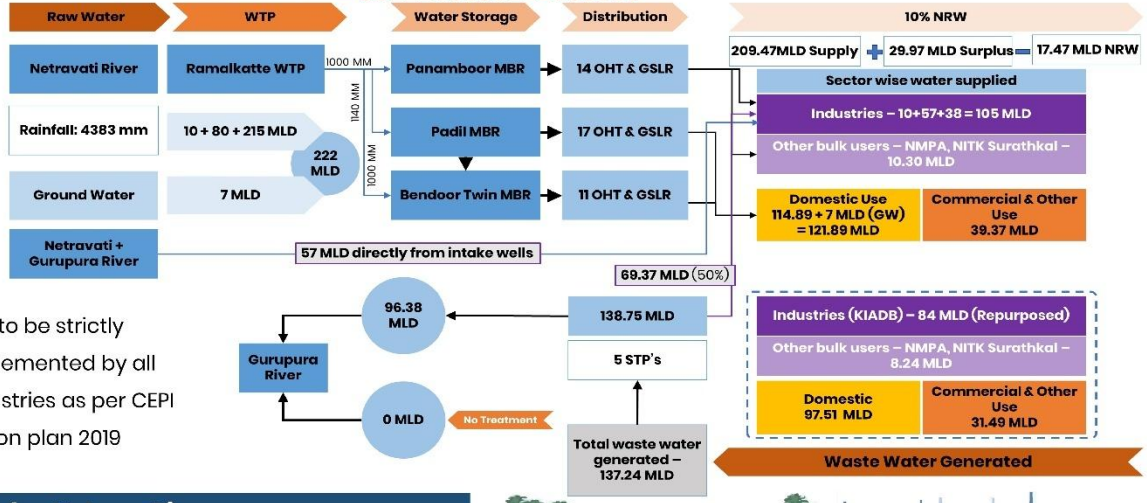
80% of water supply considered for waste water generation calculation

	2045
Waste water generated	167.57
STP	
Surathkal STP	16.5
Kavoor	43.5
Pachanady	8.75
Bajal	20
Total	**88.75**
Gap	**- 44.76**

Intervention Strategies

- **100%** Sewerage network coverage in all wards
- **50 MLD STP** to be proposed to address the treatment gap (**buffer capacity of ~5 MLD**, accommodating **peak flows** in Monsoon)

FINAL WATER BALANCE



ZLD to be strictly implemented by all industries as per CEPI Action plan 2019

KEY MAP



LEGEND / INFERENCE

SCALE :

N

SHEET NO: **36**

SHEET TITLE: **Proposals**

SOURCE:

- *Virginia Stormwater Management Handbook*
- *MCC, Mangaluru*

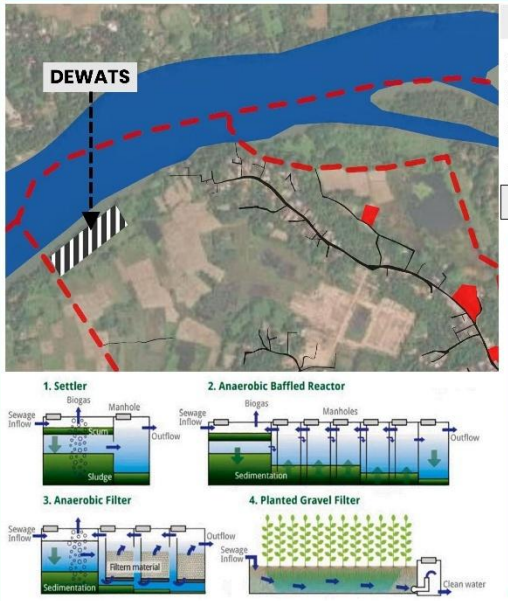
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Detail Project Report



Project: Decentralized Wastewater Treatment System (DEWATS) – 1 MLD Capacity in Ward 13

Site Area – 0.7 Ha
Site Dimensions – 50m x 140 m
Project Description: This project proposes a **1 MLD DEWATS facility** on **0.7 hectares** of land along Gurupura River, in ward 13 of Mangalore city using natural, low-energy treatment technologies for areas without centralized sewerage. This will cater to a population of 8615 in the ward, which also includes a slum which lacks basic sanitation facilities.

