

A WEBGIS VISUALIZATION TO IDENTIFY GROWTH PATTERN FOR URBAN EXPANSION USING REMOTE SENSING SATELLITE IMAGES – A CASE STUDY FOR SURAT, GUJARAT, INDIA

Samarjeet Salunke¹

¹ Research Student, Centre for Environmental Planning and Technology University, Navarangpura, Ahmedabad, Gujarat – 380009, India
Email: salunkesamarjeet@gmail.com

KEYWORDS: Shannon's Entropy, Iso Cluster Unsupervised Classification, Landsat 5-8, WebGIS, API

ABSTRACT:

Urban sprawl and settlements grow in different direction with indefinite borders between rural and urban areas leading to the development of the city. Remote sensing (RS) and Geographical Information System(GIS) technologies are to identify, study & analyze the urban expansion pattern. Surat city, Gujarat, India was the 4th fastest growing Indian city in 2016 as per a study conducted by international think tank city Mayors Foundation. This paper study mainly aims to identify urban sprawl for Surat city from 4 decade years 1990-2000-2010-2020.

Landsat 5 & Landsat 8 RS satellite multi spectral 30-meter resolution images were used as input data to identify urban sprawl. Land Use Land Cover (LULC) classification for all 4 decade years were obtained by performing Iso Cluster Unsupervised Classification from Landsat imagery. Obtained classified images were reclassified mainly into 2 classes i.e. urban and non-urban. Further urban class was separately extracted using conditional tools in ArcGIS. Shannon's entropy was computed to detect the urban growth of Surat city. Shannon's entropy standard modelling equation was used and higher value of entropy was obtained indicating occurrence of sprawl. Mutli ring buffers of each radius distance interval of 2km were created to calculate the Shannon's Entropy of the urban class for all the images.

Total Entropy value for the year 1990, 2000, 2010 & 2020 are 1.657, 1.752, 1.766 & 1.848 respectively. The values of entropy are around 55% of the $\log(n)$, hence it shows dispersion in the region. Comparison graphs was created to compare Shannon entropy values from which compact development within the first 7km of Central business district(CBD) and beyond 7km dispersed growth was observed. From the above values the growth pattern for Surat city is radial and can be seen more in the southern part of the Tapti river from south west to south east. Very little increase in the urban area is visible in the northern region of the Tapti river. Three compact clusters can be seen being developed in the eastern, south-eastern & south Surat which contribute to the dropping entropy in the 10km & 18km buffer rings.

For better visualization of urban sprawl in decision making for urban planner in development of city a webpage is created on WebGIS platform (ArcGIS online, HTML5, JavaScript, CSS, bootstrap etc.). ArcGIS JavaScript API-4.14 were used for time series visualization for urban sprawl.

Introduction:

In the developing world, an unprecedented expansion of urban area and growth of urban population can be seen at such a pace that is likely to be expected that 60 percent of the world's population will live in urban areas by 2030(Rahman et al., 2011), with most of the urban growth will occur in less developed countries. In India, during past decades, there has been a human revolution where people began to live in relatively dense urban region. Resources like industrial revolution, better economic opportunities, better infrastructure facilities, better standard of living, growth of private sector etc. have been a key reason for human to settle down himself in from rural to urban regions. The unplanned and unorganized urbanization can lead to several kind of environmental changes(Uttara et al., 2012). Therefore, monitoring land use in urban settlements is considered to be important factor, leading to the development of the city in different directions.

In India, at many places it has been witnessed that there is rapid and uncoordinated growth of urban settlements at their fringes later which can be defined as urban sprawl. Also, a linked phenomenon of rapid growth outside the actual agglomeration boundaries is described as leapfrog development, later was observed in minor, major cities across the world(Rahman et al., 2011). This kind of unplanned urbanization creates unnecessary problems and brings greater impact on environment and human life. It becomes necessary for urban planner and government to monitor land use land cover (LULC) changes across the region. Since, LULC changes needed to be monitor location wise, Geographical Information System (GIS) and Remote Sensing (RS)(Aswal et al., 2018) have been one of the important tool and technology to identify LULC changes. The physical changes and patterns of sprawl on landscapes can be detected, mapped and analyzed using GIS and RS using processed satellite imagery.

