FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 2, No. 2, 2025
Print ISSN: 1595-9686
EISSN: 1595-9708

LANDCOVER MAPPING OF EKITI STATE UNIVERSITY CAMPUS (ADO-EKITI) USING ASTRIUM PLEIADES-HR 1A IMAGERY AND GEOGRAPHIC INFORMATION SYSTEM MODEL

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https://doi.org/10/3303/jees.2025.0202/014

ABSTRACT
Remotely sensed satellite imagery and GIS technologies were utilised to map land cover of the Ekiti State University campus in Ado-Ekiti, Nigeria. GPS coordinates comprising 25 Ground Control Points (GCPs) taken with Mobile Topographer and a 1:20,000-scale basemap of the study area were also utilised in the processing. The Data were interpreted using the USGS/Anderson (1976) land cover classification and the IGU (1952) colour classification scheme. Supervised classification was performed using ArcGIS 10.3. Six landcover classes were identified, with Mixed Vegetation (MV) and Crop Field/Pasture (CF/P) accounting for the most significant areas, 156.06 hectares and 142.12 hectares, respectively. Built-up area (BU) covers only 91.63 hectares of the total land cover, with apparently sufficient space for future expansion, given judicious land allocation and adequate planning of development channels. Open Surface (OS) covers 19.91 hectares of the landcover. It occurs as barelands within the Built-up area (BU), but as bare rock surfaces in other parts of the entire university landcover. Plantation and Forest are the least, with only 11.48 hectares and 11.15 hectares, respectively, and should be conserved against further depletion. An overall accuracy of 75% and a kappa coefficient of 0.693 indicate the reliability of the classification on the final maps and data. The study demonstrated that remotely sensed data, coupled with GIS analysis, can be effectively used for land cover mapping of the study area. The resulting information can be incorporated into master and strategic plans for current and future development planning efforts and can help reduce potential environmental problems.

Keywords: Astrium Pleiades Imagery, Remote Sensing, Supervised classification, Landcover Mapping.

INTRODUCTION

The use of high-resolution satellite imagery to capture synoptic information about Earth's environment has recently gained currency, with significant implications for sustainable development. When such satellite imagery data of ground conditions are processed and classified into various land-cover categories, more information about spatial planning, patterns, processes, associations, and attendant environmental problems can be revealed.

Since the seminal work of Anderson et al. (1976), many studies have examined land cover mapping and classification using remotely sensed satellite imagery. For example, ISSS (1996) described landcover classification as the systematic arrangement of land into various categories based on selected properties of the land and its potential for some particular purposes or uses. In classical remote sensing applications, land cover is the information about the Earth's surface within the wavelength range of environmental satellites during flybys (King, 1984; Olatunji, 2009).

Knowledge of landcover classification has become increasingly important in virtually all aspects of environmental systems and management. Nations now plan to overcome their planning problems, uncontrolled development, haphazard juxtaposition of functions, deteriorating ecological quality, loss of prime arable lands, destruction of critical wetlands, and loss of aquatic and wildlife habitats, using satellite imagery data coupled with GIS technology.

In most developing countries, including Nigeria, Adeniyi and Omojola's (1999) findings, which corroborated those of Ujoh (2008), revealed that the availability of relevant and current information on land cover classification has been inadequate. The result of Ademiluyi et al. (2008)'s empirical work in Southwestern Nigeria also showed that the problem has been affecting planning efforts, the judicious allocation of land, and the achievement of sustainable development goals.

Kiran (2013) noted that observing the Earth from space is now crucial to the understanding of the time-variant influence of man's activities on his natural environment. This view has been supported by Fakeye et al. (2015), who affirm that the classification of high-resolution satellite imagery and its analysis with GIS play an essential role in landcover management and environmental planning. In a similar vein, Dale and McLaughlin (1988) opined that in situations of rapid and often uncontrolled development, synoptic observation of portions of the earth from space provides objective information on human utilisation of the environment. A similar view has also been shared by Zubair (2006).

The study area for this research is the Ekiti State University landcover in Ado-Ekiti, Southwestern Nigeria (Fig. 2). The area has gradually undergone remarkable expansion, growth, and physical development since its inception in 1982. This has resulted in increased land consumption and modifications to land cover over time.

