Developing Custom ArcGIS Tools to Prepare Data for Solar Potential Analysis using Remote Sensing Data and Image Processing Techniques

A Case Study of RajendraNagar Ward, GHMC, Hyderabad

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Abstract — we observe that India is continually relying on the Fossil Fuels to supply current electricity needs of the County. Hence there is a need to search for the alternative and cleaner Energy sources to generate Electricity. As seen during the last decade that there was a rapid growth in cities and Urbanization has its environmental effects and challenges which require a very precise study, analysis and planning of urban infrastructure such as Hyderabad city. This Paper identifies a methodology to develop a set of data preparation tools to produce various thematic Layers to Identify the Potential of the Renewable Energy especially Solar Energy in Urban, Semi Urban & rural Areas. A review of the functionality of the each custom built tool along widely available tools/toolset present in the ArcGIS Software. Methodology is studied and implemented for producing relevant data layers such as Radiation Data using DEM, an Urban Land Use Land Cover (LULC) using the Satellite image, vector layers (Feature classes) prepared based on the Survey of India (SOI) Toposheet, Google Places, etc and by applying various image processing techniques available within the software like Erdas Imagine and ArcGIS. The Resultant maps are later generated from a various custom tools built. The Remote Sensing Data used in this paper are DEM & Satellite Image with any spatial resolution as discussed below.

Keywords - DEM; Land Use Land Cover (LULC); Image Processing Techniques; Satellite Image; Remote Sensing; ArcGIS

I. INTRODUCTION

In recent times, the nature and magnitude of global energy demands are changing rapidly and increased in an uncontrollable manner, especially with today’s rapid population growth and modernization [4]; [9]. Since the Industrial Revolution from the 18th to the 19th century, conventional fossil fuels have been largely consumed [9] and consequently, various greenhouse gases (such as, CO2, CH4, etc.) have been emitted into the atmosphere. This has led to an abnormal increase in the Earth’s average atmospheric temperature and other environmental concerns [7]; [9]. Renewable or cleaner & green forms of energy have been proposed as substitute for primary energy resources, and are now generally believed to be capable of meeting much of the growing energy demand [7].

As we also observe that the solar energy is being replaced with the conventional non-renewable energy and is widely implemented around the world. Currently, the most challenging problem is how to improve the efficiency of producing solar energy. Before installing solar panels, analysis & assessing where solar panels should be placed can significantly benefit panel performance. This study aims to develop a set of the Custom Tools in ArcGIS for the Preparing the input data to conduct a site selection analysis for solar panel installation using Geographical Information Systems (GIS) [2].

The need to address the current challenge of rising demand for electricity, coupled with a declining fossil fuel base and the implications of greenhouse gas emissions, has stimulated efforts worldwide to develop cheap and reliable supplies of electricity from renewable sources. Some of these, particularly geothermal and hydro power, are restricted to highly specific locations, thereby increasing the cost of electricity distribution [8], while the potential environmental costs of developing sources such as bio-fuels and hydro necessitate appropriate policy and legislative frameworks to minimize these impacts [10];[11]. The issue of intermittent supply and matching peak demand is a problem which is particularly relevant to wind power, although the abundance of suitable sites has facilitated its adoption in many countries worldwide [5] where as its actual implementation will incur more potential cost. Resources & Assessments when compared to Solar power, involving the conversion of solar energy to electricity, which is
This solar PV electricity is commonly generated through solar cells setup, thereby enabling electricity to be generated during the sunlight hours.

Around 54 percent of the world population currently lives in urban areas. The worldwide urban population has grown rapidly estimated from 746 million in 1950 to 3.9 Billion in 2014 and is expected to surpass six billion by 2045, estimated to reach 6.47 Billion by 2050. Asia, despite its lower level of urbanization, is home to 53 per cent of the world’s urban population [26]. Persistent dynamic urban change processes, especially the remarkable worldwide expansion of urban populations and urbanized areas, affect natural and human systems at all geographic scales, and are expected to accelerate in the next several decades [19]. Worsening conditions of crowding, housing shortages, insufficient infrastructure, and increasing urban climatologically and ecological problems require consistent monitoring of urban regions.

