



Extensive Rooftop Expression Identification and Spatial Analysis

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Abstract. This Research is going to explore innovative ways for Site Evaluation and Potential Assessment to utilize sunlight hitting rooftop extent for green energy potential and agriculture practices. It may intend to green energy, green roofs and water harvesting as per extent area. In this scenario, it is essential to estimate the existing open flat roof surface with full sun on it, hitting light but absolutely no utilization of the surface. The investigation of the urban rooftop extent based on geospatial technology an extensive roof top for solar potential assessment and as to establishing a benchmark for a multifunctional system within one surface area at household level. Those are green energy potential, water harvesting and agriculture practices. A new term Agrivoltaics practice at household level an Agrivoltaics is the process of farming crops under shade of the solar system. In this scenario an Agrivoltaics is an approach for the cultivation of vegetables or portable agriculture system installation at urban rooftop. In this research a major focus on evaluation of site estimation, quantification and potential measure analysis similarly to interpret the role of technology in this scenario. This will be ensure the utilization of existing resources smartly as under stressed resources due to urbanization, population, industrialization and pollution. A specific convinced technology can boost green energy, vegetable food generation, saving water, healthy environment and major effectiveness for the solar energy potential assessment and generation truthfulness can be extended.

Keywords: Geospatial Technology · Spatial Analysis · solar energy · Agrivoltaics · green energy · photovoltaic cell · Rooftop etc.

1 Introduction

Many cities facing the challenges of area so building infrastructure is one over above, its necessity to increase the utilization of available infrastructure smartly so rooftop green (solar) energy as well as farming (Agrivoltaics) is one of the smartest ways of making use of building infrastructure. It does really have such tremendous environmental benefits to the ecosystem at small scale. It's proficient in cities around the world you know it is like a drop in a bucket, but if we gain some momentum we can really create a title shift. A shift like flipping roof gardens to rooftop farming, water harvesting and green energy.

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In case roof gardens, rooftop farming and water harvesting we use existing space as it is but only need a quantification of rooftops. For the green energy case here we need to select right rooftop for placing the solar photovoltaic system.

To select, to quantify the rooftop area of each building and to find out the whole rooftop area of institutional, social and economic infrastructures here Spatial Analysis technique and Geospatial Technology are being used. The estimation of rooftop area is for further analysis and potential assessment and right selection of suitable site also for quick and holistic rooftop potential estimation approaches considered.

The Geospatial technology for handling location based data related to urban resources and site suitability circumstances on various scales will be careful. The claims of Remote Sensing and GIS based approaches in green energy; Agrivoltaics (agro- photovoltaic-A portable farming system) planning and potential measurement analysis is going to be useful. It is being exploring innovative ways to utilize rooftop extent for green energy potential (PV-photovoltaic) system as well as water harvesting and portable agriculture practices too. Primarily it is needed to find out whole area of rooftops which comprises of institutional, social and economic infrastructure of urban. The estimation of rooftop extent in particular sense for potential assessment and planning purposes. A uniqueness of this study is to find and identify a specific building object from other urban infrastructure, counting all buildings as well as findings each building's rooftop area in square meter and then as per area analysing potential assessment of whole. Building resilience at urban level in solar energy and vegetable production is a stuff challenge due to the more investment at a time but beyond in long term sense it is cost effective. Today's changing world, especially growing industrialization and population its again essential to utilize the present space smartly in order to reduce the load on existing resources.

The Potential assessment is specifically essential for planning and installation of green energy, portable agriculture practices as growing vegetables crops in the shadow of solar panel. This can further stimulate food production and effectiveness for water conservation, as a multifunctional system within one surface area at household level is most suitable for sustainable development.

1.1 Survey of Literature

Yosoon Choi, Jangwon Suh and Sung-Min Kim has the paper title "GIS-based solar radiation mapping, site evaluation, and potential assessment: a review" in 2019 were utilized methods for site evaluation i.e. Boolean overlay, Weighted sum, analytic hierarchy process, fuzzy and artificial neural network (ANN), shadow analysis, model validation are used With DEM and DSM dataset [7].