Few studies have examined landcover characteristics within the study area, except for a few related works, such as Olatunji (2013). Without any detailed and comprehensive attempt to identify classes of current land-cover patterns or characteristics, Planners, Decision makers, and Environmentalists will have no basic tools for physical planning, infrastructure development, and resource management within the University. This view was supported by Fasona and Omojola (2005), who worked with data from contiguous parts of Southwestern Nigeria.

The primary objectives of this study are to: assess the feasibility of using high-resolution Astrium Pleiades imagery coupled with GPS data and GIS analysis to map landcover classes of the study area, and to demonstrate the advantages of utilising the landcover maps for land resources management decision-making and physical planning purposes.

LITERATURE REVIEW

Land use land cover (LULC) studies are among the most critical applications of satellite imagery and GIS, playing an essential role in urban planning and management as well as in research activities (Basheer et al., 2022; Garg et al., 2019). LULC detection is the process of determining changes in land use and land cover using georectified remote sensing data (Khan and Jhariya, 2016).

Analysis of satellite imagery helps identify and quantify differences in LULC by observing it across different time scales (Butt, Shabbir, Ahmad and Aziz, 2015). It is essential to have precise, continual, and periodic LULCC information for effective management of natural resources and for adaptation to a sustainable development programme (Butt *et al.*, 2015). The LULCC study is essential for determining the current state and managing natural resources and environmental problems (Ali et al., 2015).

While traditional inventories and surveys have been used to determine LULC satellite remote sensing is much more efficient and cost-effective for assessing the geographical distribution and temporal changes in LULC at regional or local scales. Besides, Satellite image analysis provides an effective way to study trends, changes, and developments (Ahady & Kaplan, 2021; Aliyazicioglu et al., 2021).

STUDY AREA

Ekiti State University is located along Ado-Ifaki road in the northern part of Ado-Ekiti, the capital city of Ekiti State in Nigeria. The University campus site is located approximately at latitudes 070 41’ and 070 43’ North of the Equator, and Longitudes 050 13’ and 050 16’ East of the Greenwich Meridian (Fig. 1).

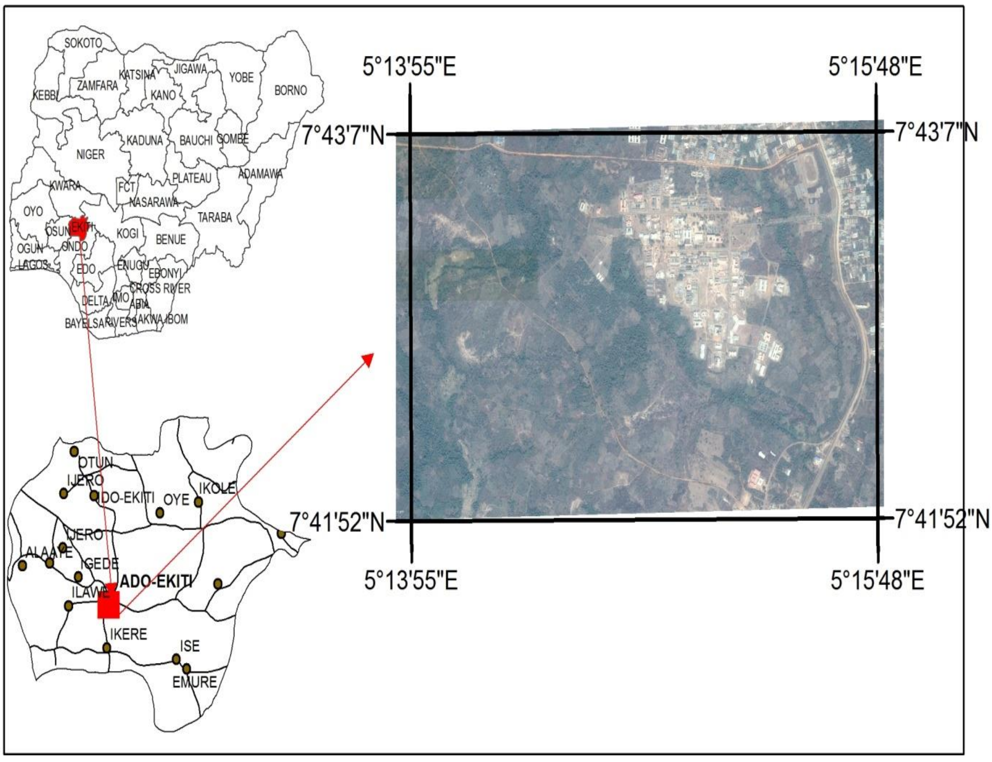

Fig 1: The Study Area, Ekiti State University, at the North-Eastern Part of Ado-Ekiti, Nigeria.