Treatment Modules

Settler (Primary Sedimentation Tank)
- **Function**: Removes large suspended solids by gravity.
- **Process**: Sewage enters the tank → heavier solids settle as sludge at the bottom → lighter materials like oil/grease float as scum.
- **Output**: Partially clarified wastewater + sludge (needs periodic removal).
- **Byproduct**: **Biogas** from anaerobic activity.

Anaerobic Baffled Reactor (ABR)
- **Function**: Biological degradation of organic matter using anaerobic bacteria.
- **Process**: Wastewater flows through multiple chambers separated by baffles → anaerobic digestion occurs → pathogens and BOD significantly reduced.
- **Efficiency**: 60–80% BOD reduction.
- **Byproduct**: Biogas + some stabilized sludge.

Anaerobic Filter
- **Function**: Further polishing through biofilm activity.
- **Process**: Wastewater percolates through filter media (gravel/plastic rings) colonized by bacteria → organic pollutants are consumed.
- **Benefit**: Enhances clarity, reduces COD/BOD further.
- **Maintenance**: Occasional backwashing or filter cleaning.

Planted Gravel Filter (PGF) *(Constructed Wetland)*
- **Function**: Final polishing and nutrient removal using natural processes.
- **Process**: Wastewater passes horizontally through gravel bed planted with wetland vegetation → microbial and plant root zones treat remaining contaminants.
- **Output**: **Clean water** (suitable for gardening, flushing, landscaping).
- **Added Value**: Aesthetic + ecological function (habitat, CO_2 absorption).

Capital Expenditure

S. No	Component	Unit Cost	Estimated Cost (INR)
1	**Land Development & Site Preparation**	₹17–20/sq.m (for 7,000 sq.m)	₹12,00,000
2	**Settler Tank (Primary)**	₹1.8 lakh per 100 KLD	₹18,00,000
3	**Anaerobic Baffled Reactor (ABR)**	₹2.5 lakh per 100 KLD	₹25,00,000
4	**Anaerobic Filter**	₹2 lakh per 100 KLD	₹20,00,000
5	**Planted Gravel Filter (PGF)**	₹400–500/sq.m (6,000 sq.m area)	₹30,00,000
6	**Plumbing, Pumps, Piping**	₹10/litre/day capacity	₹10,00,000
7	**Instrumentation, Valves, Flow Meters**	₹4/litre/day capacity (shared)	₹4,00,000
8	**Plantation for PGF (wetland plants)**	₹50–75/plant (6000 plants approx.)	₹3,00,000
9	**Boundary Wall + Landscaping**	₹1100–1300 per Rm	₹8,00,000
10	**Misc. Civil Works (manholes, footpaths)**	Lumpsum	₹5,00,000
11	**Contingency (5%)**	5% of project cost	₹6,75,000
	Total		₹1,41,75,000

Plant Species for PGF

Botanical Name	Common Name	Function
Phragmites karka	Common Reed	Fast-growing, excellent root aeration
Typha latifolia	Cattail	Strong root system, removes nutrients like nitrogen & phosphorus
Cyperus papyrus	Papyrus	Effective in sediment stabilization and aesthetics
Canna indica	Indian Shot	Beautiful, absorbs heavy metals
Colocasia esculenta	Taro/Arbi	Broad leaves, water-loving
Vetiveria zizanioides	Vetiver Grass	Sludge stabilizer, deep roots prevent clogging
Scirpus spp.	Bulrush	Tolerant to polluted water, pathogen reduction