Kakoli Saha was work under the paper title "Smart Solutions" for a Smart City: a GIS Approach" in 2017 A techniques are utilized i.e. Image preprocessing, automated extraction of urban roof area, production of reference map, accuracy assessment of the automated method, estimating potential for smart solutions by use of input data IRS-5 CARTOSAT-1 stereo images of Bhopal, acquired on 16th Feb 2012 [8].

Rishabh, Harmeet Singh Kathuria utilized multispectral spatial resolution imagery with spatial analysis Techniques solar generation on the rooftop has been calculated in 2016 under the paper title "Application of remote sensing and GIS technique in rooftop mapping and PV module layout design" [9].

Flavio Borfecchia, Emanuela Caiaffa, Maurizio Pollino worked under paper title “Remote sensing and GIS in planning photovoltaic potential of urban areas” used GIS and LiDAR Satellite Data to estimates of PV potential at roofs level in urban areas [10].

Teresa Santos, Nuno Gomes, Miguel Brito Evaluated the roof-top area suitable for installation of solar energy systems in the city of Lisbon, Portugal with paper title “Solar Potential Analysis in Lisbon Using LiDAR Dataset in 2011” [11].

L. Kang, Q. Wang, H. W. Yan has studied under title "Building extraction based on OpenStreetMap tags and very high spatial resolution image in urban area" and compare building extraction from OSM and Very high resolution data and they found that the OSM data is rich enough to directly extract almost all the buildings in 2018 [12].

2 Problem Statement

In today's changing world, especially growing industrialization and urban population it is essential to reduce the load on existing resources. Due to the urbanization, pollution, population, existing resources are getting trapped under stress. To overcome this, it is necessary to utilize existing resources smartly. Thousands of open flat roofs surface with full sun spreading light on it, hitting light but absolutely no utilization as example observe in Fig. 1.

The leading problem of the smart city is no healthy surroundings, environment, and other community issues. It's critical because of the emerging certain situations like growing urbanization, its population, industrialization so slow growth of the city etc. It's influences directly on development, so it's necessary to utilize urban rooftop smartly for sustainable development as in view green energy and green rooftop even at household level. See following Fig. 2 is an example it indicating load over resources without development plan and with development as a difference.

So due to this it will limit the return on investment so now here looking forward to an enhanced approach which considers the existing load over resources. To overcome the geospatial technology an enhanced sustainable development approach is to be considered. A precisely measure holistic approach by geospatial based rooftop potential assessment will be suitable for multifunctional system. The multifunctional system



Fig. 1. Indication Building footprints as an open space.

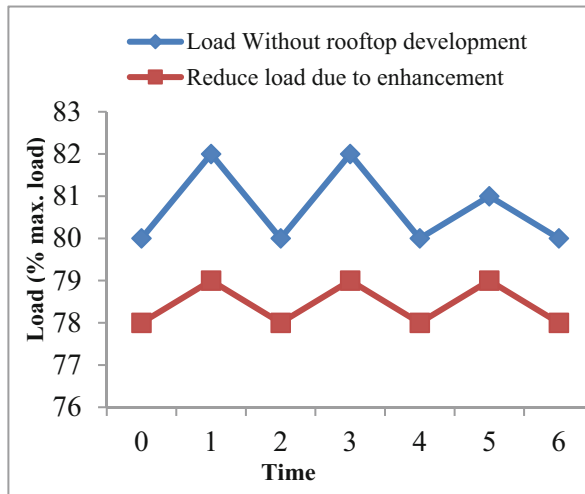


Fig. 2. As an example it indicating load over resources without development and with development as a difference.

means green energy, portable agriculture practices and water conservation within one surface area at household level.

