LIST OF FIGURES

Figure 1: Historical Development of Pune City .............................................................. 19
Figure 2: Pune and surrounding area .............................................................................. 23
Figure 3: Humidity and Rainfall of Pune and its surroundings ........................................ 25
Figure 4: Bioclimatic chart of Pune ................................................................................ 26
Figure 5: Geological Quadrangle Map ......................................................................... 29
Figure 6: Soil Regions in Pune and Surroundings ......................................................... 33
Figure 7: Population Density in Pune City and Surrounding area............................... 38
Figure 8: Decadal population growth trend in Pune ....................................................... 39
Figure 9: Forecasted population of Pune by various methods ....................................... 43
Figure 10: Road Network in City and Surrounding area .............................................. 45
Figure 11: Methodological framework of the study area ............................................. 47
Figure 12: Demographic analysis ................................................................................ 50
Figure 13: Contour map of study area (1970-80) .......................................................... 53
Figure 14: Digital Elevation Model ............................................................................... 54
Figure 15: Slope map of study area .............................................................................. 57
Figure 16: Stream Network of study area .................................................................... 59
Figure 17: Geomorphic zones of study area .................................................................. 62
Figure 18: Tree Census Map of Pune city .................................................................... 65
Figure 19: Tree Density ................................................................................................. 66
Figure 20: Vegetation Cover in Study area .................................................................... 67
Figure 21: Built-Up in study area .................................................................................. 68
Figure 22: Changes in Land Cover over the years from 1991 to 2015 (%) ...................... 76
Figure 23: LUand LC in 1991 (Landsat 5) ..................................................................... 78
Figure 24: LUand LC in 2000 (Landsat 5) ..................................................................... 79
Figure 25: LUand LC in 2010 (Landsat 5) .................................................................... 80
Figure 26: LUand LC in 2011 (Landsat 8) .................................................................... 81
Figure 27: Area under settlement (1991) ..................................................................... 83
Figure 28: Area under settlement (2015) ..................................................................... 83
Figure 29: Open/Barren Land in study area (1991) ...................................................... 85
Figure 30: Open/Barren Land in study area (2015) ....................................................... 85
Figure 31: Vegetation cover in study area (1991) ......................................................... 86
Figure 32: Vegetation cover in study area (2015) ......................................................... 87
Figure 67: Built-up area and Non Existing Streams in Ram Nadi Watershed area......152
Figure 68: Latitudinal Slope / Degree / Gradient analysis done by Profiles and buffer
around Ram Nadi ............................................................................................................154
Figure 69: Longitudinal Slope Profile of Ram Nadi....................................................154
Figure 70: Built-up area and Non Existing Streams in Nandoshi (Rivulet) ..............157
Figure 71: Cross profile of Nandoshi Watershed .....................................................158
Figure 72: Longitudinal Slope Profile of Nandoshi (Rivulet) .....................................159
Figure 73: Built-up area and Non Existing Streams in Ambil Odha (Rivulet).........161
Figure 74: Latitudinal Slope / Degree / Gradient analysis done by Profiles and buffer
around Ambil Odha (Rivulet) .......................................................................................163
Figure 75: Longitudinal Slope Profile of Ambil Odha (Rivulet) ..................................163
Figure 76: Built-up area and Non Existing Streams in Bhairoba Nala (Rivulet)........166
Figure 77: Longitudinal Slope / Degree / Gradient analysis done by Profiles and buffer
around Bhairoba Nala .................................................................................................167
Figure 78: Longitudinal Profile of Bhairoba Nala (Rivulet) ........................................168
Figure 79: Built-up area and Non Existing Streams in Wadki Nala (Rivulet) ..........171
Figure 80: Latitudinal Slope / Degree / Gradient analysis done by Profiles and buffer
around Wadki Nala (Rivulet) ....................................................................................173
Figure 81: Longitudinal Profile of Wadki -Nala (Rivulet) ..........................................173
Figure 82: Built-up area and Non Existing Streams in Wagholi (Rivulet) ...............176
Figure 83: Latitudinal Slope / Degree / Gradient analysis done by Profiles and buffer
around Wagholi (Rivulet) .........................................................................................177
Figure 84: Longitudinal Profile of Wagholi (Rivulet) ...............................................178
Figure 85: Residuals of built-up area in Ram Nadi watershed ...............................184
Figure 86: Residual plot: Distance from source vs. buil-up ....................................184
Figure 88: Figure 3: Residuals of barren land area in Ram Nadi Watershed ..........186
Figure 87: Residual plot: Distance from source vs. barren land .........................186