The literature review suggests that there are major approaches over the past decade include pixel-based (image classification, regression, etc.), sub-pixel based, object-oriented algorithms, etc. have been explored. The majority of research efforts have been made for mapping urban landscapes at various scales and on the spatial resolution requirements of such mapping. In contrast, there is less interest in Producing urban LULC by using Vector based layers and convert the satellite image to Raster LULC which matches the Exactly same as the Vector Land use and Land cover using some of the Image processing techniques. More researches are also needed to producing better and optimum Urban LULC based on the requirements for urban Planning & mapping. It is suggested that the models, methods and image analysis algorithms in urban remote sensing have been largely developed, as the advent of high spatial resolution satellite images, Space-borne Hyperspectral images and LiDAR data which is stimulating new research idea and innovations that are needed in driving the future research trends with new models and algorithms for the Urban Planning and the Land use Land cover assessment [34].

II. LITERATURE REVIEW

Model Builder is an application we can use to create, edit, and manage models. Models are workflows that string together sequences of geo-processing tools, The Model Builder can also be thought of as a visual programming language for building workflows. While Model Builder is very useful for constructing and executing workflows, it also provides advanced methods for extending ArcGIS functionality by allowing you to create and share your models as tool. Model Builder can even be used to integrate ArcGIS with other applications.

There are a variety of ways you can connect data to tools; a common method is to use the Add Connection tool.

Once you have connected data to tools, you can execute the model from within Model Builder by clicking the Run button.

There are two primary uses of Model Builder:

- To immediately execute a tool sequence we create.
- To create tools that we can use like any other tool—from the tool dialog box, from Python scripts, or in another model

a) The Model Builder interface:

Model Builder has a simple interface with drop-in menus, tools on a toolbar, and shortcut menu options as illustrated below. Shortcut menus are available for the whole model or any individual model element (variable, connector, or tool) with a right-click. The white empty space in a model onto which the tools are dragged and connected to the variables is called the canvas, whereas the appearance and layout of the tools and variables connected together is called the model diagram.

There are five pull-down menus on the main menu: such as Model, Edit, Insert, view and help.

b) Essential Model Builder vocabulary:

i. Model canvas:

The model canvas is the white empty space in a model. [3]

ii. Model diagram:

The model diagram is the appearance and layout of the tools and variables connected together in a model. [3]
iii. Model elements:

There are three main types of model elements: tools, variables, and connectors [3].

- **Tools:** Geo-processing tools are the basic building blocks of workflows in a model. Tools perform various operations on geographic or tabular data. When tools are added to a model, they become model elements [3].

- **Variables:** Variables are elements in a model that hold a value or a reference to data stored on disk. There are two types of variables:
  - **Data:** Data variables are model elements that contain descriptive information about data stored on disk. Properties of data that are described in a data variable include field information, spatial reference, and path.
  - **Values:** Value variables are values such as strings, numbers, Booleans (true/false values), spatial references, linear units, or extents. Value variables contain anything but references to data stored on disk [3].

- **Connectors:** Connectors connect data and values to tools. The connector arrows show the direction of processing. There are four types of connectors:
  - **Data:** Data connectors connect data and value variables to tools.
  - **Environment:** Environment connectors connect a variable containing an environment setting (data or value) to a tool. When the tool is executed, it will use the environment setting.
  - **Precondition:** Precondition connectors connect a variable to a tool. The tool will execute only after the contents of the precondition variable are created.
  - **Feedback:** Feedback connectors connect the output of a tool back into the same tool as input [3].

iv. Model process:

A model process consists of a tool and all variables connected to it. Connector lines indicate the sequence of processing. Many processes can be chained together to create a larger process [3].