3 Study Area

In this instance initially the study area is considered the urban region of Aurangabad Municipal Corporation. The geographical location of the Aurangabad City situated at latitude $19^{\circ} 51' 27.2952''$ N north and longitude $75^{\circ} 20' 36.3228''$ E East. The Aurangabad city is found at 581mts. From mean sea level. Its area is to be 138.50 Sq. Km. in which for this study the more focus is on the region that starts from divisional sports complex and its surrounding area situated at Gadiya Vihar, Aurangabad, Maharashtra, India, Following Fig. 3 shows study location.

4 Methodology

It's very much essential for selection of the proper procedure for smooth conduction of work. Appropriate evaluation of methodology to apply to frame the research work is most important thing to get targeted accuracy of findings (Fig. 4).

5 Spatial Analysis

5.1 Definition Required Data: Data Finding

To target the required interpretation of theme by applying step by step procedure the data must suitable, content full to extract the appropriate information. There are various types of data available in several scales and resolutions but raw data must compromises the end requirements of the application.

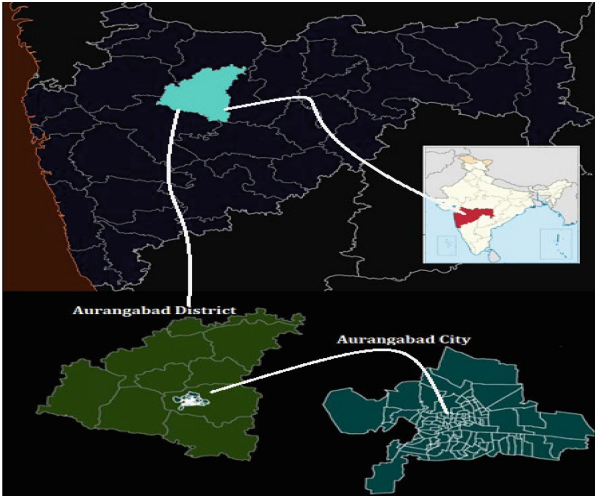


Fig. 3. Indicating Study Location

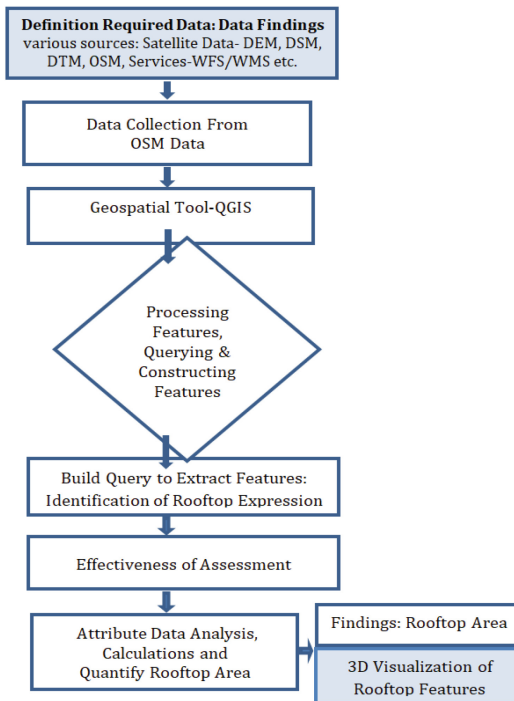


Fig. 4. Indicating the process of Spatial Analysis

There are many sources available from where the researchers can avail the data. The selection of data is totally based on the nature of the application and problem statement.

To fit the purpose here data from various sources is as suitable i.e. Satellite Data- DEM (Digital Elevation Model), DSM (Digital Surface Model), DTM (Digital Terrain Model), OSM (OpenStreetMap). At this stage for this study it is observed that now OSM has bear out the required amount of content so as its packed content it may be helpful for further analysis and interpretations for mining the targeted features.

5.1.1 Description of Data

At the hand a secondary data is available and it is also free at this movement so it has been suitable to utilize. The OSM (OpenStreetMaps) is a systematic updated database by contributors so vector format popular resource is available, again this resource offers Web Feature Service/Web Map Service (WMS) and other web based utility so through which the data is easily accessible in a QGIS environment.