Figure 89: Residuals of water bodies area in Ram Nadi Watershed ......................187
Figure 89: Residual plot: Distance from source vs. Water bodies ..........................187
Figure 91: Residual plot: Distance from source vs. Vegetation cover ....................188
Figure 92: Residuals of vegetation cover in Ram Nadi Watershed .........................188
Figure 93: Residual plot: Distance from source vs. Agriculture Land ....................189
Figure 94: Residuals of Agricultural area in Ram Nadi Watershed .......................189
Figure 95: Residuals of Built-Up Land area in Nandoshi Watershed ...................190
Figure 96: Residuals of Barren area in Nandoshi Watershed ......................................... 190
Figure 97: Residual plot: Dist. from source vs. Built-Up ............................................... 191
Figure 98: Residual plot: Dist. from source vs. Barren Land ........................................ 191
Figure 99: Residuals of Vegetation cover in Nandoshi Watershed ..................................... 192
Figure 100: Residuals of Water bodies in Nandoshi Watershed .................................... 192
Figure 101: Residual plot: Distance from source vs. Vegetation Cover ............................... 193
Figure 102: Residual plot: Distance from source vs. Water Bodies .................................. 193
Figure 103: Residuals of Agricultural land in Nandoshi Watershed ................................ 194
Figure 104: Residual plot: Distance from source vs. Agricultur land ................................ 194
Figure 105: Residuals of barren land area in Ambil Odha Watershed ............................... 196
Figure 106: Residuals of built-up area in Ambil Odha Watershed ................................... 196
Figure 107: Residual plot: Distance from source vs. Built Up ....................................... 196
Figure 108: Residual plot: Distance from source vs. Barren Land .................................. 196
Figure 109: Residual plot: Distance from source vs. Water bodies .................................. 198
Figure 110: Residual plot: Distance from source vs. Vegetation cover .............................. 198
Figure 111: Residuals of Water bodies area in Ambil Odha Watershed .............................. 199
Figure 112: Residuals of Vegetation cover area in Ambil Odha Watershed ..................... 199
Figure 113: Residual plot: Distance from source vs. Agricultural Land ......................... 200
Figure 114: Residuals of Agricultural land area in Ambil Odha Watershed ..................... 200
Figure 115: Residuals of Built-Up area in Bhairoba Nala Basin ..................................... 202
Figure 116: Residuals of Barren Land area in Bhairoba Nala Basin ................................. 202
Figure 117: Residual plot: Distance from source vs. Barren Land .................................. 202
Figure 118: Residual plot: Distance from source vs. Built Up ....................................... 202
Figure 119: Residuals of Vegetation cover in Bhairoba Nala Basin .................................. 204
Figure 120: Residuals of Water bodies in Bhairoba Nala Basin ...................................... 204
Figure 121: Residual plot: Dist. from source vs. Vegetation Cover ................................... 204
Figure 122: Residual plot: Dist. from source vs. Water Bodies ....................................... 204
Figure 123: Residuals of Agricultural Land in Bhairoba Nala Basin ............................... 206
Figure 124: Residual plot: Distance from source vs. Agricultural land .......................... 206
Figure 125: Residuals of built-up area in Wadki Nala watershed .................................. 207
Figure 126: Residual plot: Distance from source vs. Built up ........................................ 207
Figure 127: Residual plot: Distance from source vs. Barren land .................................. 208
Figure 128: Residuals of barren land area in Wadki Nala Watershed .............................. 208
Figure 129: Residual plot: Distance from source vs. Water bodies ................................ 209
Figure 130: Residuals of Water bodies area in Wadki Nala Watershed ..........209
Figure 131: Residual plot: Distance from source vs. Vegetation cover .............210
Figure 132: Residuals of vegetation cover in Wadki Nala Watershed ...............210
Figure 133: Residual plot: Distance from source vs. Agricultural Land .............211
Figure 134: Residuals of Agricultural area in Wadki Nala Watershed ...............211
Figure 135: Residual plot: Distance from source vs. Barren Land ..................214
Figure 136: Residual plot: Distance from source vs. Built Up ........................214
Figure 137: Residuals of barren land area in Wagholi Basin ..........................214
Figure 138: Residuals of built-up area in Wagholi Basin ..............................214
Figure 139: Residual plot: Distance from source vs. Water bodies ...................216
Figure 140: Residuals of vegetation cover in Wagholi Basin ..........................216
Figure 141: Residuals of water bodies in Wagholi Basin ..............................216
Figure 142: Residual plot: Distance from source vs. Vegetation area ................216
Figure 143: Residuals of Agricultural land in Wagholi watershed ...................218
Figure 144: Residual plot: Dist. from source vs. Agricultural area ....................218
LIST OF TABLE

Table 1: Climate in Pune and surrounding area ................................................................. 24
Table 2: Stratigraphic succession of region ..................................................................... 30
Table 3: Earthquake shocks in Pune and surroundings .................................................. 35
Table 4: Population details for Pune (2011) .................................................................. 36
Table 5: Gender ratio in Pune city ................................................................................ 36
Table 6: Pune city area and density ............................................................................... 37