Region of Study and Data:

We use Surat City, Surat Municipal Corporation (SMC) as the study region (Figure 1(a)). Surat city has a population(Cooperation, 2020) of 44.68 lakhs (2011 census), making it one of the highest populous city in Gujarat state. The city is located in the south-eastern region of Gujarat, India. The city's geographical location is 21.1702° N, 72.8311° E(Cooperation, 2020). In context to GIS data, the administrative city boundary data was collected from SMC in shape file format. City center was identified from given administrative boundary which later was used to create buffer rings. Four decadal years 1990, 2000, 2010 and 2020, time span were considered to identify the urban sprawl. Freely available satellite data 30 meter resolution Landsat 5 for dates 25/03/1990, 20/03/2000, 03/05/2010 and Landsat 8 for date 08/02/2020 was downloaded from earth explorer(EarthExplorer Help Documentation, 2013). To identify the urban sprawl, urban features was needed to be extracted from regular zones therefore, a multiple buffer rings of 24 km radial distance was created with respect to the city center.

Methodology and System Architecture:

Geo-spatial Boundary and Satellite Imagery -

Looking at the problem statement, a methodology (Figure 3) was developed to achieve the results. The city administrative boundary was collected from SMC which was used as reference extent of Surat city. To identify the urban sprawl taking places across the Surat city, an extent was required to be set from city center. City center was marked with respect to the city boundary which was later used to create the buffer rings for analysis. Zone wise analysis was considered which was best fit for Surat city to identify the urban sprawl. Therefore, multiple buffer rings of 24 km radial distance were created using ArcGIS pro software (ArcGIS al. 2020). The area between each buffer was considered as the zone to analyze urban sprawl. Later the satellite images with respective dates were downloaded as described above. While downloading the satellite image, data containing respective cloud free images were downloaded. As each downloaded satellite image contains several bands within it, out of which band 4-3-2 for Landsat 5 and 5-4-3 for Landsat 8 was taken for False Color Composite (FCC) combination(EarthExplorer Help Documentation, 2013). This selected bands were required to stacked in single layer for analysis. Layer stacking of image was done in ArcGIS pro to obtain single stacked image.

Processing Satellite Imagery:

LULC can be obtained through processing stacked image. To obtain the classified image, unsupervised classification function was used in ArcGIS pro over the stacked satellite image. In unsupervised classification, Iso Cluster classification method (Rahman et al., 2011)was used to obtain the classified satellite image. Since 10 number of class were defined during iso-cluster classification method, therefore the obtained classified satellite image contain 10 classes features. These 10 classes now need to be reclassified into 4 classes mainly urban, vegetation, waste land and water respectively. Reclassify geoprocessing tool was used in ArcGIS pro. Now, we have obtained processed LULC from satellite image (Figure 1(b)(c)(d)(e)). Now from obtained LULC we can observe that, value 1 specified in layer symbology indicate urban feature. Further, since we require only urban class to identify the urban sprawl, we need to extract only urban pixel (value 1) from the processed satellite. Below expression is used in raster calculator geoprocessing tool in ArcGIS pro to extract the urban pixels.

CON ("LULC layer name"==1, "LULC layer name")

For above, "LULC layer name" indicate the layer name from urban class feature needs to be extracted and 1 is the value of urban pixel containing the urban class. Repeat the entire process from layer stacking to urban feature extraction for all the downloaded images of respective dates. After completing this process, you can get map of required urban feature (Figure 3 (a)(b)(c)(d)) respectively.

Shannon's Entropy, determine urban sprawl:

An index was required that can determine and characterizes the distribution of the built up as a function of the area of built up within the defined spatial unit zones. One of the measures commonly used to study growing pattern of urban sprawl is Shannon's Entropy (Rahman et al., 2011)which show case the concentration or dispersion of a spatial variable within the specified given region. Below formula is used to measure the degree of spatial concentration or dispersion of geophysical variable.

$$\text{Shannon's Entropy } (H_n) = -\sum P_i \log_e (P_i)$$

where, P_i is the probability of variable occurring in the i^{th} zone that is total urban area in a zone divided by total area of that particular zone and n is the total number of zones. Use extract by mask geoprocessing tool from ArcGIS pro to mask urban pixel for buffer zone. Use this equation against the obtained extracted urban feature layer. Further, proceeded to calculate urban area in each zone using zone histogram geoprocessing tool in ArcGIS pro and transpose the fields then join with the obtained buffer shape file (Figure 4 (a)(b)(c)(d)). From the attribute table of obtained layer used field calculate and calculate Shannon's Entropy values for each year. All obtained entropy values are listed below (Table 1). Further to identify the growth patterns and spread of urban sprawl sum of all the Entropy value of respective year.