Funding & Subsidies

Funding Source	%	Amount (INR)
AMRUT 2.0	50%	₹70,87,500
SBM 2.0	30%	₹42,52,500
KUIDFC (State Fund)	10%	₹14,17,500
ULB (Net Cost)	**10%**	**₹14,17,500**
Total	100%	₹1,41,75,000

Annual O & M Cost

Item	Description	Cost (INR/Year)
Labour	3 operators (round-the-clock)	₹6,00,000
Electricity	Pumps, lighting	₹1,20,000
Sludge Management	Dewatering/desludging every 6 months	₹1,00,000
Maintenance	Spare parts, chemicals	₹80,000
Monitoring & Testing	BOD/COD, turbidity, Fecal coliform	₹60,000
Total O&M/Year		**₹9,60,000** (~₹10 lakh/year)**

Revenue Mechanism

Stream	Description	Potential Income
Treated Water Sale	₹15/KL for construction/gardening use	₹4.5–5 lakh/year
CSR-Based O&M Support	Tie-ups with local industries	₹5–10 lakh/year
Carbon Credits / ESG Branding	Offset via emissions reductions	Long-term value
Green Certification & SDG Score	Improves city-level environment index	Non-monetary value

Impact Summary

Parameter	Before Project	After DEWATS
Wastewater Treated	~0 KLD	1,000 KLD
Households Benefitted	0	5,000–7,000
Surface Water Contamination	High	Reduced
Flood Risk	Medium	Lowered via infiltration
Operational Energy	High (if STP)	Low (gravity/biogas)
Community Engagement	Limited	Participatory O&M

Project Timeline (*M – Month)

Activity	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12
Land Acquisition & Clearances	■	■										
Detailed Project Report (DPR)	■	■										
Funding Approvals & Tendering		■	■	■								
Site Development & Excavation			■	■	■							
Civil Works - Settler & ABR				■	■	■	■					
Civil Works - Anaerobic Filter & PGF Bed						■	■	■				
Plumbing, Electrical & Instrumentation							■	■	■			
PGF Plantation & Landscaping								■	■	■		
Commissioning & Testing										■	■	
Staff Training & Handing Over											■	■

KEY MAP



LEGEND / INFERENCE



SCALE :

N

SHEET NO: **37**

SHEET TITLE: **Proposals**

SOURCE:
- *A review on decentralized wastewater treatment systems in India*
- *Author*

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Case Study of Gurupura River in the Coastal City of Mangaluru