5.2 Data Collection

With the help of GIS environment a as per the extent a required data searching and its collection (observe Table 1) has been completed using the open source tools i.e. QGIS and its plugins see Table 2.

Once the raw data gets selected, it must be packed content for the analysis and interpretations concern. The OSM data is giving an opportunity to utilize it in the GIS environment for further processes, like analysis and quantification of areas.

5.3 Geospatial Tool-QGIS

It's GIS Software to Construct Features. Now a day's lot of software systems offers GIS decision-making capabilities. As a concern, variety of software & hardware tools the important factor is the level of integration of these tools to provide a smoothly operating and fully functional geographic data processing environment.

So on the basis of its processing environment, functionality it's necessary to choose correct tool. As a processing part firstly here need to configure the existing QGIS Version 3.22.8 tool using external plugins. There are three most suitable plugins available for required feature extraction purpose for this study to process the features the required configuration accomplished by QuickMapService, QuickOSM Plugin and Qgis2threejs Plugin. Look in Table 2 it shows its utilization description (Table 3 and 4).

5.4 Build Query to Extract Features: Identification of Rooftop Expression

Think of real world features like streets, roads, Buildings and cities etc. Each feature on OpenStreetMap, is described as one or more geometries with attached attribute data (for example Building the Buildings carries some additional information about what it represents for example its name and its type etc. are its attribute data). In OSM the geometries/ features are described with three different elements i.e. nodes, ways and relations with its associated attribute data (Tags). Nodes are the equivalent to a point, ways are like lines that connect points and relations are collections of points or ways that represent a larger whole. See following Fig. 5. Attributes are described as **tags** that

Table 1. Details of Data used in the study.

Source	Visibility- Geospatial Coverage	Scale	Data Type	Availability	Accessed
OSM Data (OpenStreetMaps)	Public – whole World	Scale-Dependent visibility (Mini 1:500 To Max 1:1000000)	Vector Data	By Web feature Service (WFS) / Web Map Service (WMS)/ In GIS Tool	In QGIS using plugin i.e. QMS
Maxar Premium Imagery	Public – whole World	Scale-Dependent visibility (50 to 80 cm.)	Raster Data	By Web feature Service (WFS) / Web Map Service (WMS)/ In RapiD Editor	Using RapiD Editor Tool.
Google Satellite	Public – whole World	Scale-Dependent visibility	Raster/Vector Data format	By Web Map Service (WMS) / Web feature Service In GIS Tool	In QGIS

can be part of a node, a way or a relation. These elements carry associated geometry and with its additional information about what it represents to be i.e. in the form **tags**.

5.4.1 Tags

Nodes and ways need to describe the type of feature they actually represent. For this it is possible to attach tags to nodes and ways so due to tag one can understand the type of feature it will be (observe Fig. 5. For example tags like forest, road, hill and Building Auditorium). Tags consist of a key and a value; we usually write down a tag as key = value. An example of a tag is the name tag (more precisely: the tag with the key name), that defines the name of the object. For instance, the way representing the Auditorium building on the above Fig. 5 map has the tag name = Auditorium & building = yes. There are also many tags that do not naturally need a value. Those tags usually take the value yes; for example building = yes means that something is a building which do not have a value or may default value.

Table 2. Details of QGIS Plugins Utilization Description.