Visualization:

An WebGIS user interactive webpage (Figure 5(a)) is developed using ArcGIS JavaScript Application Protocol Interface(API)(Now et al., 2019). Extracted urban feature layers of respective years are published on using ArcGIS online server. Using this API function and methods are used to develop a WebGIS webpage. Here, user can select, query, filter and time series visualize meta data of layer to understand and visualize urban sprawl.

Results:

Total Entropy value for the year 1990, 2000, 2010 & 2020 are 1.657, 1.752, 1.766 & 1.848 respectively. The values of entropy are around 55% of the $\log(n)$, hence it shows some dispersion in the region. From the (Figure 5(c)), it is visible that the value of Shannon's Entropy is less near the Central business district (CBD) and increases beyond the radius of 7km approximately. This says that there is compact development within the first 7km from CBD. Beyond 7km, dispersed growth is visible as people might be moving towards outer rings or increase in population due to urbanization can be the reason for the expansion of the city. Very little increase in the urban area is visible in the northern region of the Tapti river. Three compact clusters can be seen being developed in the eastern, south-eastern & south Surat which contribute to the dropping entropy in the 10km & 18km buffer rings. An overlay of all urban extracted feature (Figure 5 (b)) can visualize and interpreted that, beyond SMC administrative boundary there is an urban expansion dispersed growth in southern, south-west & north –west side of city. Using WebGIS webpage, user can visualize urban sprawl and growth pattern.

References:

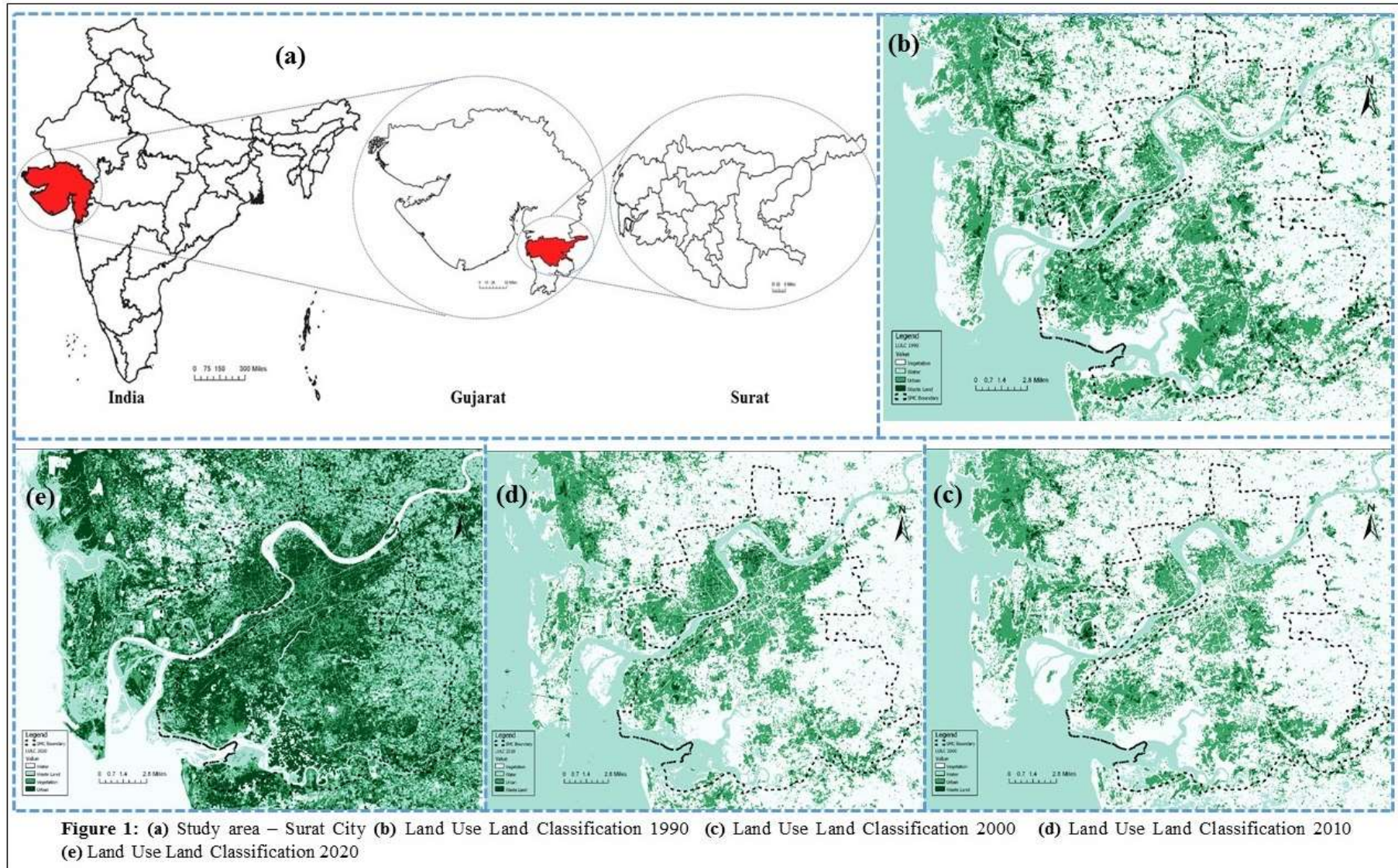
- Aswal, P., Saini, R., & Tanzeem, M. (2018). Spatio Temporal Monitoring of Urban Sprawl using GIS and Remote Sensing Technique . *International Journal of Computer Applications*, 182(27), 11–24. <https://doi.org/10.5120/ijca2018918100>
- Coorporation, S. M. (2020). *Wikipedia Surat Muncpal Coorporation*. Wikipedia contributors. (2020, October 14). Surat. In Wikipedia, The Free Encyclopedia. Retrieved 09:08, October 14, 2020, from <https://en.wikipedia.org/w/index.php?title=Surat&oldid=983444927>. <https://en.wikipedia.org/wiki/Surat>
- EarthExplorer Help Documentation*. (2013). *September*.

