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Exploring the Utilities of Unmanned Aerial Vehicle (UAV) Imageries for Assessing Planned Housing in a GIS format: A case study of Savar Upazilain Dhaka, Bangladesh

Nessar Uddin Ahmed[1*], **Md. Shahedur Rashid**[2]

[1]Urban Planner, Development Design Consultants Limited, Mohakhali,Dhaka 1212,
[2]Department of Geography and Environment, Jahangirnagar University, Dhaka-1342, Bangladesh.

Abstract

People's need for a safe and comfortable place to reside is among the most fundamental. But governments worldwide, notably emerging nations like Bangladesh, are finding it increasingly challenging to build housing to meet their needs in light of their growing populations. Therefore, accurate mapping of the housing project area is required to achieve the goals of having planned housing and a sustainable environment. Using an unmanned aerial vehicle (UAV), the purpose of this investigation is to compile a plot-level GIS database from Mauza at the study site of Arunapalli, Savar upazila of Dhaka district, as well as investigate the advantages and drawbacks of employing UAVs to evaluate housing societies. Orthophoto and DTM were the results of the study. This DTM revealed that the RL of the project area ranged from a minimum of 4.93 meters to a high of 11.85 meters. The majority of the land is taken up by vegetation, around 35.76 percent of the total area. According to the findings of the structural analysis, the research area encompasses a total of 207 different structures. Most of the buildings are homes and other residential land uses.

Keywords: Digital Terrain Model (DTM), Housing society, Mauza mapping, UAV communication network, Unmanned Aerial Vehicle (UAV).

Introduction

Housing is one of the essential services forthe human beings. But well-planned housing in the face of the increased population is a great challenge for all countries especiallydeveloping countries like Bangladesh. The World Health Organization defines housing as a "residential environment that includes, in addition to the physical structure that man uses for shelter, all necessary services, facilities, equipment, and devices required or desired for the family's physical and mental health and social well-being." In fast-growing cities in developing nations, however, up to 75 percent of the population lives in squatter settlements without access to

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[*] Author for Correspondingemail: shishir01.urp@gmail.com; m.s.rashid@juniv.edu

essential utilities. Moreover, cities are expanding at a rate frequently disproportionate to the urban planning and development. [8]

The city's housing sector is profit-driven, and development is leading to a decline in the quality of life. Nowadays, the housing sector has been overlooked as a critical component of empowerment because it is more prosperous and effective at improving the quality of life for city dwellers. The importance of space comfort inside and outside the home, in addition to basic facilities and infrastructure, is emphasized, as is the convenience of residents and neighborhood relations. This will enhance the quality of life, particularly in urban areas [2]. A comprehensive assessment of the housing project (existing housing and infrastructure, services, environmental conditions, hazards, etc.) is necessary to identify critical issues and plan the housing settlements. As a result, spatial data is considered critical for upgrading housing settlements [15]. Accurately mapping the housing project area is the precondition of a planned housing and healthy living environment. Therefore, spatial data is vital for better housing planning. Spatial data are generally a particular type of data used to identify information about the location or geographical extent, simply information about places [29]. Spatial data can aid in predicting human behavior and identifyingvariables that may influence an individual's choices. Spatial data can predict human behavior by performing spatial analysis on communities, like identifying community nuisances, environmental relationships among people, etc.By conducting spatial analysis of our communities, we can ensure that all residents can access to and use their neighbourhoods. For example, a common type of spatial data is a road map. A road map is a two-dimensional object comprised of points, lines, and polygons that depict cities, roads, and political boundaries such as states or provinces. A road map is a graphical representation of geographic data. Similarly, existing land use, topography, infrastructure, road network, land elevation (DEM) etc. the examples of spatial data which are very important for housing planning.

The overall aim of this research is to explore the potentiality of using UAV imageries in housing planning. This study is guided by the following three research questions a) How can a Mauza map be used to generate a plot-level GIS database for housing development? b) What and how can spatial data be derived from UAV imagery? c) What are the opportunities and challenges of using UAV imagery to assess housing societies?

Based on the overall objective and research questions, three objectives of this study are a) to explore the opportunities and challenges of UAVs to assess the housing societies, b) To develop a GIS database of the study site using UAVs, c)to prepare plot level GIS database from Mauza Map of the study area.

Spatial data for housing planning

Whether a person is searching for a new residence, a developer is drafting a planning application, or a government official is revising a local plan, spatial data for planning and housing is essential. Housing and planning are complex disciplines involving all levels of government, the business and non-profit sectors, and each of us as renters or homeowners [3]. Better housing planning requires accessible, accurate, and precise data to provide the insights necessary to make informed decisions for housing settlement planning.Spatial data is any data that links directly or indirectly to a given geographical area or location. Geographic location describes the earth and its properties in terms of spatial data. For example, a pair of latitudes uniquely identifies a point on Earthand longitude coordinates [2].

Approach to spatial data collection

Using field mapping exercises, spatial data can be collected on the ground.This strategy's potential to include local citizens in mapping activities is a prominent feature. Another option is to use remotely sensed imagery, such as satellite or aerial photography.This can speed the mapping process, collect data in locations with limited access, involve off-site specialists, and offer evidence of settlement at a specific timestamp. [9]. However, the physical settlement conditions documented by remote sensing photography are only sometimesreflective of the current living conditions of the population or other socioeconomic features. Despite this limitation, satellite imagery aids in housing settlement management by identifying settlements, detecting changes in settlement boundaries over time, generating surface data, classifying land use, identifying buildings and other objects for mapping purposes, and conducting reconnaissance. [14].UAVs, also known as drones, Unmanned Aerial Systems (UAS), and Remotely Piloted Aircraft Systems (RPAS), are autonomously operating small aircraft. UAV applications have recently exploded due to the widespread availability of low-cost, off-the-shelf UAV systems and advancements in automatic image processing from computer vision [13]. In recent years, Unmanned Aircraft Systems/UAVs/Drones have become the most advanced technology, giving an ideal platform for aerial photography, remote sensing research, topographical surveys, and mapping. In addition, these UAVs utilize LIDAR and the data obtained from these active sensors, which can provide detailed 3D point clouds from which urban planning and development-related building structural information can be established [11].

The solution consists of high-resolution cameras mounted to drones, which can map out urban or rural landscapes more quickly, affordably, and securely than ever before. In addition, innovations in virtual reality, complicated 3D space scanners (such as LiDAR), and photograph meshing offer significant potential when combined with

UAVs. A UAV functions similarly to traditional aerial photography for mapping applications. After generating a Digital Surface Model (DSM) and stitching together original UAV image segments, an orthomosaic can be constructed [7, 5].

The spatial resolution of ortho-mosaics made by UAVs is comparable to that of conventional aerial images. However, this depends on the UAV's flight settings, such as altitude, camera type, and image acquisition angle. Photographs captured at oblique angles may provide information on the facades in urban situations. Another benefit is that UAVs may fly over clouds (though rain remains a risk), a recurrent problem for optical satellite images. Although DSMs derived from UAVs may rival the accuracy of field measurements using a DGPS, this accuracy is heavily reliant on flight settings, image quality, and ground control points (GCPs) (Khosiawan and Nielsen, 2016).