Table 7: Decadal growth rate of Pune from 1921 to 2011 .............................................. 39
Table 8: Forecasted population of Pune by various methods ......................................... 42
Table 9: Data Layer and its sources ............................................................................... 48
Table 10: DEM details .................................................................................................. 56
Table 11: Villages included in PMC limit as per 2014 .................................................... 69
Table 12: Pune Urban expanse zone ............................................................................. 70
Table 13: LANDSAT 5 Satellite Sensor Specifications .................................................. 72
Table 14: Landsat 5 Thematic Mapper (TM) .................................................................. 72
Table 15: Landsat 8 Thematic Mapper (TM) .................................................................. 73
Table 16: Overview of changes in Land Cover over the years from 1991 to 2015 ......... 75
Table 17: Difference from year 1991 to 2015 ................................................................. 82
Table 18: Morphometric parameters of Major Watersheds .......................................... 90
Table 19: Comparative LULC of Ram Nadi Watershed (1991 and 2015) ................. 104
Table 20: Comparative LULC of Nandoshi Watershed (1991 and 2015) ............... 112
Table 21- Comparative LULC of Ambil Odha Watershed (1991 and 2015) ............ 117
Table 22- Comparative LULC of Bhairoba Nala Watershed (1991 and 2015) ....... 124
Table 23 - Comparative LULC of Wadki Nala Watershed (1991 and 2015) .......... 131
Table 24 - Comparative LULC of Wagholi Watershed (1991 and 2015) .............. 137
Table 25: Existing Scenario of Streams in Watershed Areas ....................................... 141
Table 26: Existing Status of Streams in Pune City ......................................................... 142
Table 27: Wards and Village wise physiographical details ........................................... 143
Table 28: Land Use and Land Cover in 1991 (Hectors) ............................................... 146
Table 29: Land Use and Land Cover in 2015 (Hectares) .............................................. 147
Table 30: Latitudinal Slope / Degree / Gradient analysis of Ram Nadi ................. 153
Table 31: Longitudinal Slope / Degree / Gradient analysis of Ram Nadi ............... 154
Table 32: Longitudinal Slope of Ram Nadi ................................................................. 154
Table 33: Built-up area analysis of Ram Nadi Watershed area .................................................. 156
Table 34: Latitudinal Slope / Degree / Gradient analysis of Nandoshi (Rivulet) ................. 157
Table 35 : Longitudinal Slope/Degree/Gradient analysis of Nandoshi (Rivulet) ................. 158
Table 36: Longitudinal Slope Profile of Nandoshi (Rivulet) ..................................................... 159
Table 37: Built-up area analysis of Nandoshi (Rivulet) watershed area ............................. 160
Table 38: Latitudinal Slope / Degree / Gradient analysis of Ambil odha (Rivulet) ............ 162
Table 39 : Longitudinal Slope / Degree / Gradient analysis of Ambil Odha (Rivulet) ...... 163
Table 40: Longitudinal Slope Profile of Ambil Odha (Rivulet) ............................................. 163
Table 41 : Built-up area analysis of Ambil Odha (Rivulet) Watershed area ....................... 165
Table 42 : Latitudinal Slope / Degree / Gradient analysis of Bhairoba Nala (Rivulet) .. 166
Table 43 : Longitudinal Slope/Degree/Gradient analysis of Bhairoba Nala (Rivulet) .... 168
Table 44: Longitudinal Profile of Bhairoba Nala (Rivulet) ................................................. 168
Table 45 : Built-up area analysis of Bhairoba Nala (Rivulet) Watershed area ................. 169
Table 46: Latitudinal Slope / Degree / Gradient analysis of Wadki Nala (Rivulet) ...... 171
Table 47 : Longitudinal Slope/Degree/Gradient analysis of Wadki Nala (Rivulet) ........ 173
Table 48: Longitudinal Profile of Wadki -Nala (Rivulet) ..................................................... 174
Table 49 : Built-up area analysis of Wadki -Nala (Rivulet) Watershed area .................... 175
Table 50 : Latitudinal Slope / Degree / Gradient analysis of Wagholi (Rivulet) ............ 176
Table 51 : Longitudinal Slope/Degree/Gradient analysis of Wagholi (Rivulet) ............ 177
Table 52: Longitudinal Profile of Wagholi (Rivulet) .......................................................... 178
Table 53 : Built-up area analysis of Wagholi (Rivulet) Watershed area ........................ 179
Table 54: Residuals of built-up area .................................................................................. 185
Table 55: Residuals of Barren land area ........................................................................... 186
Table 56: Residuals of Water bodies area ....................................................................... 187
Table 57: Residuals of Vegetation cover area .................................................................. 188
Table 58: Residuals of Agriculture land area .................................................................. 189
Table 59: Residuals of Built - up .................................................................................... 191
Table 60: Residuals of Barren Land ............................................................................... 191
Table 61: Residuals of Water bodies .............................................................................. 193
Table 62: Residuals of Vegetation Cover ......................................................................... 193
Table 63: Residuals of Agricultural land ........................................................................ 195
Table 64: Residuals of Built-up ...................................................................................... 197
Table 65: Residuals of Barren Land ............................................................................... 197