- Now, L., Server, A., Api, A. S., Api, A. S., Api, A. S., The, J., & Api, A. S. (2019). *Basic Steps for Creating an Application with the ArcGIS Server API for JavaScript*.
- Rahman, A., Aggarwal, S. P., Netzband, M., & Fazal, S. (2011). Monitoring Urban Sprawl Using Remote Sensing and GIS Techniques of a Fast Growing Urban Centre, India. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 4(1), 56–64. <https://doi.org/10.1109/JSTARS.2010.2084072>
- Uttara, S., Bhuvandas, N., & Aggarwal, V. (2012). IJREAS Volume 2, Issue 2 (February 2012) ISSN : 2249-3905 IMPACTS OF URBANIZATION ON ENVIRONMENT. *Ijreas*, 2(2), 1637–1645.
- Wikipedia contributors. (2020, October 14). Surat. In *Wikipedia, The Free Encyclopedia*. Retrieved 09:36, October 14, 2020, from <https://en.wikipedia.org/w/index.php?title=Surat&oldid=983444927>
- Wikipedia contributors. (2020, September 26). ArcGIS. In *Wikipedia, The Free Encyclopedia*. Retrieved 09:41, October 14, 2020, from <https://en.wikipedia.org/w/index.php?title=ArcGIS&oldid=980380783>

Table

| Buffer Distance(km) | Shape Area(Sq.km) | Urban (1990) | Urban (2000) | Urban (2010) | Urban (2020) | Entropy (1990) | Entropy (2000) | Entropy (2010) | Entropy (2020) |
|----------------------------|--------------------------|---------------------|---------------------|---------------------|---------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 2 | 12.558 | 3.867 | 5.357 | 6.834 | 5.171 | 0.159 | 0.158 | 0.144 | 0.158 |
| 4 | 50.249 | 17.751 | 20.839 | 28.893 | 20.331 | 0.159 | 0.159 | 0.138 | 0.160 |
| 6 | 113.072 | 37.354 | 40.317 | 54.592 | 38.929 | 0.159 | 0.160 | 0.153 | 0.159 |
| 8 | 201.028 | 60.818 | 60.723 | 83.747 | 59.207 | 0.156 | 0.157 | 0.158 | 0.157 |
| 10 | 314.118 | 91.872 | 77.36 | 105.425 | 73.350 | 0.148 | 0.150 | 0.159 | 0.156 |
| 12 | 452.139 | 127.795 | 99.031 | 130.000 | 90.572 | 0.140 | 0.144 | 0.151 | 0.155 |
| 14 | 615.461 | 167.904 | 130.344 | 157.088 | 109.125 | 0.133 | 0.143 | 0.147 | 0.154 |
| 16 | 803.914 | 215.253 | 163.290 | 187.242 | 129.915 | 0.128 | 0.141 | 0.147 | 0.153 |
| 18 | 1017.502 | 259.047 | 195.353 | 217.167 | 150.425 | 0.123 | 0.138 | 0.143 | 0.151 |
| 20 | 1256.220 | 306.355 | 232.077 | 255.118 | 175.365 | 0.119 | 0.135 | 0.141 | 0.149 |
| 22 | 1520.073 | 360.618 | 274.304 | 299.741 | 204.790 | 0.117 | 0.134 | 0.139 | 0.148 |
| 24 | 1809.053 | 423.538 | 326.019 | 343.581 | 235.696 | 0.115 | 0.134 | 0.137 | 0.148 |
| SUM | | | | | | 1.657 | 1.752 | 1.766 | 1.848 |