Application of UAV data

The use of unmanned aerial vehicles (UAVs) for non-military applications has piqued the interest of researchers and is now deemed essential for urban building development. The adaptability and maneuverability of UAVs allow them to access difficult-to-reach regions and cover large-scale housing developments cost-effectively and efficiently whileoffering visual access via photographs or real-time recordings. These properties make this technology ideally suited for mapping and monitoring activities, enabling its application at all phases of home planning, building, and monitoring [6]. As a result, site engineers and planners now have access to detailed and up-to-date data on the logistics and schedule of construction operations.The most challenging obstacle was the data collection procedure, which was always uncertain regarding the data's veracity [7, 10]. Numerous remote sensing applications have profited from the deployment of drones due to the mission's cost, the need for rapid reaction, or the need to make observations in a potentially hazardous or inaccessible location for humans [10].

Several studies have been undertaken with UAVs/drones and remote sensing techniques. The investigations includearchaeology, monitoring of vegetated regions, 3D modeling, and cataloging of tree species in a park area, as well as rangeland studies [6]. Other research has evaluated the utility of the application in disaster management. UAVs/drones are employed as agricultural equipment and for environmental conservation objectives in Japan, including tree planting and the distribution of orang-utan habitat [4]. Urban planners and other city employees are frequently tasked with revamping anentire city neighborhood. Using airborne UAVs/drones, photographs and videos of the to-be-renovated block or region can be obtained. Rapid reaction imaging via UAV/UAVs/drones has also garnered substantial interest in urban planning, as evidenced by road accident simulations, pedestrian detection on TUD-crossing image sequences, traffic monitoring, and zoning and land use planning [1].

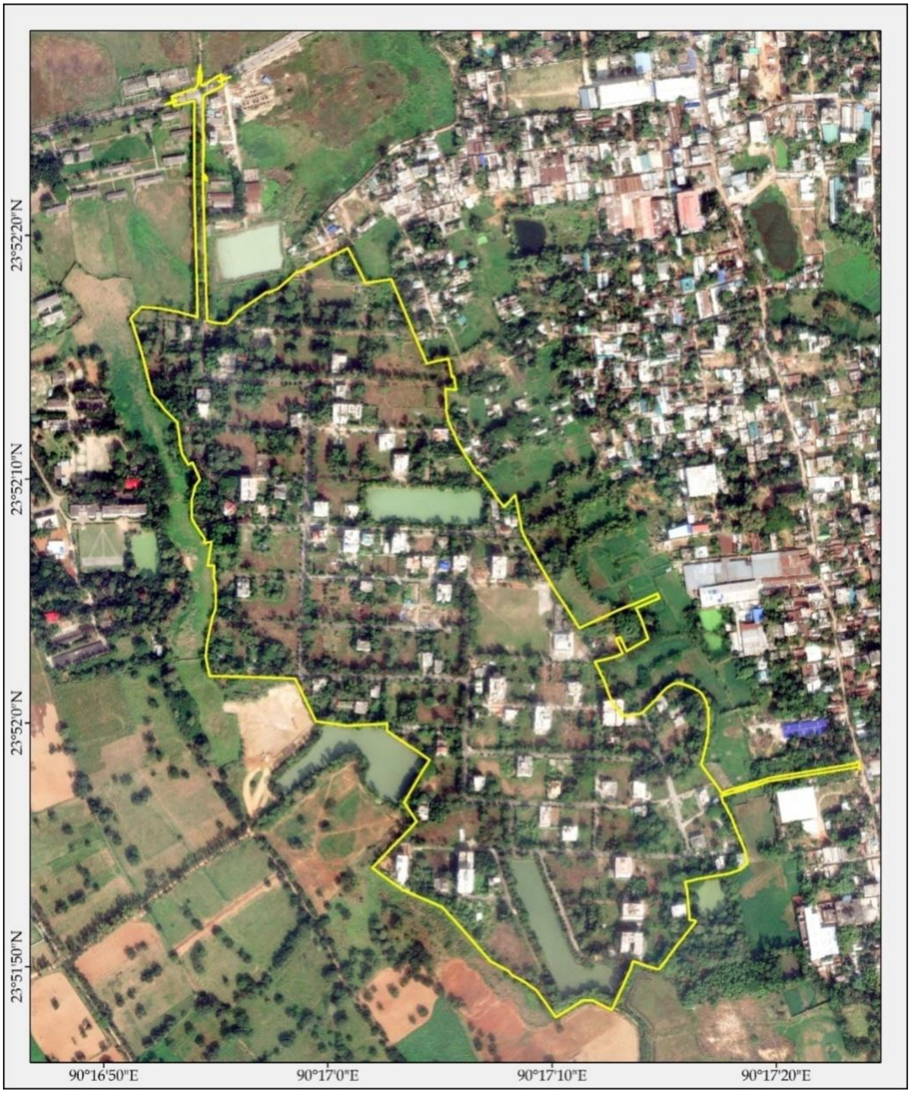


Figure 1. Arunapalli Housing Area (Source: 30cm Satellite Image, Sensor: WorldView-3, Maxar Technologies, USA, Capture Date: 31.12.2019

Materials and method

Study area

Aurnapalli is a housing project developed by Jahangirnagar University Co-operative Housing Society Ltd. located at Savar upazila of Dhaka district, Bangladesh. This project is registered under the Bangladesh Samabay Samity Act 2001 & Bangladesh Samabay Samity Act Amendment Act 2002. The objective of the housing project is to provide quality living conditions for the members by offering facilities to secure liveable residential accommodations. The area of operation of the Society is restricted to activities in the concerned area of Jahangirnagar University Co-operative Housing Society Limited (ARUNAPALLI) in Upazila - Savar, Zila -Dhaka; and other places, which are contiguous to the existing land, as may be proposed by the Managing Committee. The location map of the study area is given in Figure 1.

Data and description of the instrument used

Different types of data were used to fulfill the study’s objectives. For example, objectives 1 and 2 require different types of data. Objective 3 was fulfilled based on the data and output of objectives 1 and 2. The description of the data is listed in Table 1.

In this study, UAV Mavic 2 Pro was used to survey the study area. The DJI Mavic Pro is a relatively cheap, off-the-shelf Unmanned Aircraft System (UAS) with unique sensors and proprietary algorithms to help automate and make it easy to use. If the environment, weather, and pilot experience are the same, the Mavic 2 Pro can create large datasets that are more reliable and accurate much faster than the traditional method. The UAV could also easily avoid obstacles. This makes it an excellent tool for use in rivers in rural areas. The Mavic Pro 2 has a Hasselblad L1D-20c camera, which has a full-frame equivalent focal length of 28mm, an ISO range of 100-12,800 for stills, and an ISO range of 100-6400 for video. Because of these features, the Mavic 2 Pro is a good choice for professional photographers and videographers. However, less experienced UAV pilots can also enjoy an effortlesstime flying it thanks to GPS positioning, smart safety features, collision avoidance, and geofencing [26].