The University campus falls within the Tropical Humid Rainforest Zone of Nigeria, with distinct wet and dry seasons. The wet season is from March to October, while the dry season is between November and February. Mean monthly temperature is 29^0C while mean relative humidity is over 70%. Mean total annual rainfall ranges between 1400 and 1700mm (Ebisemiju, 1992a).

Rainfall is brought by prevailing southwesterly winds from the insular Atlantic Ocean during the wet season. The cold and dry Northeasterly winds (Harmattan), which originate from the African Continental Interior (Sahara), prevail during the dry season. The University campus is located within an intermontane basin bounded by weathered rocky inselbergs. Experience has shown that this area is the wettest part of the entire region, as the moisture-laden southwesterlies are often shed by interveining inselbergs (Adebayo, 1993).

The upland intermontane inselbergs are composed of coarse-grained, granite-gneisses and charnockites of old-suite pre-Cambrian origin. Within the built-up areas of the University campus, the lowest recorded elevation is about 329.76m above mean sea level in the marshy area near the Goodluck Ebele Jonathan lecture theatre in the western part. In contrast, the highest elevation of 389.25m above mean sea level was recorded at the Faculty of Engineering area towards the eastern part of the university area (Table 5).

The campus site is an approximately 2^0-5^0 m gently sloping pediplain that abuts the valley of a small third-order stream (River Omosuo) in the eastern part of the University campus (Olatunji, 2007; Olatunji and Ashaolu, 2019).

The University campus also falls within the Upper Ogbese Drainage Basin. This is part of the much larger Benin Owena River Basin Development Authority (BORBDA), which has been earmarked for planning purposes in Nigeria. The major drainage river is the River Elemi, with numerous but intermittent tributaries (Ebisemiju, 1993; Olatunji, 1998a).

MATERIALS AND METHODS

Basemap, GPS coordinates, and satellite imagery are the data layers used for manual and automated mapping, combining image processing with GIS technology for the study. An archival 1:20,000-scale basemap was acquired and converted to digital format to provide geographic registration for the satellite imagery (Table 1).

Table 1: Data Acquisition and Sources

Data Types	Date	Spatial Resolution and Scale	Acquisition Source
Astrium Pleiades	12/01/2016	0.5m	Google Earth
GPS Coordinate	17/01/2017	± 5m	Mobile Topographer
Basemap	Archival	1:20,000	Physical Planning Unit

Mobile Topographer for Android (version 4.5.1) was used for GPS field survey of 25 sufficient and highly dense Ground Control Points (Ground Truths) of interest that are visible on the satellite imagery of the study area. These are coordinate data for specific cultural features (mainly buildings) identified on the imagery to train image-to-map registration, and for analysis and interpretation. Table 5 displays the GPS coordinates for the GCPs, which were georeferenced to the local zone 31 UTM Cartesian E, N, and Z orthometric height datum (Minna a08 datum, Nigeria National Origin) and the WGS 84 geodetic datum (of Geographical Latitudes and Longitudes).

Astrium Pleiades satellite imagery with 50-70cm resolution was downloaded from Google Maps via the Astrium Geo Store Portal for the study. The imagery data were geographically registered to the existing 1:20,000-scale basemap, and a subset of the imagery scene covering the study site was extracted (fig. 3).

A supervised maximum-likelihood classification using the image processing routine in Trimble-powered eCognition Essential Software 8.3 was run on the imagery subscene to categorise each raster polygon by landcover type. The resultant raster dataset was imported into the ArcGIS 10.3 environment to produce a six-class thematic landcover map that met digital, visual, analytical, and geographical requirements.

Landcover classification accuracy was assessed using overall, producer and user's accuracies, and error matrix based on Kappa Statistics (K) and procedures of Cohen (1968), Weng (2010) and McHugh (2012) (Table 7).

The final procedures employed for landcover classification and mapping in this study were implemented on a Windows 8.1 PC running a 64-bit OS, utilising ArcGIS 10.3 for processing. Figure 3 is the GIS–generated and resampled 1:1000m-scale thematic landcover classification map of the study area with 6 classes. Table 6 shows the area covered by each class in hectares and as a percentage.