Figures



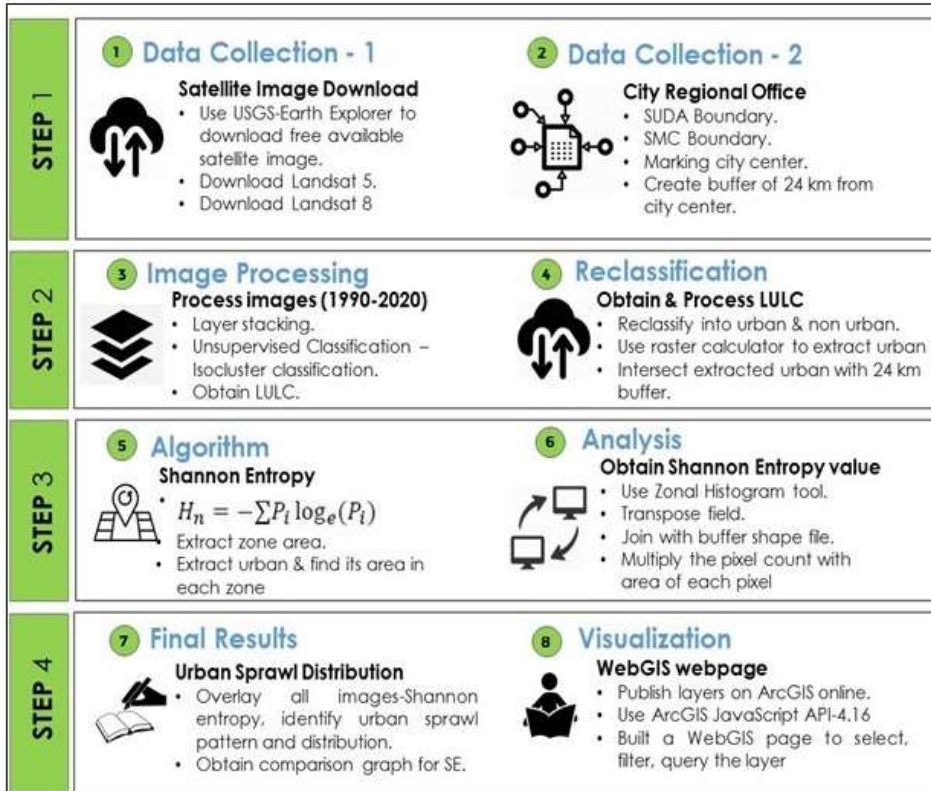


Figure 2: Methodology

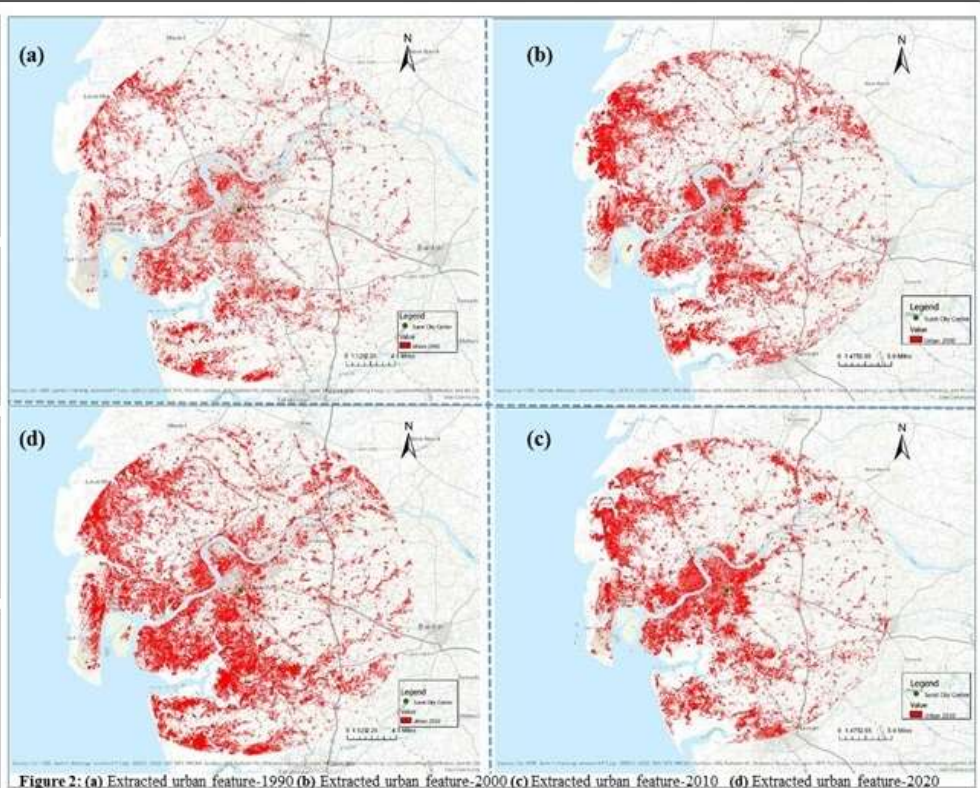


Figure 3: (a) Extracted urban feature-1990 (b) Extracted urban feature-2000 (c) Extracted urban feature-2010 (d) Extracted urban feature-2020