QGIS Plugins	Utilization Description
QuickMapService (QMS) Ver.0.19.29	<ul style="list-style-type: none"> • A QGIS plugin to Insert BaseMap for example from OSM Standard. • OSM- it is open database so to get access it, the supportive services such as WMS – Web Map Service, and WFS – Web Feature Services are helpful so through QMS plugin one can access data using these services. These services are helpful for searching and finding datasets and basemaps. So one can easily insert appropriate BaseMap in QGIS. • Now then you can able to access and find the required extent and its data you are interested in see Fig. 7. • In QGIS As per local zone find out Coordinate reference System (CRS) and Re-Project as per that Local CRS (In this study CRS: EPSG: 4326 - WGS 84 – Geographic, utilized) Projection.
QuickOSM Ver.2.0.1	<ul style="list-style-type: none"> • QuickOSM plugin allows you to work quickly with OSM data in QGIS due to Overpass API. Overpass API is helpful for execute the query to render required appropriate features. • To write query as per syntax and semantics the Overpass API provides Overpass Query Language. Initially it's a challenging task (due to querying spatial a georeferenced data regarding geometry as being unaware about its attributes i.e. keys and values regarding the dataset) without proper skill set of Overpass Query Language (OQL) but due to QuickOSM plugin a task become handy and easy. • It helps to write some queries for you by providing an interface, key/value of features/preset. (A pair's key/value- it's a Tags means an attributes data of the features means additional information about feature, each feature have at least one tag or more than one tag too). Tag describes the type of feature the concern elements do represent. • With help of interface one can able to select specific required extent boundary of your study area. Likewise one can customize the query and building a query as per end user application, target or geometry the features interested in the extent. • In our case we are interested in the real world geometry i.e. Building object and its rooftop area. So with support of QuickOSM customizing the query and tackle the appropriate feature very quickly due to plugin. • A QuickOSM plugin offers an interface to query interactively on a basemap.

(continued)

Table 2. (continued)

QGIS Plugins	Utilization Description
Qgis2threejs Plugin Ver. 2.7.1	<ul style="list-style-type: none"> • This plugin visualizes vector data in 3D on web browsers. • So you can build required 3D objects and generate files for web publishing in simple procedure shown by interface. • In addition, you can save the 3D model in glTF format for 3D printing.

Table 3. As per associated ID a sample attribute table shows each building’s footprint roof area in square meter.

ID	Type	Area_Cal (Square Meter)
118729410	building	315
120161637	building	2262
220281897	Hotel Taj Residency	3164
257873002	Garware Company	3029
257879923	Shivchhatrapati College	1680
257960575	Reliance Mall	5686

Table 4. Shows at this stage the extracted total number of buildings and its total area in square meter.

Total No. of Buildings	Area (Square Meter)
1115	328959

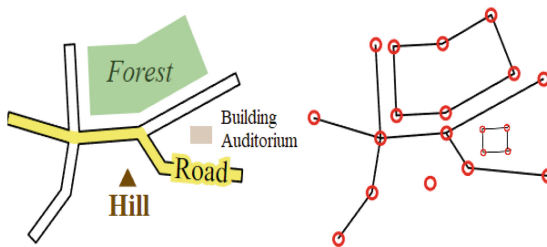


Fig. 5. Representations of real world geometries with its associated additional information in the form tags and lastly end up with its node, ways and relations.

5.4.2 Query

Once we know the representation of data with the help of elements and with its tags one can easily query the data. Query can control what information is extracted and output from the OSM database. The QuickOSM allows you to work quickly with OSM data in QGIS and Overpass API can support for this.

A node represents one single point on the map; a node carries its geographical location (latitude and longitude) and a unique identifier number.

A way represents a polyline or (closed) polygon on the map. Ways do not store their own location; instead they carry an ordered list of node identifiers.

When you drill down from relations and ways you always end up with nodes see Fig. 5. Nodes are the most basic element of the data model: a point on the map with some data attached to it as tags (name-value pairs).

In order to extract the geometries here need to build an appropriate queries and with help of nodes, ways and relations (these elements carry associated tags regarding with its geometry) one can able to construct the query to get required features you interested in. The main things are that a query consists of a series of statements which OSM database does have regarding feature elements with tags. Tag describes the type of feature the concern elements do represent. An Overpass Query Language/ Overpass QL (OQL) query is a list of statements that are executed by the API. More complex queries will consist of many more statements of different types. When you use Overpass QL (OQL) you're likely to be querying information based on the location or metadata, rather than their identifiers only. These statements build up sets of results that are then returned to the user.