Phasing and Governance

	Proposals	1 Year	2 - 5 Year	5 - 10 Year	> 10 Year	Acts/Policies/Schemes	Funds
Region	Regenerative Agriculture	Framers outreach & training	Pilot projects, scale-up in target villages	Region wide transition to regenerative model		Soil, health cards, Parampaaragat Kishi Vikas Yojana (PKVY)	ICAR, MoA&FW, PM-KISAN, NABARD's AgriSURE, SKDRDP
			Implementation on agriculture fields across Gurupura River Basin				
	Eco-Village	Village identification, workshops with farmers	Implementation & monitoring progress	Capacity building for livelihood diversification & transition to eco-village	Scaling up with multiple eco-villages in Gurupura Watershed	RURBAN Mission, Jal Sakthi Abhiyan, MGNREGA	RURBAN, CSR, International climate adaptation grants
	River Corridor	Demarcating riparian buffer and integrating in Regional Plan, Training for Traditional Water Harvesting techniques.	Riparian zone plantation by Community, Implementation of sustainable solutions	Monitoring & removal of invasive species		National River Conservation Plan, CAMPA	RURBAN, CSR, CAMPA, Panchayat funds
Planning Area	Infrastructure development & Livelihood diversification	Natural drain mapping, workshops for aquaculture, Pilot agro lab	Implementing soft infrastructure, testing salt tolerant crops, MAR & shallow dug wells for irrigation	Development of physical infrastructure	100% Sewer network coverage	Atal Bhujal Yojana, Jal Shakti Abhiyan, AMRUT 2.0	MoWR, SDRF, ULB funds, CSR
	Mangrove plantation & Wetland park	Awareness & training for mangrove afforestation, selection of species	Implementation & Monitoring of progress	Maintenance & monitoring		CRZ Notification 2019, NMCG, Wetland guidelines 2020	MoEFCC, NMCG, State Fisheries department, CAMPA
City	Eco-Industrial Park	Integrating Eco-industrial park into City Master Plan & site plans of proposed industries	Implementing & monitoring progress	Achieve 40% Target	Achieve 80% Target	NGT Guidelines, CPCB ETP norms, AMRUT 2.0	KIADB, AMRUT, Industries (PPP)
	River Bank Zoning	Integrating into master plan, Implementation	Achieve 40% Target	Achieve 80% Target		NMCG, CRZ, RRZ, Water Act, 1974	NMCG, AMRUT 2.0, Smart cities mission, Forest Department
			Implementing & monitoring progress				
	Focus area – wards (13 & 27)	Awareness & workshops for residents	Implementation & Monitoring program	Maintenance & monitoring		NUSP, Swachh Bharat Mission (SBM), Building bye-laws	SBM, ULB, Development bank fundings, CSR
	Green & Grey infrastructure	Augmentation & Implementation	Implementing & monitoring progress	Achieve 40% Target	Achieve 80% Target	SBM, AMRUT 2.0, Smart Cities Mission, URDPFI	AMRUT 2.0, ULB, KUIDFC
	Mangrove Conservation & Afforestation	Awareness & training for mangrove afforestation, selection of species	Implementation & Monitoring of progress	Achieve 40% Target	Achieve 80% Target	CRZ Notification 2019, NMCG, Wetland guidelines 2020	MoEFCC, NMCG, State Fisheries department, CAMPA
				Maintenance & monitoring			
	River Precinct	Integration in local area plan	Implementation & achievement – 100%			URMP, CRZ, Waterfront development guidelines - MoHUA	NMCG, AMRUT 2.0, Smart cities mission, ULB, CSR

Governance



	Proposals	Sector & Stakeholders	Implementation
Region	Regenerative Agriculture	*Agriculture, Irrigation, Farmers*	*Gram Panchayat and Agriculture Dept.*
	Eco-Village	*Environment, Tourism, Farmers*	*Gram Panchayat, Tourism Dept. GoK*
	River Corridor	*Environment, Water Resources, Gram Panchayat*	*Forest Dept., Gram Panchayat*
Planning Area	Infrastructure development & Livelihood diversification	*KUIDFC, Karnataka Water Resource Department, KUWSDB, Mangaluru Urban Development Authority, Residents & Farmers*	*KUIDFC, MUDA*
	Mangrove plantation & wetland park	*Environment, Karnataka Forest Department, CZMA, Fisheries department, Residents and Farmers*	*Karnataka Forest Dept., MUDA, CZMA*
City	Eco-industrial park	*Environment, Industry, Industries, KIADB, KSPCB, Residents, M.Corp, Industrial workers, Local communities, Fishermen*	*KIADB, KSPCB, Industries*
	River Bank Zoning	*Environment, Karnataka Water Resources, M.Corp, MUDA, CZMA*	*MUDA, M.Corp*
	Focus Area – wards	*Environment, Infrastructure, M.Corp, MUDA, Residents*	*KUIDFC, M.Corp*
	Green & grey infrastructure	*Infrastructure, M.Corp, MUDA, Residents*	*KUIDFC, M.Corp*
	Mangrove conservation & Afforestation	*Environment, CZMA, M.Corp, MUDA, Karnataka Tourism Department, Residents*	*Karnataka Forest Dept., MUDA, CZMA, M.Corp*
	River Precinct	*Environment, M.Corp, MUDA, Karnataka Tourism Dept, Residents*	*MUDA, M.Corp*

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KEY MAP



LEGEND / INFERENCE

SCALE :

N

SHEET NO: **38**

SHEET TITLE:
Phasing & Governance

SOURCE:
- *Author*

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