Table 1. Description of the data

Objectives	Description of data	Source/Acquisition
Objective 1	Point data: Location of Important Infrastructure, Electric Pole, Drainage Outfall, Light Post, Security Camera, GCP, Geodetic Control Point (SOB 3D BM), Mauza Plot as Point	Recent Mauza Map from DLRS, Bangladesh, Scanned Mauza Map (300 dpi), On-screen digitization, RTK GPS Survey through GNSS system
	Line data: Road Central Line, Electric Line, Drainage, Mauza Plot Line, Mauza Sheet Line	On-screen digitization, Geo-referencing
	Polygon data: Mauza Poly (Pucca/Katcha Road, Halot, River/Canal/Khal, Structure, etc.), Flight Plan for UAV	On-screen digitization, Geo-referencing, Topology Building, Edge Matching, Fishnet, Flight Plan draw on UAV Apps
Objective 2	Raw Overlapping Images, High-resolution UAV image	Field Collection, Data acquisition through Flight Apps
	Elevation (DSM, DTM, CHM)	AT, Overlapping Stereo Images
	Orthophoto Image	Orthorectification
	Contour	Interpolation, Spatial Analyst Tool
	3D Model	3D Point Cloud, 3D Mesh
	GCP, DTM, 3D Model	Orthorectification
	Land use and physical feature data	Extraction from UAV Images
Objective 3	Recent Mauza Map from DLRS, Bangladesh. Orthophoto Image, 30cm Mono High-Resolution Satellite Image.	Georeferencing, Overlaying, Field Visit of Plot to Plot
	Structure Footprint / Layout	Field Survey and Orthophoto Image
	Orthophoto Image and Raw UAV Images	Field Survey

Methods

The first objective of this study is to prepare plot level GIS database from the Mauza Map of the study area. The Mauza map sheet was the primary source to prepare this dataset. Several steps were performed to prepare these databases. This section describes the step-by-step methodology of preparing a GIS database from Mauza sheet maps.

Mauza map collection and scanning

The first step is the collection of the Mauza map and scanning them. 07 mauza sheets cover the study area.So, the first mauza sheets from DLRS have been collected. Then the mauza sheets were scanned. Finally, the scanned mauza image was sorted in folders on the computer hard drive. Folders were named after thana’s name. However,naming the individual file iscrucial for its identification.

Onscreen Digitization and Database Creation of Mauza Map Sheets

The scanned Mauza sheet was used for digitization whereas the on-screen digitization method was adopted for the digitization of Mauza maps/ sheets. ArcGIS software was used to perform the digitization process. All features (Line, Point, and Annotation) were saved in a shape file, each with its ID or code. Polygon features were created using the line, point, and annotation features of ArcGIS (Version 10.8). To maintain the uniqueness of all features, each feature’sID or code number was finalized based on the project authority's suggestions and discussions. During the digitization process for individual Mauza maps, the following stages were taken:

a) Preparing the Manuscript.

b) Converting Digitized Maps to Shapefile format

c) Mauza Map Digitizing and Database Building

d) Edit Plot Check of Digitized Mauza Map Sheets

Geo-referencing of Mauza map Sheets

Georeferencing is the process of referencing different geographic data sources to the Earth’s surface. Geo-referencing satellite pictures entails establishing linkages between each point of the land and its corresponding representation on the image by assigning coordinates to a spatial reference system linked to the land and related features.

On the mauza map, the junction of latitude and longitude values has been drawn. Four reference points on each mauza sheet in this manner have been introduced. The mauza sheets were georeferenced using four sites.

Edge Matching of Mauza Map Sheets

After georeferencing was complete, a mosaic mauza map of the project area by combining all mauza features (points, lines, and polygons) with GCP points in separate layers was created. Different Mauza sheets of the same Mauza were imported into the same file and their edges were matched regarding the grid and the features on the maps. All dangles (undershoot/overshoot), label errors, "must not overlap" and "must not have gaps" of adjacent mauza maps/sheets were eliminated. One must guarantee that polygon features, such as parcels, and line features, like rivers, highways, etc., are complete. Duplicate elements around the edge, particularly symbols, must be eliminated. Finally, topologically accurate features were created and quality tested for the study region.

Collection of Ground Control Points (GCP)

The orthophoto of the research region was created using GCP. Ground Control Points (GCPs) are recognized locations on the earth's surface used to geo-reference raw satellite photographs. In an aerial mapping survey, GCPs are locations that the surveyor can locate precisely; with a few numberscoordinates, it is possible to map enormous areas correctly. I collected 21 GCP points from the field using RTK-DGPS for known sites identified on satellite imagery and the earth's surface. From the Survey of Bangladesh, one BM value was collected (SoB). GCPs were collected in WGS 84 Coordinate System and projected into Universal Transverse Mercator (UTM46).

Flight planning

The second objective of this study is to develop a GIS database of the study site using UAVs. Mavic 2 Pro was used for the photogrammetric survey of the whole study area.

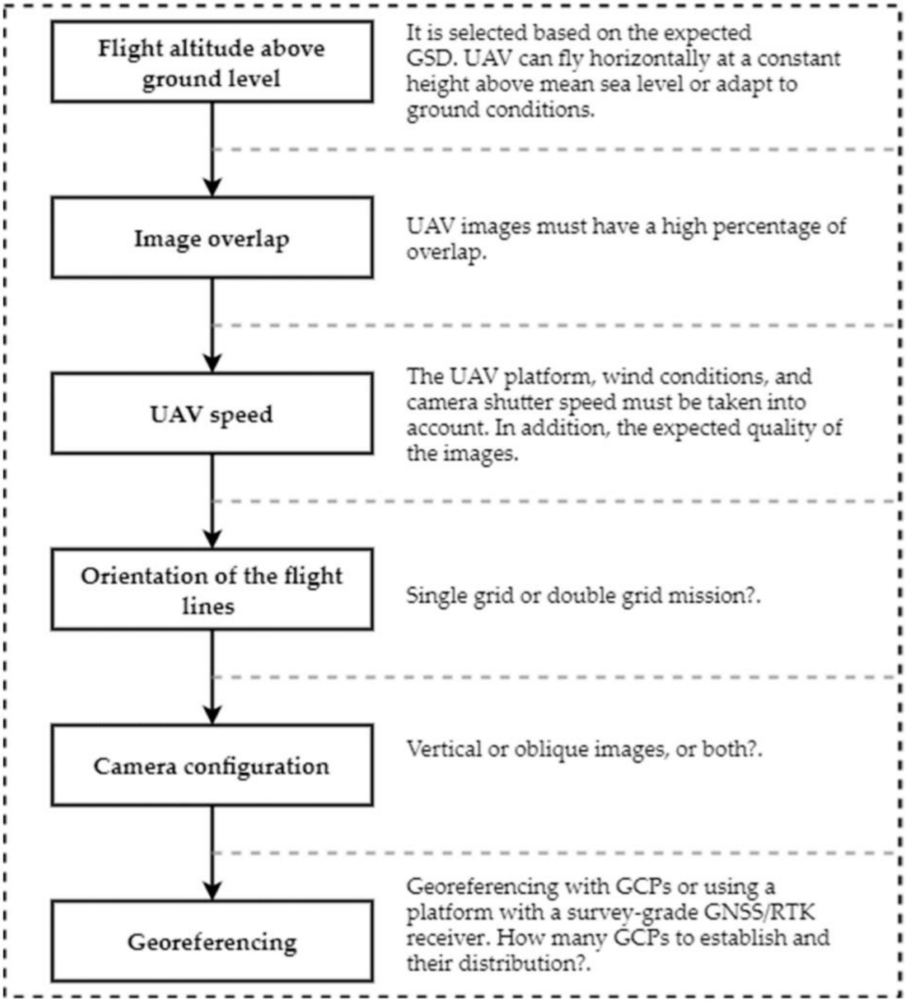


Figure 3. Flight planning parameters (Jiménez-Jiménez et al., 2021)

Getting the best output from the UAV survey requires several steps for flight planning andfinal dataprocessing. Planning a flight is the initial stage in UAV surveying. Through web-based flight planning, flight paths can be established in advance and reviewed by the entire team for inefficiencies or safety concerns. [22]

Figure 4. GCP and Flight planning

In this project, 21 GCPs were used to cover the whole area. Several 4 GCPs were taken for each flight. When flying, every flight has to fly in the same rhythm. But I took two flights in different ways which do not match the other three flights. These 2 flight plans were at the lower left of the whole flight plan. I took two flights differently because, during the first flight, the Vulture collided with the first flight on the upper left. It can be mentioned that the Army authority operates a dairy farm on the leftof the project area. There are many ows and goats in the dairy firm. Therefore there is a lot of Vulture there. For this, the pattern of the bottom two flights on the left side was changed so that the birds have less time to damage the UAV.