Evaluation of Astrium Pleiades Imagery For Landcover Classification and Mapping
The satellite imagery used in this investigation is Astrium Pleiades imagery acquired in 2016. The satellite imagery was acquired through a constellation of two Very High Resolution (VHR) Optical Earth Observing and Imaging Spacecrafts (Pleiades–HR 1A and Pleiades-HR 1B). Figure 2 depicts the raw Astrium Pleiades imagery used for Landcover classification and mapping in the study area.

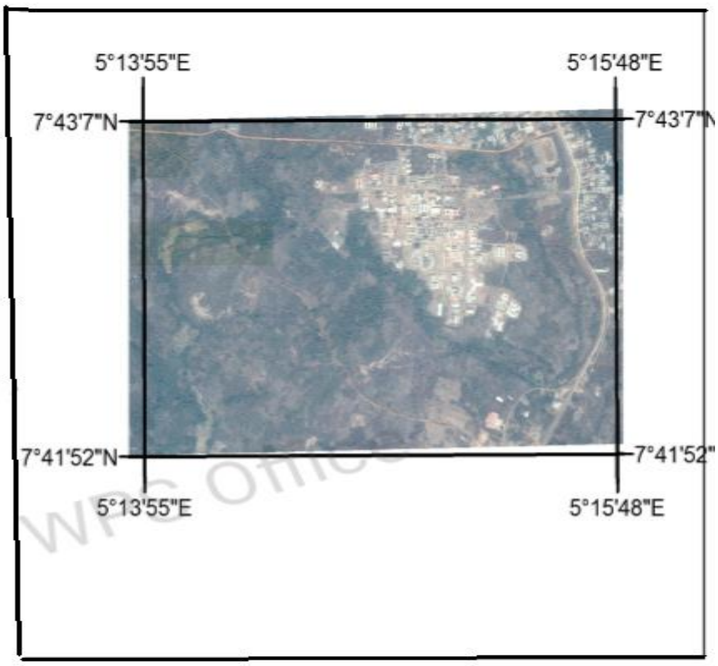

Fig.2: Raw Astrium Pleiades Imagery used for Landcover Classification and Mapping of the Study Area

The Pleiades satellite systems were designed under the French–Italian OR FEO Programme (Optical Radar Federated Earth Observation) between 2001 and 2003, and the programme was officially launched in October 2003 with the French Space Agency (CNES) as the overall system operator. The French Space Agency (CNES) has since granted EADS Astrum, a leading European space technology company, the prime contractor role for the Space Segment of the Pleiades programme.

On September 18th 2013, Astrium again agreed with Google Inc to provide satellite imagery to support Google Maps and other Google products and services from its mosaics of Pleiades and SPOT satellite imagery. These are now readily available via the Astrium Geo-Information team to researchers and prospective users in its GeoStore Portal, which was opened previously in 2012. This is the channel through which Astrium Pleiades imagery was acquired for this study.

Both Pleiades – HR 1A and – HR 1B are essentially the same and were launched via a Russian Soyuz STA rocket from the Guiana Space Centre in Kourou, French Guiana, on December 17th 2011 (02:03 UTC) and December 2nd, 2012 (02:02 UTC), respectively (Table 2).

Table 2: Astrium Pleiades – HR 1A and – HR 1B Payload Parameters

S/N	Satellite Payload Parameters	Astrium Pleiades – HR 1A and – HR IB
1.	Mission	Earth Observing/Earth Imaging
2.	Operator	CNES (France Space Agency)
3.	COSPAR ID	1A 2011 – 076F; 1B 2012 – 068A
4.	SATCAT no	IA 38012; 1B 39019
5.	Mission Duration	5 years (planned)
6.	Bus	AstroSat – 1000
7.	Manufacturer	EADS Astrium
8.	Launch Mass	970kg (2,140 1b) each
9.	Launch Date	1A: 02:03 Dec. 17, 2011 (UTC) 1B: 02:02 Dec, 2, 2012 (UTC)
10.	Rocket	Soyuz STA with Fregat Upper Stage
11.	Lauch Site	Guiana Space Centre – ELS Soyuz launch Pad
12.	Reference System	Geocentric
13.	Regime	Sun-Synchronous
14.	Eccentricity	~ 0
15.	Perigee Attitude	695 km (432 ml)
16.	Apogee Altitude	695km (432 ml)
17.	Inclination	98.2^0
18.	Resolution	Panchromatic: 50cm, 70cm Multispectral: 2m Pansharpened: 50/70cm Bundle: 50/70cm (PAN), 2m (mss/xs)
19.	Footprint	20km Swathlength Single Pass Mosaics up to 100 x 100km