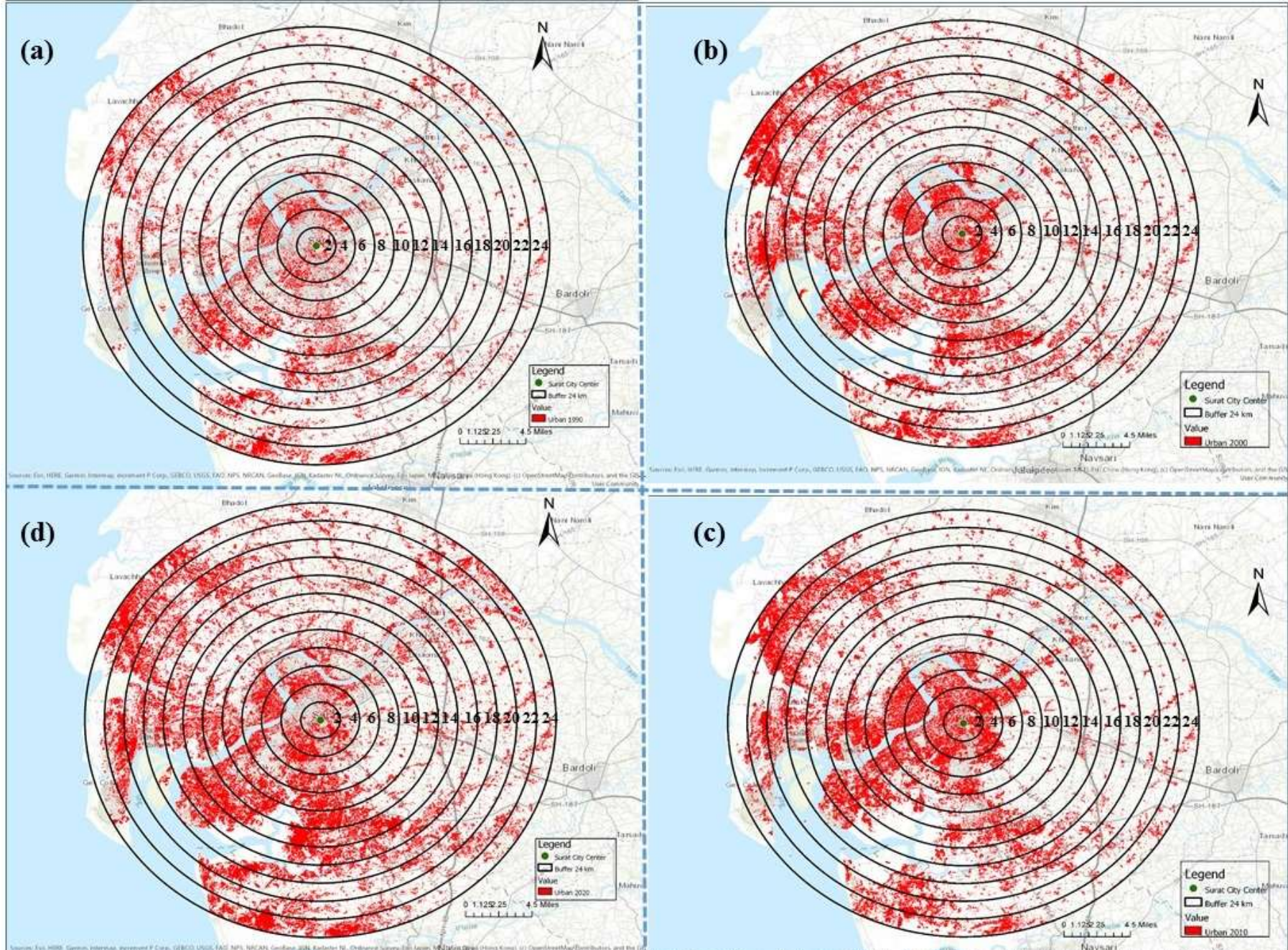


Figure 4: (a) Urban feature with buffer-1990 (b) Urban feature with buffer-2000 (c) Urban feature with buffer-2010 (d) Urban feature with buffer-2020