As a part of the Remote sensing data we can use the DEM and Quick-Bird, LISS III Data as In recent years, we observe that there are series of earth observation satellites available which provides abundant data at high resolutions (0.6–2.5 m; Quick-Bird, IKONOS, Orbit-View, SPOT and ALOS) to moderate resolutions (15–30 m; ASTER, IRS, Cartosat-1 and LANDSAT etc.) for urban area mapping. Remote sensing data from these satellites have specific potential for detailed and accurate mapping of urban areas at different scales. The high resolution imagery provides data for monitoring urban infrastructures [35]. A wide range of urban remote sensing applications from both sensors is available to date [[14]; [18]; [28]; [30]]. The advances in remote sensing technologies and the increasing availability of high resolution earth observation satellite data provide great potential for acquiring detailed spatial information to identify and monitor a number of urban environmental problems at desirable scales [[14]; [30]]. The Transitions in architecture and building density, vegetation and intensive socioeconomic activities at a particular block level in cities will often transform the urban landscape towards heterogeneity [13]. Therefore, the urban environment represents one of the most challenging areas for remote sensing analysis due to the high spatial and spectral diversity of surface materials [[20]; [28]].

Despite advances in satellite imaging technology, computer-assisted image classification is still unable to produce land use and land cover maps and statistics with high enough accuracy [27]. Image analysis techniques are evolving rapidly, but many operational and applied remote sensing analyses still require extracting discrete thematic land surface information from satellite imagery using classification-based techniques [33]. Only Very few studies [15]; [22]; [27]; [31]; [32]; [33] have compared different image classification methods with different satellite sensors to determine how the organization of information inherent to the classification scheme influences classification accuracy. Automated classification procedures of satellite imagery have been based mainly on multi-spectral classification techniques (per-pixel classifiers). These procedures assign a pixel to a class by considering its statistical similarities, in terms of reflectance, with respect to a set of classes [19]. The unsupervised classification approach provides an automated platform for image analysis, mainly based on surface reflectance and generally ignoring basic land cover characteristics (i.e., shape and size) of landforms [16]. The supervised classification approach can preserve the basic land cover characteristics through statistical classification techniques using a number of well distributed training pixels. However, the maximum likelihood classifier often used in supervised classification has been proven ineffective at identifying land uses at urban fringe areas due to the heterogeneity of urban land cover [[21]; [27]]. Suburban residential areas form a
complex mosaic of trees, lawns, roofs, concrete, and asphalt roadways. Such a complex urban environment develops mixed pixel problems, often causing misclassification of remote sensing images. Considering the complexity of the urban landscape and the importance of spectral and radiometric resolution to land use and land cover classification accuracies, we discuss the benefits of approaches: unsupervised; supervised, GIS base classification. These approaches can address a wide range of mapping problems in urban frontiers and provide alternatives to improve mapping accuracies for urban planners [35]. The objectives of this study the derived land use land cover maps using Vector based LULC Classification based on the National Urban Information System (NUIS) applying the image processing techniques the unsupervised Classification system for Data Preparation in Erdoa Imagine Software to produce a Raster LULC over a given Satellite image that can in-turn be used to prepare required input data for the solar Potential analysis by Developing the Custom ArcGIS tools using Model Builder.. The approach in mapping urban area using QuickBird, Digital Globe data of the RajendraNagar Ward of the Greater Hyderabad Municipal Corporation (GHMC), Region of Hyderabad city of Telangana state. This GHMC ward is selected as it has a mixed Urban Land use & Land Cover and to test this Methodology mapping approaches and is an interesting place to study remote sensing applications as it includes both heterogeneous and homogeneous anthropogenic landscape patterns.