Source: Pleiades Eoportal Directory, 2015

The Pleiades satellites provide Earth's surface coverage with a 26-day repeat cycle and orthorectified imagery products at 50–70 cm resolution. The system was designed for a range of

VHR remote sensing applications requiring high levels of detail, such as (a) landuse/landcover planning with detection and identification of features, (b) Agricultural/Land Management, (c) Forestry, and so on. These qualities make Astrium Pleiades satellite imagery a prime candidate for use in the present study.

The two Astrium Pleiades satellites operate in the same phased orbit and were offset by 180^0 to offer a daily revisit capability over any point on Earth's surface. The satellites also share the same orbital plane with the SPOT 6 and SPOT 7 programmes of CNES. They thus form a larger constellation with 4 observing Earth imaging satellites within the Astrium services at 90^0 apart from one another – a 360^0 complete coverage of Earth's systems.
Pleiades orbit is sun-synchronous, phased and near-circular at a mean altitude of 695km (432 ml). The satellites have four ground receiving stations: 2 in Toulouse, France, 1 in Kerguelen Island, Spain, and 1 in Kiruna, Sweden.

Classification Scheme and Colour Scheme
The classification scheme adopted in this study was developed in the USA by USGS/Anderson et al. (1976) to meet the needs of Federal and State Agencies for an up-to-date overview of land-use and land-cover characteristics throughout the country. This was done on the basis that the scheme will be receptive to data from satellite remote sensors. In applying the scheme, 6 major classes at the first level of landcover were selected, as presented in Table 3.

Table 3: Landcover Classification Scheme

S/N	Major Classes	Description
1.	Built-Up Areas	This class includes urban fabrics, commercial areas, transport units, residential areas, and other related built-up areas of non-agricultural and non-vegetated areas within the University campus.
2.	Cultivation	Crops, pastures, and irrigated lands are included in this class. The class also includes heterogeneous agricultural areas and agroforestry areas.
3.	Forest	This class comprises areas with a high density of trees
4.	Open Spaces	Open spaces with little or no Vegetation, beaches, dunes, sands, bare rock surfaces, and sparsely vegetated areas.
5.	Mixed Vegetation	Shrubs and other mixed forestlands, herbaceous vegetation, and associations.
6.	Plantation	A body of single-stand crop plants such as cocoa, coffee, palm oil, cassava, plantain and other tree crops.

Source: USGS/Anderson et al (1976).

To provide a systematic and uniform approach to the presentation of landcover processed from satellite imagery in map format, a colour-coding scheme adapted from the International Geographical Union (1952) was adopted, as shown in Table 4.

Table 4: USGS Level 1 Landcover Colour Code Used in the Classification Scheme

S/N	Landcover Type	Colour Code
1.	Urban or Built-Up Land	Red
2.	Agricultural Land	Light Brown
3.	Rangeland	Light Orange
4.	Forest land	Green
5.	Water	Dark Blue
6.	Wetland	Light Blue
7.	Barren land	Grey
8.	Tundra	Green-Gray
9.	Perennial Snow or Ice	White

Source: USGS/Anderson et al. (1976); IGU (1952)

Supervised Classification and Landcover Mapping

Supervised classification using the maximum likelihood method was performed in eCognition software on a Windows 8.1 PC, using imagery data to train the imagery into a map format for landcover mapping. This requires high-quality training datasets that are well distributed across the entire satellite imagery subscene and are aided by ground-truth GPS coordinates or Ground Control Points (GCPs) within the study area.

Therefore, conspicuous cultural features, mainly buildings with high, known locational accuracy, identified in the Astrium Pleiades imagery and map data, were captured using a mobile Topographer GPS with 5m accuracy. 25 such GPS coordinates of Ground Control Points were selected across the entire imagery subscene for this purpose, as shown in Table 5.