Capturing Aerial Photographs using UAV

Aerial Photography was carried out covering the project area with at least a 20m buffer to produce a topographic map, Digital Elevation Model (DEM), and Digital Surface Model (DSM) of the study area.

Image calibration

Image calibration gives a pixel-to-real-distance conversion factor (i.e., the calibration factor, pixels/cm), which enables the scaling of images to metric units. This information can subsequently be used throughout the study to transform image pixel measurements to their equivalent real-world values [25]. Images obtained were calibrated using Pix4Dmapper. Pix4Dmapper requires the internal parameters of the camera that was used to gather the photos for processing as input.

Aerial Triangulation

The primary objective of aerial triangulation is to generate sufficient points in the photogrammetric models from the ground control so that each model can be oriented accurately as required for stereo compilation, in either DTM generation and enhancement (for orthophoto production) or feature extraction. Aerial triangulation is the technique of identifying each image’s correct position and orientation in a series of aerial photos to create a map. Aerial triangulation primarily depends on evenly dispersed Ground Control Points "GCPs for Georeferencing." [24]. In this research, I have used Pix4D Enterprise Version 4.5.6 software for Aerial triangulation.

Pix4D Enterprise contains an aerial triangulation (AT) module for UAV/medium/large format sensors, which enhances exterior orientation values and camera calibration parameters from image data. The accuracy of AT results depends on the quality of the subsequent DSM, DTM, point clouds, and orthomosaics. The AT toolbar contains direct access to all AT steps. I have performed the following sequential order for Aerial Triangulation in Pix4D Enterprise software:Tie Point

Extraction, GCP Creation, Tie Point Editing, Bundle Adjustment, Quality Assessment, Image List Filtering, and Coarse DEM Extraction.

Generation of DSM and DTM

DSM is a three-dimensional representation of the earth's surface terrain, encompassing natural and human-made things. DSMs with high accuracy and resolution is advantageous for various tasks, including general construction surveying, viewpoint selection, line of sight analysis, urban planning, flood modeling and simulation, and several other tasks that require information about the earth's surface elevation. Thus, they can be combined with DSMs to determine the height of objects on the surface. [18]. The large amount of data acquired by UAVs is processed by expert photogrammetry software to generate digital models that may be utilized with GIS tools. I have generated DSM and DTM using the pix4D program.

The DSM and DTM were generated using the Structure from Motion (SfM) approach. Numerous investigations have established that SfM can generate point clouds of comparable quality to those generated by Aerial Laser Scanning (ALS). This capability is now well-understood and widely accepted. [27].

Accuracy assessment of DTM

The accuracy refers to the positional accuracy and more specifically, the positional accuracy of horizontal and vertical positions with respect to horizontal and vertical datums. The positional accuracy of Geo-rectified images is defined in terms of root-mean-square error (RMSE). Horizontal accuracy is the horizontal (radial) component of the positional accuracy of a data set with respect to a horizontal datum, at a specified confidence level. It is calculated by the following equation.

$$Horizontal\ Accuracy, RMSE_r = \sqrt{RMSE_x^2 + RMSE_y^2}$$

Where,

$$RMSE_x = \sqrt{\frac{\sum(Error\ X)^2}{number\ of\ GCPs}}$$

$$RMSE_y = \sqrt{\frac{\sum(Error\ Y)^2}{number\ of\ GCPs}}$$

Vertical accuracy is the measure of the positional accuracy of a dataset with respect to a specified vertical datum, at a specified confidence level or percentile. It is calculated by the following equation .

$$RMSE_z = \sqrt{\frac{\sum(Error\ Z)^2}{number\ of\ GCPs}}$$

According to Federal Geographic Data Committee (FGDC), Vertical accuracy is reported in terms of circular error (LE95). It is also known as the linear error at the 95% confidence level. $LE95$ is calculated by the following equation (Federal Geographical Data Committee, 1998).

$$LE95 = 1.96 * RMSE_z$$

Preparation of orthophoto

An orthophoto, also known as an orthophotograph or an orthoimage, is a photograph taken from above that has been corrected for lens distortion, camera tilt, perspective, and topographic relief, or changes in the height of the earth's surface. These rectified orthophotographs contain no distortion and a uniform scale throughout the entire image. Due to the precision and accuracy of orthophotos, orthophotos, and orthomosaics are of the same caliber as maps and can be used to measure actual distances [23].

The following steps were performed to generate the orthomosaic:

Input: Images with viewpoint (for example facades are visible, but roofs do not have the correct size as the scale is not preserved).

Processing:

- Calibrate images and compute 3D and 2.5D models.
- Project images on the 2.5D model to generate the orthomosaic.

Output: Orthomosaic (similar to satellite imagery, facades are not visible, roofs have the correct size).

Development of GIS database

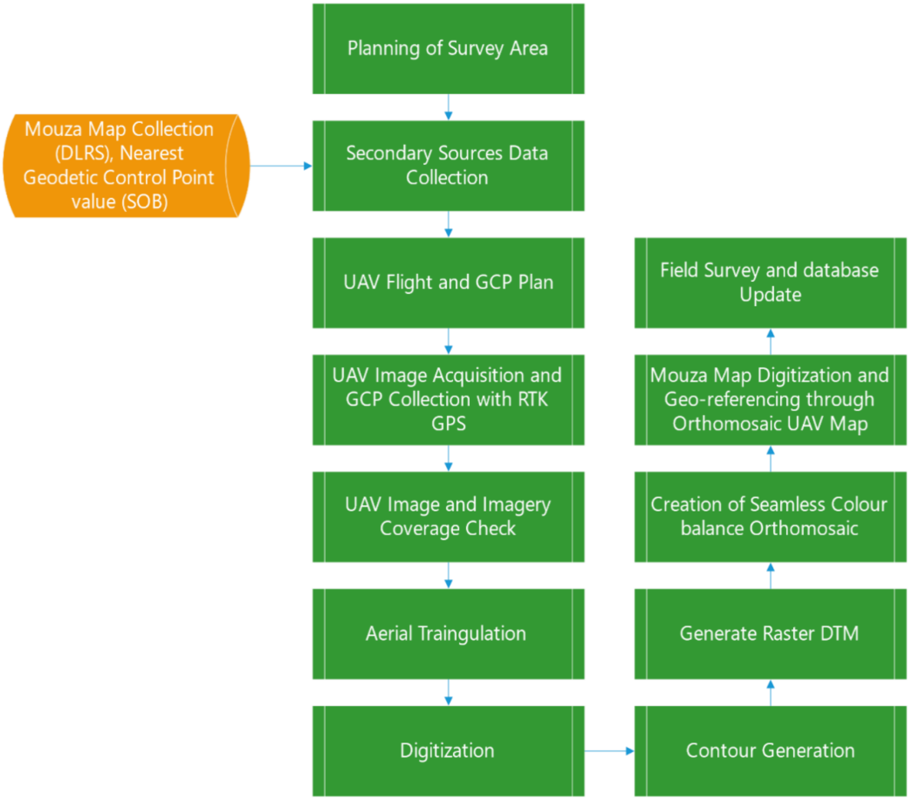


Figure 5. Overall Research Flowchart

Finally, a GIS database was developed using the DSM and other physical features which were extracted from the orthophoto. Both Raster and Vector models were used to build the GIS database. The Raster model was used for DSM and DEM. Vector model was used for other features like road networks, buildings, water bodies, land use, etc. Mainly ESRI shapefile (point, line, and polygon) was created for these features.