Table 66: Residuals of Water bodies .............................................................................. 198
Table 67: Residuals of Vegetation cover .................................................................198
Table 68: Residuals of Agricultural area .................................................................200
Table 69: Residuals of Built Up..................................................................................203
Table 70: Residuals of Barren Land .............................................................................203
Table 71: Residuals of Water Bodies ............................................................................205
Table 72: Residuals of Vegetation Cover .................................................................205
Table 73: Residuals of Agricultural area .................................................................206
Table 74: Residuals of Built Up ..................................................................................208
Table 75: Residuals of Barren Land .............................................................................209
Table 76: Residuals of Water bodies ...........................................................................209
Table 77: Residuals of Vegetation Cover .................................................................211
Table 78: Residuals of Agricultural area .................................................................212
Table 79: Residuals of Built Up ..................................................................................215
Table 80: Residuals of Barren Land .............................................................................215
Table 81: Residuals of Water bodies ...........................................................................217
Table 82: Residuals of Vegetation cover .................................................................217
Table 83: Residuals of Agricultural area .................................................................218
LIST OF PHOTOPLATS

Photo 1: Retaining wall in Ram Nadi channel (Front View) ........................................ 106
Photo 2: Retaining wall in Ram Nadi channel (Back View) .......................................... 106
Photo 3: Dumping in Channel ..................................................................................... 107
Photo 4: Construction and Dumping near Channel ...................................................... 107
Photo 5: Construction on Hill Slope (Bavdhan Area) .................................................... 107
Photo 6: Construction on Stream (Banner - Pashan Road) .......................................... 107
Photo 7: Sewage dumping in channel (Pashan Gaothan) .............................................. 109
Photo 8: Silt deposition near Pashan Lake ..................................................................... 109
Photo 9: Construction on stream near Chandani chowk – Bawdhan ......................... 109
Photo 10: Sewage dumping and unwanted vegetation in channel (Bhugaon) .............. 109
Photo 11: Sewage in Channel ..................................................................................... 114
Photo 12: Garbage Dumping in Channel near Kirkitwadi ........................................... 114
Photo 13: Ambil Odha from Katraj Lake ................................................................... 114
Photo 14: Condition of Channel at Bibvewadi ............................................................ 120
Photo 15: Construction in Channel at Mangadewadi .................................................. 120
Photo 16: Slope cutting near Bhilarewadi Lake ............................................................ 120
Photo 17: New Katraj Lake ......................................................................................... 121
Photo 18: Dumping in Channel at Katraj ..................................................................... 121
Photo 19: Sewage line from Katraj Lake ..................................................................... 121
Photo 20: Hill cutting at Mangadewadi, Bhilarewadi .................................................. 121
Photo 21: Massive dumping near Gangadham Society ............................................... 121
Photo 22: Quarrying activity at Yevalewadi ................................................................. 126
Photo 23: Construction material along the road (Kondhwa) ....................................... 126
Photo 24: Hill Cutting at Kondhwa road ..................................................................... 127
Photo 25: Dumping in channel at Kondhwa road ....................................................... 127
Photo 26: Construction material along the channel ..................................................... 127
Photo 27: Construction on the stream near hill slope ................................................. 127
Photo 28: Hill cutting at upper catchment area ............................................................ 133
Photo 29: Construction at hill slope ............................................................................ 133
Photo 30: Quarrying activity near Bapdev ghat ........................................................... 134
Photo 31: Construction and dumping along the stream .............................................. 134
Photo 32: Dumping in stream ................................................................. 134
Photo 33: Condition of Autadewadi Lake .............................................. 134
Photo 34: Hill cutting and plotting at Undri ........................................... 134
Photo 35: Construction material in the channel at Nagar road highway 139
Photo 36: Sewage dumping in the stream .............................................. 139
Photo 37: Road on stream ................................................................. 140
Photo 38: Construction of school on stream (Stream blocking) .......... 140
Photo 39: Stream blocking by construction in Kharadi ....................... 140
Photo 40: Construction on Stream ................................................. 140