Single pixel sampling of a relatively large number of 52 individual pixels was randomly selected for each landcover class. This is to obtain image-map training statistics using Trimble-powered eCognition Essential software 8.3. GPS coordinates also aided these for critical cultural features and a 1:20,000-scale basemap of the study area. According to Campbell (1981), who was also supported by the findings of Labovitz and Masuoka (1984), this type of training pixel selection helped prevent violations of the statistical independence assumption.

After completing the supervised classification task on the trained Astrium Pleiades imagery above, the product was entered into ArcGIS 10.3 for map generation and analysis. The software was launched on a Windows 8.1 PC with a 64-bit operating system. Figure 3 is the GIS–generated and resampled 1:1000m-scale thematic map of the study area. It portrays a combination of an image subscene extract with GPS coordinates and a GIS-generated map into a single geographically registered thematic landcover type, according to Welsh et al. (1990).

Table 5: GPS Coordinates of Locations of Selected Cultural Features to Enhance Training Data

GPS GCP	WGS 84 Geographical Latitudes	WGS 84 Geographical Longitudes	UTM Northings(m)	UTM Eastings (M)	Height (M) Above MSL	Attribute Information
01	7.71407000 7^{0}4250.65	5.26014000 5^{0}15'36.50"	749298.797	833348.331	381.26	Main Gate
02	7.70774500 7^{0}42'27.88"	5.25547833 5^{0}15'40.88"	748788.044	852645.854	383.96	Dept. of Physiology
03	7.70692000 7^{0}42'27.88"	5.25362500 5^{0}15'13.05"	748583.994	852553.502	382.16	College of PGS
04.	7.70718333 7^{0}42'25.85"	5.25362500 5^{0}15'9.83"	748488.177	852760.623	385.66	GEJ Lecture Theatre
05.	7.70879667 7^{0}42'31.66	5.25276670 5^{0}15'9.96"	748488.177	852760.623	380.46	Main Library
06.	7.71044167 7^{0}42'37.59"	5.25093833 5^{0}15'3.377"	748285.441	852941.550	380.46	New Faculty of Science
07.	7.7096466.7 7^{0}42'34.72"	5.24893500 5^{0}14'56.16"	748864.82	852852.432	375.06	Entrepreneurship Centre
08.	7.71457000 7^{0}42'52.45"	5.24648500 5^{0}15'40.88"	747791.575	853395.689	389.25	Faculty of Engineering
09.	7.71426333 7^{0}42'51.34"	5.24445167 5^{0}14'40.02"	747567.362	853360.580	388.15	Kingsley K. K. Student Centre
10.	7.71619500 7^{0}42'58.30"	5.24887000 5^{0}14'55.93"	74853.829	853576.854	388.26	UBA Bank
11.	7.71466000 7^{0}42'52.77"	5.27889333 5^{0}14'56.01"	74857.299	853407.046	386.06	Reservoir
12.	707136400 7^{0}42"4988"	5.27990333 5^{0}14"59.65	748169.354	853294.783	385.06	Wema Bank
13.	7.71460833 7^{0}42"52058"	5.25204333 5^{0}15'7.355"	748404.954	853403.163	383.66	Health Centre
14.	7.71653000 7^{0}42"59.56"	5.25189000 5^{0}15'6.804	748386.910	853615.674	380.36	Second Gate
15.	7.71344000 7^{0}42'48.38"	5.25233833 5^{0}15'8.417"	748438.191	853274.679	384.66	Lawrence Omolayo Admin Block
16.	7.71143833 7^{0}42'41.17"	5.25339333 5^{0}15'12.21"	748555.788	853853.243	385.86	Fac. Of the Soc. Sciences
17.	7.70834667 7^{0}42'30.04"	5.25360000 5^{0}15'12.96"	748580.401	852711.324	377.26	3000 Seater LT
18.	7.71053167 7^{0}42'37.91"	5.25280667 5^{0}15'10.10"	748491.575	852952.595	383.16	Faculty of Law
19.	7.70625833 7^{0}42'22.52"	5025532167 5^{0}15'19.15"	748771.624	852481.287	376.76	EKSU Funeral House
20.	7.71027500 7^{0}42'36.99"	5025649500 5^{0}15'23.38"	748898.763	852926.349	384.96	Fac. Of Mgt Sci.
21.	7.71407500 7^{0}42'50.67"	5.125445667 5^{0}15'16.04"	7486771.595	853345.366	380.36	Alumni Centre
22.	7.70964667 7^{0}42'34.72"	5.24893500 5^{0}14'56.16"	748064.820	852852.432	375.06	CEC Admin Block Irasa
23.	7.70545167 7^{0}42'19.62"	5.25466667 5^{0}15'16.80	748699.809	852391.662	377.96	Tarred Rd End Col. Of Medicine
24.	7.70692000 7^{0}42'24.91"	5.25362500 5^{0}15'13.05"	748583.994	852553.502	329.76	Tarred Rd End GEJ LT
25.	7.71356000 7.42'48.81"	5.25503167 5^{0}15'18.11"	748735.352	853288.925	380.06	Rd 1, Col. of Medicine Junction