III. METHODOLOGY

A. Study Area

The area selected to test the methodology out of the present research covers the RajendraNagar Ward of the GHMC region of Hyderabad City of the newly formed Telangana Statehood, India, which environs bounded by 78° 26' 43.17" - 78° 27' 56.70" East to 17° 24' 42.34" - 17° 26' 26.28" North. Rajendranagar Ward is located in the Suburban of the Hyderabad Municipal Region and is a part of the GHMC region, where it’s western edge touching the Himayath Sagar Lake, where as the musi river passes through it. Hyderabad, Hyderabad city is referred as the “City of Pearls”, due to the presence of traditional shopping bazaars historically famous for the pearl and diamond trading centers. Many of the city's traditional bazaars, including Laad Bazaar, Begum Bazaar and Sultan Bazaar, have remained open for centuries. The Musi River and its tributaries constitute the local river system of the City where as the Hussain Sagar Lake an artificial lake lies in the center of the city [39]. The Rajendra Nagar Ward GHMC region is located with Semi Urban populated mostly comprising of the Agriculture Lands, Grazing Lands, Forest, Water bodies, mixed Residential, Commercial, Universities, Industries, Educational institutions, Hostels, Recreational and Hotels, etc is The study area is characterized by sub-tropical climate. Temperature ranges from 25°C to 42°C during summer and 10°C to 27°C during winter. The rainfall pattern is monsoonal covering the period from middle of June to middle of October.

The major land cover types that dominate the area are viz. Built-up lands, plantation, Public lands, Transpiration, Recreational, etc. The Existence of this heterogenous mixed density of Population and its rapid growth has caused considerable change in the weather patterns and rise in average temperatures. This has also resulted in gradual decrease in the ground water levels.

B. Location Map

![Figure 1. Location map of the GHMC Rajendra Nagar Ward](image)

C. Work Flow

![Figure 2. A Methodology/flow chart for generating LULC using Satellite Image and Image processing Techniques](image)

The Work flow is divided in to 4 Phases, Phase I is the Data Input Phase, Phase II is Data Processing in Custom Tools prepared in ArcGIS, Phase III is...
Outputs from the respective tools of the each thematic layers is Further Processed for the Solar Potential Analysis, In Phase IV the Resultant analysis & Maps are Prepared.

D. Description of the Satellite Data

Satellite, sensor and acquisition dates for the data used during analysis are given in Table 1.

E. Data Collection and Analysis

The spatial data consisting of Survey of India Toposheet, satellite imagery and DEM data from the Bhuvan which is generated from the Cartosat 1 Data were used after pre-processing. Various digital image-processing techniques to obtain valuable information related to study and also to identify the classes and feature. Using ERDAS EMAGINE 9.1 software, the data was loaded in the computer. Geometric rectification of the data was carried out with the help of Survey of India (SOI) Toposheet for assigning geographical coordinates to keep pixel of the image.

Using the Above Preliminary data a LULC s generated in which the classification system of land use/land cover different categories have been taken, because Remote Sensing and Geographical Information System (GIS) techniques give us broad tool for better identification. The classes which have been identified and different LULC Layers were created, which in-turn form input to these tools [41].

Table 1. Description of the Satellite Data used

<table>
<thead>
<tr>
<th>Satellite Images Used</th>
<th>Satellite</th>
<th>Quick Bird (Digital Globe)</th>
<th>IRS-I, ISRO, Bhuvan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor resolution</td>
<td>Panchromatic 61 cm GSD at nadir</td>
<td>LISS III, 24m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multispectral 2.44 m GSD at nadir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal swath width</td>
<td>16.4 km at nadir</td>
<td>141 km</td>
<td></td>
</tr>
<tr>
<td>Month/Year</td>
<td>Jan 2011</td>
<td>Dec 2011</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEM Data Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite/Sensor</td>
</tr>
<tr>
<td>resolution</td>
</tr>
<tr>
<td>Month/Year</td>
</tr>
</tbody>
</table>

F. LULC Classification

A NUIS Level 2 Classification is adopted schemes provide frameworks for organizing and categorizing information that can be extracted from image data [35]. A proper classification scheme includes classes that are both important to the study and discernible from the data on hand [12]. Furthermore, SOI Toposheet, field survey data, photographs, The QuickBird image, DEM Data, GHMC Ward maps, Google Places and documents were carefully analyzed while preparing the classification scheme.