Analysis and Discussion

Documentation of Mauza-Based GIS Database

The methodology of developing mauza based on the GIS database has been presented. As mentioned earlier, a total of 07 mauza sheets for the study area havebeen prepared. After digitizing and georeferencing the individual mauza map, a combined mauza map has been prepared by joining individual mauza maps together. Figure 6. shows the combined mauza map and sheet boundary of the digitized mauza. After combining the individual mauza sheets a detailed GIS database of mauza plots was developed. The GIS database contains 16 types of information about the plot. The most important of them include Mauza's name, Plot no, plot type, J.L no sheet number, etc.

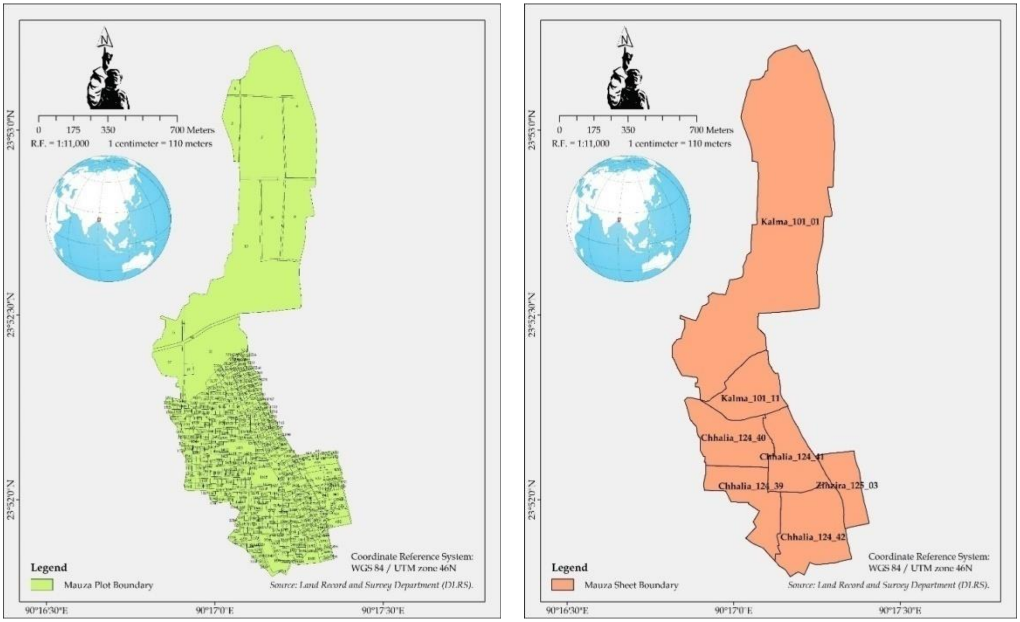


Figure 6. Geo-referenced and combined mauza sheet (left)and sheet boundary (right) of the digitized mauza map.

Integration and Managing UAV database

Using the UAV survey, a total of 894 high-resolution images for the study area have been gathered. The accuracy of UAV images is directly related to the spatial resolution of the input imagery. In this study, the UAV images of 2.11cm of spatial resolution have been acquired. These high-resolution images from UAVs can compete with traditional aerial mapping solutions that bank on highly accurate alignment and positioning sensors on board. A sample of UAV images acquired has been given in Figure 7.

Figure 7. Sample of ultra-high-resolution image collected through UAV

In the next step, the acquired images were processed for further use. The processing of UAV photos has unique difficulties. Aerial Triangulation is the initial procedure. GCP and Actual Check Point (ACP) reports have been created at this stage. This is an iterative phase until the requisite precision is achieved. The Aerial Triangulation Report of UAV image processing is given in Table 2.

Table 2. Aerial Triangulation Report of UAV image processing

Label	X (cm)	Y (cm)	Z (cm)
GCP-01	4.777	15.222	1.242
GCP-02	17.411	-6.979	0.090
GCP-03	-7.423	-12.243	-1.872
GCP-04	-21.890	7.078	-1.402
GCP-05	-12.832	-19.148	0.004
GCP-06	-38.987	21.337	0.844
GCP-07	19.672	-7.571	-1.097
GCP-08	9.141	-13.689	2.646
GCP-09	-5.872	6.458	0.859

Label	X (cm)	Y (cm)	Z (cm)
GCP-10	-29.194	23.484	-0.532
GCP-11	5.507	7.133	-1.726
GCP-12	24.844	3.547	0.118
GCP-13	27.006	4.424	1.042
GCP-14	9.208	-12.471	1.737
GCP-15	-10.830	-7.499	0.488
GCP-16	-15.930	8.615	-0.973
GCP-17	16.464	-6.795	0.646
GCP-18	21.113	-20.091	0.568
GCP-19	-5.527	0.746	1.202
GCP-20	-7.538	8.628	1.537
Ref-01	0.796	0.054	-4.532
Total	17.647	12.020	1.548

After completion of the aerial triangulation, the multiple images were mosaiced and a combined orthorectified image was created. An image mosaic is an image that is built from a set of smaller individual images. This image is an orthomosaic image. An orthomosaic is a photogrammetrically orthorectified image product mosaicked from an image collection, where the geometric distortion has been corrected and the imagery has been color balanced to produce a seamless mosaic dataset. Figure 8. shows the orthorectified images of the study area. This orthomosaic is in the ultra-high resolution of 3cm.

Generation of DSM from images requires consistent data. For this project, two major changes were done to achieve consistency in the coordinate system of obtained data. Firstly, the transformation was done to convert the horizontal coordinate system of camera location into a projected coordinate system. Then, the elevation difference was calculated to bring consistency in the reference system for the elevation of provided datasets. The DSM of the study area is given in Figure 9.

Figure 8. Orthomosaic image of the study area

After creating the DSM, the DTM has been generated. Though DTM generation is a simple process, it is a must optimize photogrammetric procedures, and survey parameters as well as to follow essential UAV flight rules to ensure high DTM accuracy. Using SfM algorithms detailed topographic models are produced from images collected through UAVs [23]. The primary product of the SfM process is a 3D point cloud of identifiable features which are present in the input images. These inputs (images) then generate the output in the form of DTM. The final DTM has been presented in Figure 10.