Source: Author's Field Survey, 2017

RESULTS AND DISCUSSION

Results

The results of this investigation are presented in two parts: landcover classification and mapping, and accuracy assessment. The map was produced in accordance with the Anderson et al. (1976) classification scheme (Table 3) and the IGU (1952) colour scheme (Table 4). The overall spatial structure of landcover types and area statistics was presented in Table 6, with 6 pattern or class types. The classes comprise Built up (BU), Cropfield/Pasture (CF/P), Forest (F), Mixed Vegetation (MV), Open Surface (OS), and Plantation (P).

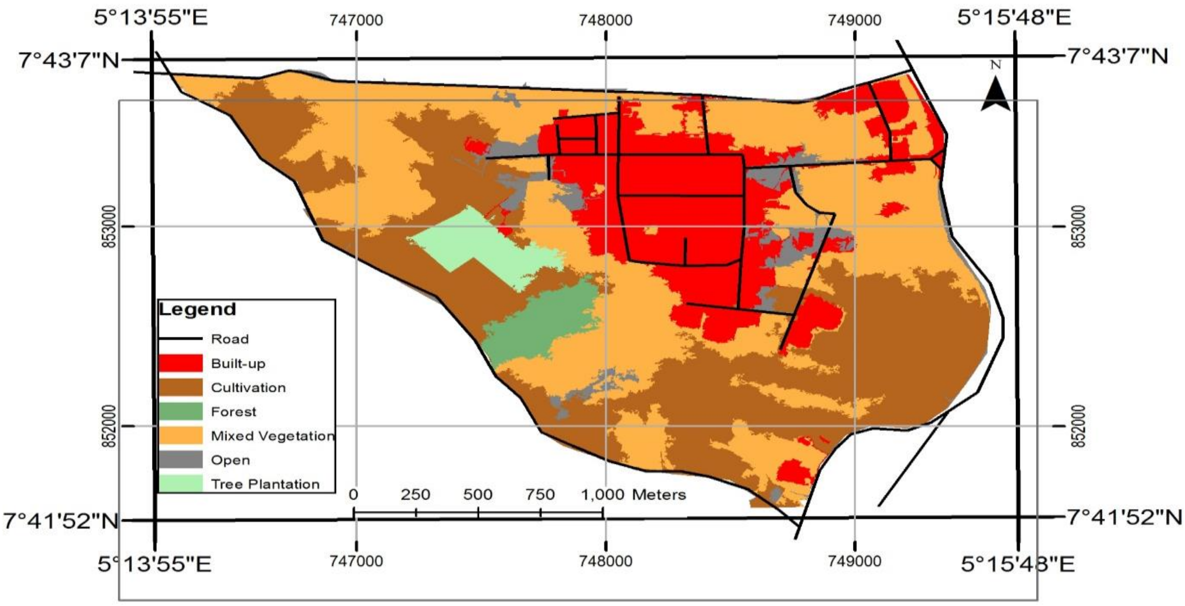

Fig 3: The GIS-Generated Six Classes Thematic Landcover Map of the Study Area

Table 6: Landcover Types Used in the Classification and Area Statistics

S/N	Landcover Types	Abbreviation	Colour Code	Area (ha)	Percentage
1.	Built Up	BU	Red	91.63	21.19
2.	CropField/Pasture	CF/P	Light Brown	142.12	32.87
3.	Forest	F	Green	11.15	2.58
4.	Mixed Vegetation	MV	Yellow	156.06	36.10
5.	Open Surfaces	OS	Gray	19.91	4.60
6.	Plantation	P	Light Green	11.48	2.66
	Total Area (ha)			**432.35**	**100.00**