All the Line Features such as Transport Layer, Major Roads, and Transmission lines are built out of ArcGIS and are associated with Agriculture Lands, residential, facilities, Educational Institutions, etc. The land use categories recommended by the SOI, are also reviewed. After analyzing these information sources, we decided to extract 19 types of land use and land cover classes were developed as thematic information from the image. Simultaneously some of these vector layers were processed through the custom tools to prepare the input Data for the Solar Potential analysis tool, developed accordingly [41].

G. Image classification

Land cover classes are typically mapped from digital remotely sensed data through digital image classification and interpretation. The overall objective of the image classification procedure is to categorize all pixels in an image into land cover classes or themes [26]. In this study, approaches (supervised Classification & GIS were used for data Preparation and Image Processing Techniques) were used for image classification and mapping of the urban/ Semi Urban area. However, the land use prediction methods are constrained by the spatial resolution of satellite imagery, the mapping approach, and expert knowledge of the study area [36].

H. Unsupervised classification approach

The unsupervised classification approach is an automated classification method that creates a thematic raster layer from a remotely sensed image by letting the software identifies statistical patterns in the data without using any ground truth data [[24]; [26]]. Clusters are defined with a clustering algorithm that uses all pixels in the input image for analysis.

I. Raster Image Processing AOI Tools and Commands used

The AOI Tools enable us to select, create, and edit areas of interest (AOIs). These AOIs are often used as input to the Signature Editor prior to image classification. See Rules for Pixel Inclusion within Polygons for a discussion of how IMAGINE determines if a pixel is included within an AOI polygon [23].

This tool palette opens when we select AOI -> Tools... from the Viewer menu bar, or, if the AOI layer is the top layer in the Viewer, when we click the
K. Raster Image Processing Area Fill

This dialog allows us to edit the area fill functions in a displayed raster layer. This dialog opens when we select Raster > Fill... from the Viewer menu bar. It also opens when we click the icon on the Raster tool palette.

This dialog varies in options, depending upon whether the data file displayed contains continuous or thematic data and whether the data contains multiple layers or a single layer (for example, grayscale).

Raster editing permanently changes the file (when edits are saved) and should be used with caution. It does not create a new file. Each individual raster editing operation may be undone by selecting Undo from the Raster menu before the file is saved.

There are two main types of raster editing: continuous or thematic. Continuous raster editing operations include focal, filter, value, and interpolation methods. These methods are recommended for use with continuous raster layers. Thematic raster editing operations include recode and fill methods. These methods are recommended for use with thematic raster layers. Either type of raster editing may be used on continuous or thematic data depending on the application. [41]

Continuous Data: Function these options are available when the viewer contains true color imagery.

Constant Fill: Function Click to fill the area with a constant. If we select the Constant option, we must specify the value to use [25].

IV. RESULTS AND DISCUSSION

A. Land Use and Cover Type Classification

According to NATIONAL URBAN INFORMATION SYSTEM (NUIS)-TM-10K, A Manual for Thematic Mapping the Level I, II Land use Land Cover classes are detailed below:

Level –I Classes are as Follows:

They are Built-up Lands, Agriculture Lands, Forestlands, Grazing Land, Wastelands, Wetlands, Water bodies and others [17].

Level-II Classes are as follows:

Class Built Up are divided into Built-up (Urban), Built-Up (Rural),

Class Agriculture class are divided into Cropland, Fallow land, Plantation / Orchards,

Class Forest are divided into Dense Forest, Open Forest, Plantations, Mangroves,
Class Grazing land Wastelands class are divided into Salt-affected, gullied / Ravenous, Land with / without scrub, Barren / Rocky, Sandy area,

Class Wetlands are divided in to Marshy / Swampy, Mudflats, Waterlogged, Salt pans,

Class Water bodies are divided into River/Streams, Canal, Lakes/ Ponds, Reservoirs, Tanks, Cooling Pond / Cooling Reservoir, Abandoned quarries with water,

Class others are divided into Quarry / Brick Kilns, Dam / Barrage, Coral reef / Atoll [17].

In this study we have made a LULC at the Level 2 Classification and from it some of the Individual thematic layers were taken and processed into the Custom Tools for analysis.