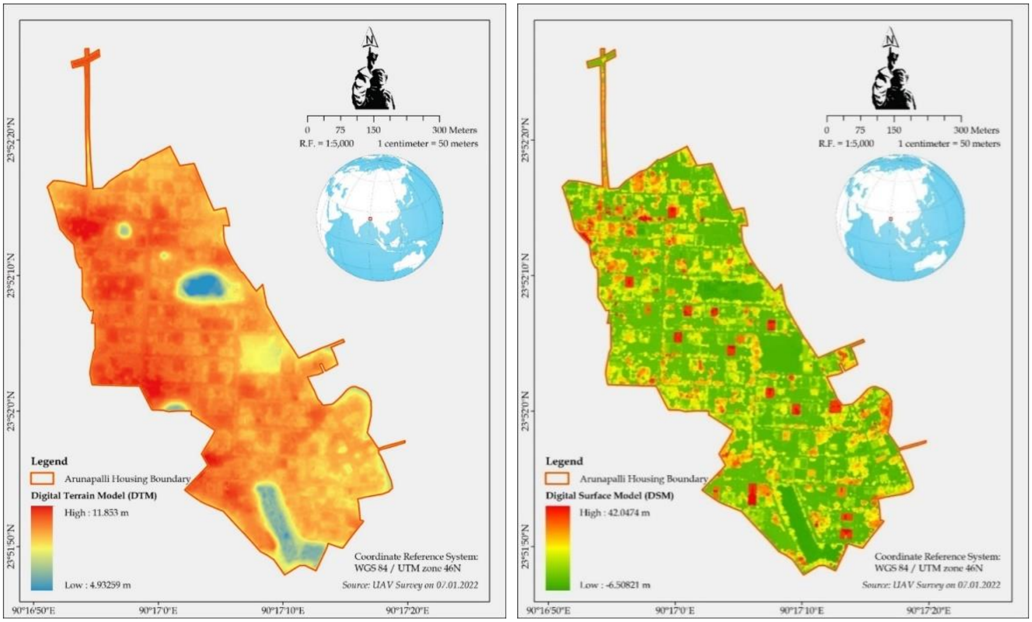


Figure 9. DSM (left) and DTM (right) of the study area.

Analysis of Digital Terrain Model (DTM)

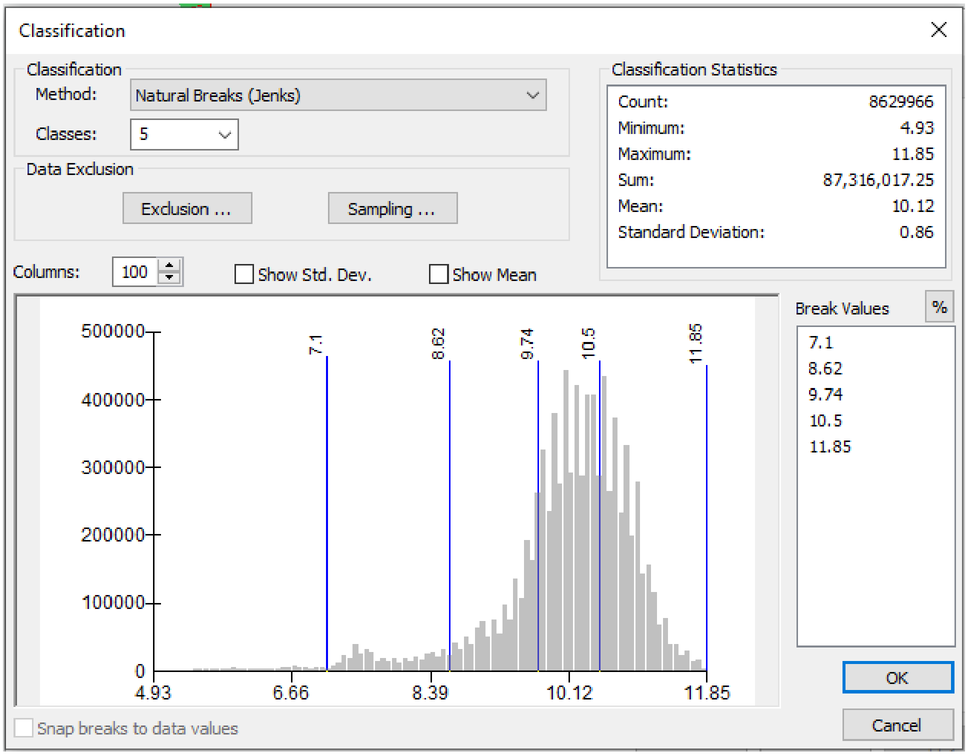
Digital Terrain Models (DTM) sometimes called Digital Elevation Models (DEM) is a topographic models of the bare Earth that can be manipulated by computer programs. The data files contain the elevation data of the terrain in a digital format that relates to a rectangular grid. Vegetation, buildings, and other cultural features are removed digitally - leaving just the underlying terrain. DTM is a raster-based digital dataset of the topography. DTM presents a continuous and functional topographic surface, which is a 3D representation of the terrain's surface over 2D. It shows the elevation and the shape of the terrain, which ultimately depicts the changes in terrain level over the survey area. Table 3. shows the land height classification of DTM in the study area.

Table 3. Land Classification based on elevation in MSL

Class	Elevation (m MSL)	Area (Acre)	Cumulative Area	Area (%)
1	4.93-7.1	0.80	0.80	0.93
2	7.11-8.62	4.24	5.04	4.97
3	8.63-9.74	13.31	18.34	15.60
4	9.75-10.5	36.10	54.44	42.32
5	10.51-11.85	30.86	85.30	36.18
Total		85.30	-	100

Source: Generated from Field Survey, January 2022

Table 3. shows the land classification of the survey area. This classification is based on the natural breaks (Jenks) method. The minimum and maximum RL of the project area is found 4.93m and 11.85m respectively.



Classification

Classification

Method: Natural Breaks (Jenks)

Classes: 5

Classification Statistics

Count:	8629966
Minimum:	4.93
Maximum:	11.85
Sum:	87,316,017.25
Mean:	10.12
Standard Deviation:	0.86

Columns: 100 ☐ Show Std. Dev. ☐ Show Mean

Break Values

7.1
8.62
9.74
10.5
11.85

☐ Snap breaks to data values

Figure 10. Histogram of the DTM in the study area based on the standard deviation method

The average elevation of this area is 10.12m. The histogram of the DTM has been shown in Figure 10. This histogram and table 3 illustrate that elevation less than

8.62m occupies about 4.97% area and elevation above 10.51m occupy only 36.18% of the total area. It is noticed that around 42.32% of areas are having elevations between 9.75m and 10.5m.

Accuracy Assessment of the DTM

The accuracy of our generated DTM with respect to my own surveyed GCPs has been assessed. 21 GCPs have been collected to evaluate the accuracy of the DTM. Table 4. shows the different types of the accuracy of the DTM in which Mean, SD, MaxE, MinE, MIDe, and RMSE represent Mean error, Standard deviation, Maximum error, Minimum error, Median error, and Root Mean Square Error respectively.

Table 4. Accuracy of DEM with respect to GCP

With respect to	Direction	MaxE	MinE	MIDe	Mean	SD	RMSE	LE95
GCP	Z	0.27	0.00	0.06	0.07	0.07	0.1	0.20

Based on Table 4. and the above definitions the summary of the accuracy of the DTMis as follows:

- Vertical Accuracy, $RMSE_z$ =0.1 (With respect to GCP)
- Linear error at the 95% confidence level, $LE95 = 0.2$ (With respect to GCP)
- DEM Resolution/post spacing: .2 m.