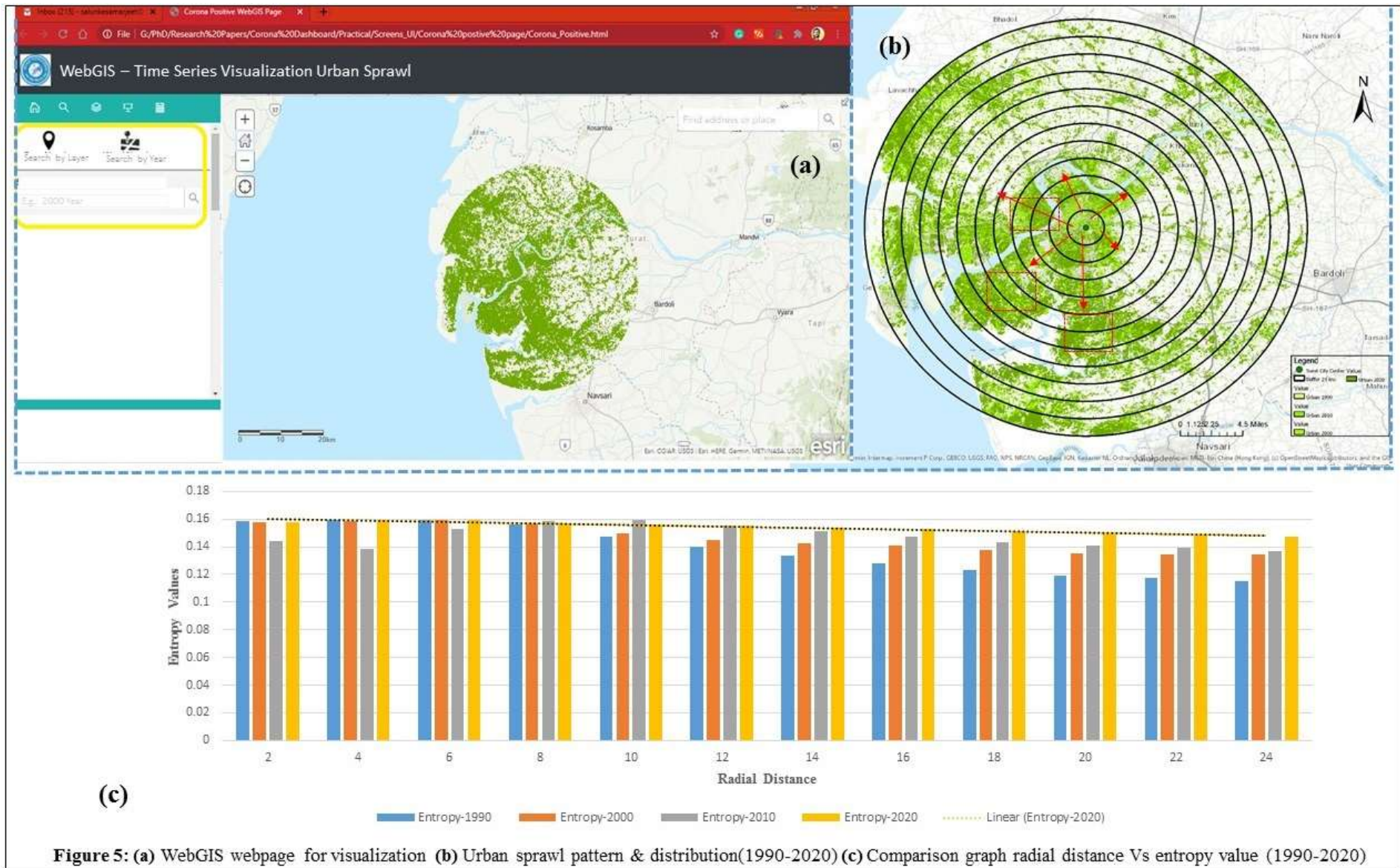


Figure 5: (a) WebGIS webpage for visualization (b) Urban sprawl pattern & distribution(1990-2020) (c) Comparison graph radial distance Vs entropy value (1990-2020)