**Table 2. Calculated Areas in Square ACERS WITH LULC CLASSES (2012)**

<table>
<thead>
<tr>
<th>Code</th>
<th>LULC Class Name</th>
<th>Area in Sq. Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Roads</td>
<td>458.18</td>
</tr>
<tr>
<td>11</td>
<td>Built-up Urban</td>
<td>941.24</td>
</tr>
<tr>
<td>12</td>
<td>Built-up Rural</td>
<td>1464.75</td>
</tr>
<tr>
<td>21</td>
<td>Agriculture Crop Land</td>
<td>873.08</td>
</tr>
<tr>
<td>22</td>
<td>Agriculture Fallow Land</td>
<td>198.5</td>
</tr>
<tr>
<td>23</td>
<td>Agriculture Plantation</td>
<td>927.3</td>
</tr>
<tr>
<td>32</td>
<td>Open Forest</td>
<td>197.58</td>
</tr>
<tr>
<td>33</td>
<td>Forest Plantation</td>
<td>93.21</td>
</tr>
<tr>
<td>41</td>
<td>Grazing Land</td>
<td>402.75</td>
</tr>
<tr>
<td>53</td>
<td>Land With Or Without Scrub</td>
<td>1114.4</td>
</tr>
<tr>
<td>54</td>
<td>Barren Rocky</td>
<td>560.67</td>
</tr>
<tr>
<td>62</td>
<td>Mud Flats</td>
<td>0.34</td>
</tr>
<tr>
<td>63</td>
<td>Water Logged</td>
<td>27.83</td>
</tr>
<tr>
<td>71</td>
<td>River</td>
<td>181.07</td>
</tr>
<tr>
<td>73</td>
<td>Lakes Or Ponds</td>
<td>58.5</td>
</tr>
<tr>
<td>74</td>
<td>Reservoirs</td>
<td>80.5</td>
</tr>
<tr>
<td>75</td>
<td>Tanks</td>
<td>31.02</td>
</tr>
<tr>
<td>77</td>
<td>Abandoned Quarries With Water</td>
<td>23.66</td>
</tr>
<tr>
<td>81</td>
<td>Quarry Brick Kiln</td>
<td>258.57</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>7893.15</strong></td>
</tr>
</tbody>
</table>

**Map 1. DEM of the Rajendra Nagar, Thematic Input Layer**

**B. Result analysis**

From the above graph and Results it is observe that, at this level 2 of classification of the Rajendra Nagar Ward of GHMC, Built-up Urban areas around 941.24 Square Acers, Built-up Rural is around 1464.75 Sq. Acers & remaining LULC Classes, Where as Land with or without Scrub is 1114.4 Sq Acers, Barren Rocky around 560.67 Sq Acers, Transportation (All Roads) is around 458.18 Square Acers; all the above urban classes do not have any portion of vegetation.

There are some tools design are described that are designed for preparing the Input Data for the Solar Potential Analysis in Final Custom Tool.

**a) Custom Tool to Prepare required Aspect:**

This Tool take DEM as Input and Generate an Aspect which is further processed and is reclassified to pick only those values that are appropriate for the Analysis.

**Figure 3. Custom to generate the Required Aspect from DEM.**

**b) Custom tool to prepare the Required GHI:**

This Tool take DEM as Input and Generate a Solar GHI Values for the AOI and is further Classified to Fuzzy the Output [40] and Prepare a Data that can be used as Input to the Potential Analysis in further Custom Tools.
c) Custom Tool to Prepare the Water Thematic:

This Tool Process the Input Water Feature layer taken from the LULC is used as input and a thematic Layer is prepared maintaining an appropriate distance from the water sources, the output generated is used as input for the further processing and solar optimum site selection analysis.

Figure 5. Custom to generate the Required Water Thematic.

Thus the Output from these set of tools some of it are detailed above prepares the input preliminary data for further processing and analysis of the Solar Potential of a Given AOI and Site Selection Analysis using Custom Tools.

V. ACKNOWLEDGEMENT

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VI. REFERENCES


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