Analysis of Land use in the study area

The study area is mainly residential. So, the main category of land use in the study area is the Residential area. The total area is comprised of 85.30 acres of land. Out of the total area, about 13.21% of land is still vacant and is under the process of development. Table 5. shows the distribution of land use in the study area. The vegetation land shares the major portion of the land, which is about 35.76% of the total area followed by the communication network comprising about 19.73% of the land. Relevant to vegetated land there is also a garden in the study area which occupies about 2.21% of the study area. The residential land shares about 18.93% of the total land. Waterbodies are an important component of land use in the study area. The waterbody occupies about 5.64% of the total land. About 3.24% of the total land is occupied by community facilities. In addition to these major land classes there are also graveyards (0.83%) and mixed-use (0.46%). Figure 11. shows the spatial distribution of land use in the study area.

Table 5. Land use in the study area

Land use	Area	
	Acre	Percentage
Circulation Network	16.83	19.73
Community Facilities	2.76	3.24
Garden	1.89	2.21
Graveyard	0.71	0.83
Mixed Use	0.39	0.46
Residential	16.15	18.93
Vacant Land	11.27	13.21
Vegetation Land	30.50	35.76
Waterbodies	4.81	5.64
Total	85.30	100.00

Analysis of structure used in the study area

There are a total of 207 structures within the study area. Most of the structures are occupied by residential land use. The number of residential land use is 197. In addition, there are 3 administrative structures, 4 commercial structures, 2 community facilities structures, and 1 transportation structure within the study area. Table 11. shows the distribution of structure used in the study area.

Table 6. The structure used in the study area

Structure Use	Frequency
Administrative	3
Commercial	4
Community Facilities	2
Residential	197
Transportation	1
Total	207

Analysis of structure type in the study area

There are three types of structures in the study area. These are pucca, katcha, and semi-pucca structures. About 97 structures are pucca, 31 structures are semi-pucca and 63 structures are Katcha in the study area. Some pucca structures are under construction. The number of this type of building is 16. Table 7. shows the distribution of structure types in the study area.

Table 7. Type of structures in the study area

Structure Type	**Frequency**
Katcha	63
Pucca	97
Under construction (Pucca)	16
Semi Pucca	31
Total	**207**

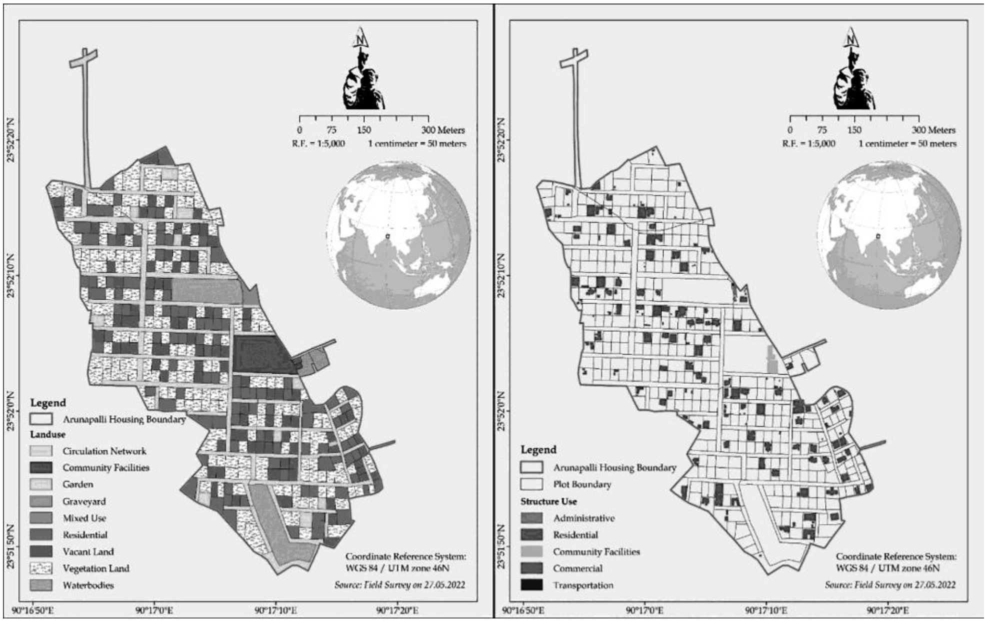


Figure 11. Land use Map (left) and structure use (right) of Arunapalli housing society

Analysis of Utility facilities in the study area

Utility facilities are the core ofa clean and healthy environment in a housing project. Utility facilities can be identified from UAV images to some extent. I have identified utility facilities like electric poles and light posts from the ultra-high resolution orthophoto. Further, I have printed the orthophoto and identified it from the field and updated these layers. I have found 02 Drainage Outfalls, 200 Electric Poles, 02 Light Posts and 27 Transformers.

Table 8. Utility Services in the study area

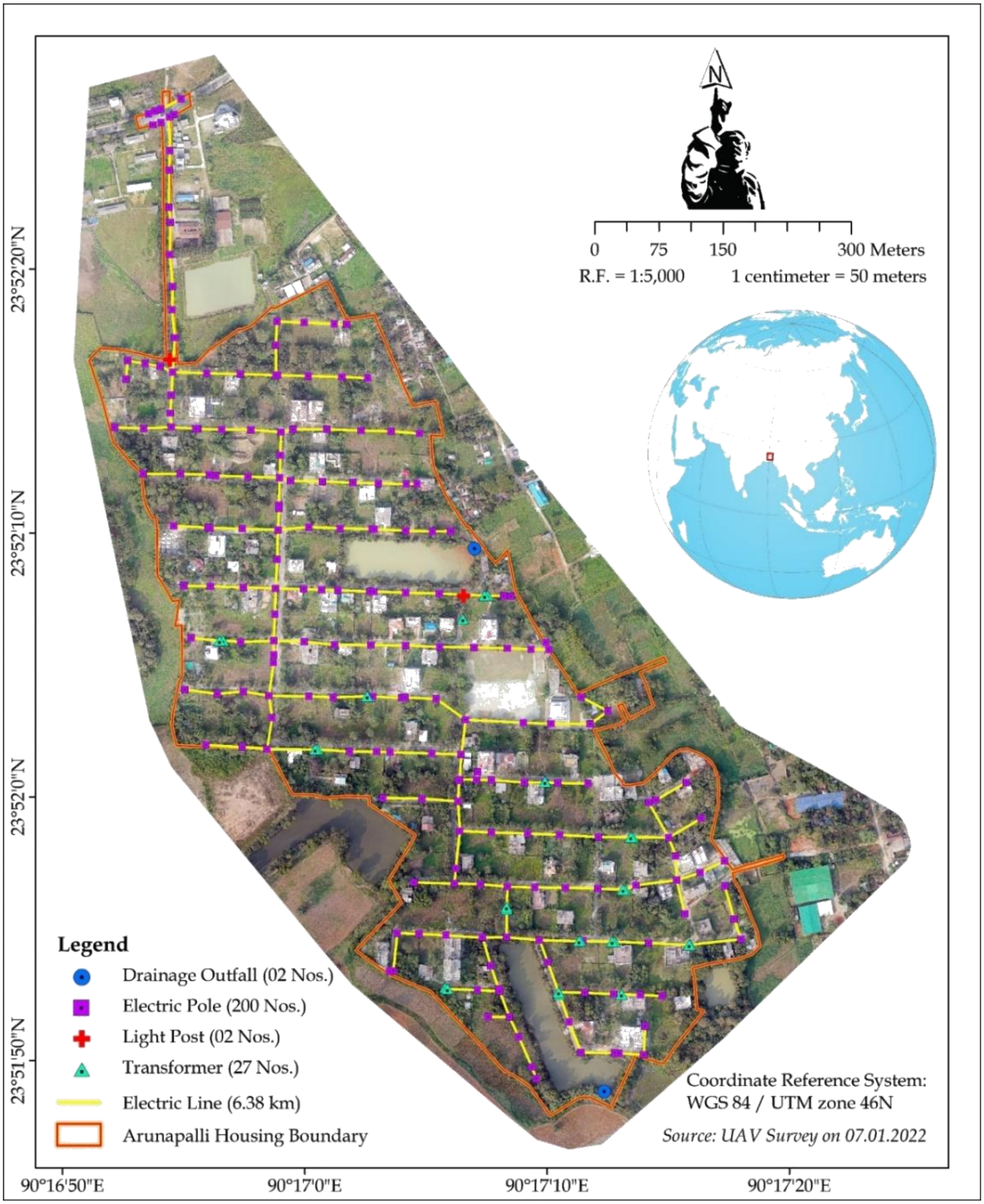
Utility Services Name	**Frequency**
Drainage Outfall	2
Electric Pole	200
Light Post	2
Transformer	27
Total	**231**