Supplementary Material:

Below is the part of javascript code used to create WebGIS webpage using ArcGIS JavaScript API-4.14

```
<html>
<head>
  <meta http-equiv="Content-Type" content="text/html; charset=utf-8">
  <meta name="viewport" content="initial-scale=1, maximum-scale=1,user-scalable=no" />
  <title>Urban Sprawl Visualize</title>
  <link rel="stylesheet" href="https://js.arcgis.com/4.14/esri/themes/light/main.css" />
  <script src="https://ajax.googleapis.com/ajax/libs/jquery/3.4.1/jquery.min.js"></script>
  <script src="https://cdnjs.cloudflare.com/ajax/libs/popper.js/1.16.0/umd/popper.min.js"></script>
  <script src="https://maxcdn.bootstrapcdn.com/bootstrap/4.4.1/js/bootstrap.min.js"></script>
  <style> html,body{ padding: 0;margin: 0;height: 100%;width: 100%;overflow: hidden;}
</style> <script src="https://js.arcgis.com/4.14/"></script>
<script> require([
  "esri/Map",
  "esri/views/MapView",
  "esri/geometry/Extent",
  "esri/widgets/Home",
  "esri/widgets/Search",
  "esri/widgets/BasemapToggle",
  "esri/widgets/ScaleBar",
  "esri/widgets/FeatureForm",
  "esri/layers/GroupLayer",
  "esri/layers/FeatureLayer",
  "esri/widgets/Legend",
  "esri/widgets/Expand",
  "esri/widgets/LayerList",
  "dojo/dom-class",
  "dojo/domReady!"
], function (Map, MapView, Extent, Home, Search, BasemapToggle, ScaleBar,
  FeatureForm, GroupLayer, FeatureLayer, Legend, Expand, LayerList, domClass);
var template1 = {
  title: "PopUp Deatials - Permit Details",
  content: [{type: "fields",fieldInfos: [{
    fieldName: "app_id",
    label: "Application Number",
    format: {
      digitSeparator: true,
      places: 0
    }
  }
  }
  ]
  }
  }];
// call hosted feature layer from ArcGIS online portal
var Layer1 = new FeatureLayer({url:
  "https://services5.arcgis.com/SdS7y1YLWQcteheU/arcgis/rest/services/Scantioned_sam
  ple_data/FeatureServer",
  popupTemplate: template1,
  title: "Permit Data",
  visible: true,
  visibilityMode: "exclusive"});
// set default function of esri
var map = new Map({basemap: "topo",layers: [Layer3, Layer2, Layer1]});
var view = new // set view esri parameter
MapView({container: "viewDiv",map: map,center: [73.1480,18.9894],zoom:13});
var featureLayerPermitNumber = Layer1; sources: [{ layer: featureLayerPermitNumber,
  var searchWidget = new Search({ searchFields: ["app_id"],
  view: view, displayField: "app_id",
  searchAllEnabled: false, suggestionTemplate: "{app_id}",
  includeDefaultSources: false, exactMatch: false,
  locationEnabled: false, name: "app_id",
  popupEnabled: false, placeholder: "Eg: 10",
  allPlaceholder: "Search", enableSuggestions: true },]);
  container: "PIN",
// view layer legend
var legend = new Legend({view: view,container: "legend",title: "Legends"});
// view basemap toggle
var toggle = new BasemapToggle({view: view,nextBasemap: "satellite"});
view.ui.add(toggle, "bottom-right");
var scaleBar = new ScaleBar({view: view,unit: "dual" });
view.ui.add(scaleBar, { position: "bottom-right" });
const nameArcade = "$feature. Urban";const nameClass = {labelPlacement: "above-center",
  labelExpressionInfo: {expression: nameArcade},maxScale: 100000,
  minScale: 16000}; Layer2.labelingInfo = nameClass;
</script>
</head>
<body class="calcite">
  <nav class="navbar navbar-expand-sm navbar-dark bg-dark fixed-top"><!-- Brand/logo -->
  <a class="navbar-brand" href="#"> <span style="padding-left:10px;">NAINA - CIDCO</span> <a> </nav>
</body>
</html>
```