In this study case we able to get access the OSM data in a GIS format by QGIS as it is possible via the QuickOSM plugin. This plugin support to write some queries by providing preset (geometry features are set in OSM database) and also with key/values see Fig. 6. Through plugin interface then choose required extent and then select features you required to extract like point, lines, Multilinestrings and Multipolygons as per your interest features. Once query get built up then Click on run query option observe Fig. 6. The query starts execution and once finishes it will added new layer to the existing QGIS layers panel, switch to the main QGIS window. You will see a new layer get added to the Layers panel. Now if you aware the canvas will show the extracted geometries feature. Then next step is filter or extract this newly added layer as exactly feature you interested in i.e. the interested feature is Building Rooftop Footprints of the urban buildings. So once get filtered by query the extensive rooftop expression identification gets resolved. In main while a simultaneously attribute data table get generated while processing the query for extraction of features and when query is proper new layer get added with its attribute data. That attribute table resides inside that specific layer property.

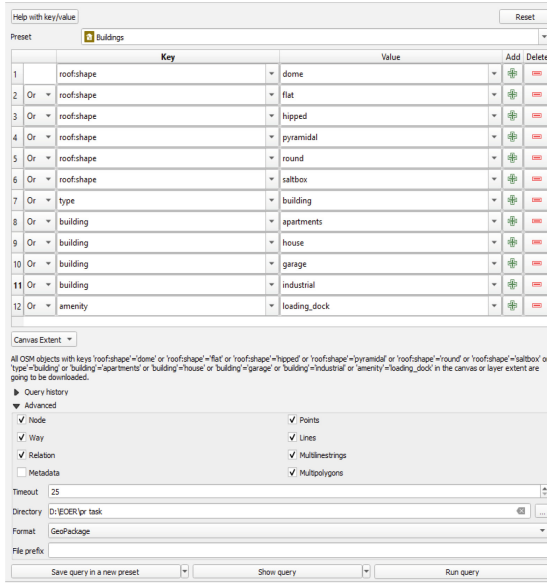


Fig. 6. QuickOsm Plugin Interface to Build Query to Extract Features

5.5 Effectiveness of Assessment

After appropriate features extraction here need to check the effectiveness of the assessment by comparing with the help of google satellite map or with ground truth here checked out and by visual observation it gives the sense of its validness. A valid or invalid meets as per the end users application so the end users purposes get meets then and then it's considered as a valid interpretation.

5.6 Attribute Data Analysis, Calculations and Quantify Rooftop Area

The extracted features/ layer properties displays attribute table option so open it for analysis and examine the attributes data as per associated with features with its locations. Inspect relationships of spatial features in data through overlay and other analytical techniques in order to locate the proper data with its associated features. Observe columns and row data as per specific building rooftop feature for total count and appropriate calculations. Once observed so there no area related information in attribute table. So in order to calculate area of rooftops in attribute table here need to add a new column for area calculation of each building's rooftop as per column of table data as building feature's id for proper quantification of each building rooftop area in square meter. In this way attribute table's data are organized, analyzed and necessary fields are calculated as per the required unit and end target. Finally all buildings are visualized in 3D by use of Qgis2threejs plugin.

5.6.1 Findings: Rooftop Area and 3D Visualization of Rooftop Features

So the final output also expressed and represented in two separate ways. A data analysis phase is originated in attribute tables of the constructed features, the calculated area also expressed with help of graph and another way is with 3D visualization of Buildings (Fig. 8 and 9).

6 Findings and Visualization

Experiment on Input Data to tackle buildings, building footprints and rooftop area.