Exploring Challenges and Opportunities in the context of Arunapalli

- **Challenges:**

A total of 5 flights have been imaged here. As a rule, all flight patterns should be the same. But, in the east/west direction of Arunapalli, there were a lot of crows wandering due to the farmhouse of the army. Had to take two flights to the left. During the first flight, the crow bumped the UAV, causing the UAV to become stationary for a while. It had no problem capturing images and the UAV. This requires changing the flight pattern during the second flight, so that the crow has less time to damage the UAV.

In general, there are several challenges in using UAVs in housing surveys. These problems are caused by things like the limited capacity of the device battery, short flight time, payload, the sensitivity of the sensors used in the device set, the uncertainty of the weather, etc. These problems limited the flexibility and versatile ways of using UAVs for a different purposes. Especially, the limited battery capacity and short flight duration of UAVs make it troublesome to use them outside of populated areas.In addition, there are some problems with the processing of data. The data that UAVs collect in a wide range of spectral bands are different in ways that are typical of Big Data. They are different from each other, often not finished, have a lot of them, and change quickly. But they also have various features which make them very useful; for instance- they are multidimensional, have high resolution in space and time, and can gather a lot of data from any type of area in a short time. Because how these data are different, they present specific processing problems that the scientific community works to solve.



Source: UAV Survey on 07.01.2022

Figure 12. Utility Services Map of Arunapalli Housing Society

- **Opportunities:**

For better housing planning, a lot of spatial information is needed. The need for more information in fields like cadaster and land information management systemss, as well as the need for information about both space and time, led to the creation of models with more than two dimensions. This information must be collected in a timely fashion. Technological evolution has significantly impacted the design of research and the spatial planning process. A range of new technological tools is now widely used in data collection as well as in the depiction and evaluation of planning proposals. UAVs are such tools that can make a significant contribution to mapping cities. UAVs can be used in many civil applications including housing planning due to their ease of deployment, low maintenance cost, highmobility, and ability to hover. UAVs are projected to be a prominent deliverer of civil services in many areas including farming, transportation, surveillance, and disaster management. The results of this study suggest that UAVs could be a concrete example of how useful they are for surveying big cities, and for housing planning. Finally, it can be concluded that the use of UAVtechnology along with lligent flight planning and data processing methods, is very perspective in different sectors of city planning including residential housing planning.

Conclusion and Way Forward

Conclusion

The combination of unmanned aerial vehicle (UAV) technology with intelligent flight planning and data processing technologies has promise for numerous economic areas. UAVs are mostly used for monitoring the surrounding area and acquiring photos, especially multispectral ones, which are then processed utilizing onboard and ground-based computing systems. UAVs can also organize communication, search, transportation, fertilization, the application of herbicides, etc., in addition to monitoring. The objectives of this study were to a) prepare plot level GIS database from the Mauza Map of the study area, b) develop a GIS database of the study site using UAV and c) explore the opportunities and challenges of UAV to assess the housing societies. In this study, UAV technology was used to collect and develop a spatial database needed for housing management. For developing the Mauza database, the scanned Mauza sheet was used for digitization whereasthe on-screen digitization method was adopted for the digitization of Mauza maps/ sheets. ArcGIS software was used to perform the digitization process. After digitization, the mauza database was developed incorporating plot-level information for further analysis. Then each mauza sheet was joined to develop thecomplete mauza database of the study area. In this study, UAV Mavic 2 Pro was used to survey the study area. Aerial Photography covered the project area along with at least a 20m buffer to produce a topographic map, Digital Elevation Model (DEM), and Digital Surface Model (DSM) of the study area. Different outputs were derived. Mauza database is the first of them. The core output is the generation of DTM. The findings from DTM show that This area is 10,12m above sea level on average. It was also found that elevations less than 8.62m take up about 4.97% of the total area and elevations above 10.51m take up only 36.18%. Finally, the UAV can be used in housing planning with a promising opportunity.

Way Forward

Throughout this research,problems and challenges were identified. These problems and challenges are related to the technical aspects of UAVs. In addition, there are recommendations about mauza mapping. The following can be recommended to solve the future problem of mauza mapping and using UAVs.

- In the field of Mauza database development:

✓ RS and CS mauza maps can be used to develop aGIS database. But either RS or CS can be used to maintain the consistency of database development.

✓ Care should be taken before scanning the mauza sheets. Because sometimes the old mauza sheets become distorted. This distortion leads to improper georeferencing of the mauza map.

✓ While joining the adjacent mauza sheet, it is recommended that mauza sheets overlap over the common boundary line to ensure accurate spatial adjustment.

✓ The mauza boundary and area of the mauza plot boundary should be matched and rechecked to ensure there is no sliver polygon, overshoot, and undershoot.

- In the field of flight control and planning:

✓ Algorithms for the planning of the most efficient paths for diverse groups of unmanned aerial vehicles (UAVs) to complete particular tasks in various economic sectors

✓ It enhances the software that is freely accessible for managing groups of unmanned aerial vehicles with varying degrees of technological complexity.

✓ When capturing photographs with a UAV, it is possible that specific images will be skipped, and that other areas of the area in between flights will not be captured. As a result, inspecting the photograph after each flight is highly recommended. Taking oblique photographs is the most common cause of Crab and Drift Errors. In addition to this, prolonged use of the system causes it to get increasingly hot.

- In the field of data processing and computer vision:

- ✓ a collection of data sets to be used for instructing the computer vision systems that are associated with the applications.
- ✓ the creation of novel neural network architectures or the modification of previously established ones.
- ✓ the development of ways for processing the varied data that is collected by UAVs.
- ✓ Processing images using a CPU alone is highly inefficient compared to using a GPU, which is the primary requirement for UAV image processing. The processing of images is performed in three stages by the Pix4D software.

1. Initial Processing
2. Point Cloud and Mesh
3. DSM, Orthomosaic, and Index

In this case, the second step (Point Cloud and Mesh) takes a considerable amount of time (if the point cloud data export quality is high) and calls for a very advanced graphic card (Minimum Xeon series).

- ✓ The amount of data (raw UAV images and post-processing outputs) involved in the project is very much high. During processing, a vast portion of space on the hard disk is necessary. In addition, if the system crashes in the middle of the processing, the whole procedure must be repeated, which is time-consuming.

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