Attribute Table

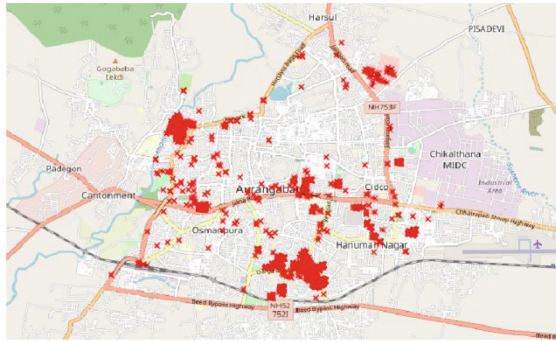


Fig. 7. Study Area shows the physical feature on ground for example settlements, road, buildings etc.

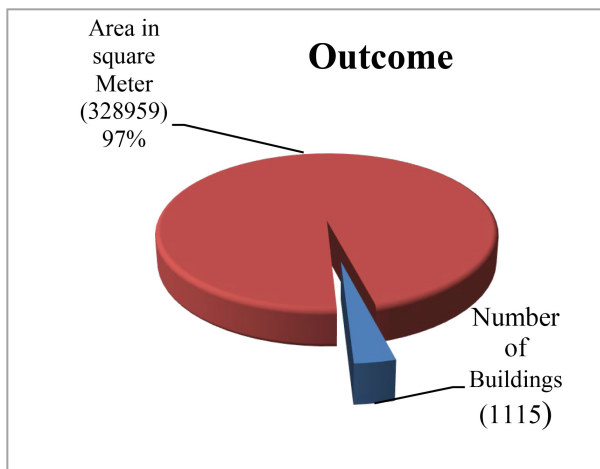


Fig. 8. Graph shows with all together the number of buildings and its collective area in square meter.

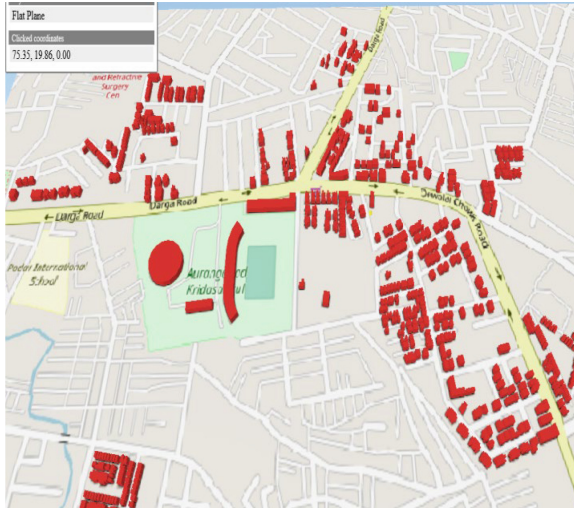


Fig. 9. Shows the Study areas Surrounded Buildings as an Extensive Rooftop Footprint Expression In 3D Form.

7 Conclusion

In this study, we tried to extract building rooftop from OSM here extracted all buildings are almost accurate the accuracy of the extracted buildings is confirmed by comparing the extraction result to google satellite. So here observed that all the OSM's vector data structure is better to describe geological objects rather than raster satellite images. Although the OSM data is constantly under improvement at global scale, the completeness and quality of the data annotations in different regions are different so in our case for this particular region here observed and found total number of buildings are 1115 and its area 328959 Square Meter, but matter of fact that as per theme/region of interest at this stage the quantity concern accuracy is less to retrieve actual number of buildings and its rooftop area as per the urban ROI (Region of Interest). So for more accuracy for this specific location the data is required to be up to date updated with rich contentful. Otherwise, to resolve this type of study here required high resolution data like LiDAR DEM and DSM data then the feature extraction will get resolve with more accurately. Distinctive advantage of this study is that people get aware about OSM for its mapping contribution concern so the benefit is that people get open-source geospatial data easily and updated around us. So geospatial geo-referenced data meets the peoples need for example research, commercial application and daily navigation concern also.

In this scenario it is more suitable for quick and 'holistic' rooftop potential estimation approach. Identifying and finding the area of each building for innovative applications such as solar energy, Agrivoltaics a portable farming and water conservation. Unique benefit of this study to the society/community around us is having opportunity to link urban people in to their solar power energy, food production system and water conservation system.

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