Amongst the 6 patterns identified, Mixed Vegetation (MV) constituted the most predominant landcover type. It covers 156.06ha (36.10%) and was depicted in yellow.
Crop Field/Pasture (CF/P) is the next-largest land cover type, covering 142.12ha (32.87%) of the total land cover, with a light brown colour code on the map. Built-up area (BU) covers 91.63ha (21.19%) and is depicted in red. Open Surfaces (OS), Plantation (P), and Forest (F) have the least area coverage. Open Surfaces (OS) cover 19.91ha (4.60%) of the landcover types. Plantation and forest land cover are the least, with only 11.48 ha (2.66%) in light green and 11.15 ha (2.58%) in green, respectively.

Discussion

Ekiti State University, the study area, provides a suitable test bed for applying Astrium Pleiades imagery to land cover classification and mapping. The area is relatively small and offers favourable atmospheric conditions, with homogeneous, cloud-free conditions during satellite flybys. This enhanced the quality and accuracy of the captured imagery subscene utilised for landcover classification and mapping.

Based on the analysis and results presented in Figure 3 and Table 6, most landcover types within the study area are self-explanatory. The juxtaposition of the much larger Mixed Vegetation landcover with Built-Up areas provides ample opportunity for the planned future expansion of the latter. This also means there is a possibility of further reduction in the size of Mixed Vegetation due to encroachments by Built-Up areas and contiguous Cropfield/Pasture landcovers.

Open surfaces occur as barelands in between other landcover types, but as bare inselberg rock surfaces (mainly 2-3m high, low-lying rock pavements of dwala and ruwares) in different parts of the entire university lands. Much higher elevations of weathered inselbergs, however, form intermontane basins around the larger university region (Ebisemiju, 1993; Olatunji, 2007; Olatunji and Ashaolu, 2019).

The Plantation is the Faculty of Agriculture's experimental lands, and the Forest constitutes the remaining aboriginal forest cover of the area, which should be conserved against further encroachments and depletion. Future planned development should be channelled towards Mixed Vegetation and, to a lesser extent, towards Crop Field/Pasture landcover. Currently, these two landcover types are experiencing pressure and gradual encroachments from other competitive and contiguous landcover types.

The study has also shown that raster satellite imagery (in pixels), basemap, and GPS can be used together to train image-to-map data and classify landcover types. This was achieved through supervised classification (using the maximum likelihood method) of the raw Astrium Pleiades satellite imagery using eCognition Essential 8.3, running on a Windows 8.1 PC with a 64-bit operating system. The training data were selected using 25 GPS coordinates, pure pixel selection, and a 1:20,000-scale basemap of the study area. It was also easy for the analyst to locate the 3 datasets in the raw orthorectified image and in the generated landcover map.

52 (11) stratified random pixels were chosen for accuracy assessment. Their ground information, determined from GPS coordinates and a basemap, was compared with the classification result using Kappa statistics, as shown in Table 7. The relatively high level of accuracy achieved (Kappa coefficient of 0.693) indicates that the method adopted for landcover map production permits the upload of orthorectified Astrium Pleiades imagery into the ArcGIS 10.3 environment using the training data. According to Ma et al. (2001), the accuracy and quality of the final landcover map are as good as the training data used to develop it.

The process of delineating pixel-by-pixel raster polygons from satellite imagery adopted the patterns observed in the colour composite and colour scheme of Anderson et al (1976) and IGU (1952). The result is the visual and automated interpretation of the ArcGIS 10.3-generated landcover classification map in Figure 3.

Two factors, however, have been recognised as influencing landcover classification and mapping results from high-resolution satellite imagery, such as Astrium Pleiades, according to Gong and

Horworth (1990). First, improved resolution conveys greater spatial heterogeneity in the image, which, in turn, influences the training process and makes it more complex. It also reduces the probability of statistically separating the image into distinct landcover classes, according to Cheriguene et al. (2018). Second are the use of minimum and maximum likelihood classifiers, which are per-pixel classifiers that base their decisions solely on spectral information provided by individual pixels. In such situations, Gong and Horworth (1990) argued that large amounts of spatial data obtained from surrounding pixels are often ignored.

The addition of other datasets, including GPS coordinates of conspicuously identified cultural features on the satellite imagery, their georeferencing, and registration on the study area basemap, can improve image-raster polygon training in a GIS environment to generate landcover maps. Several scholars have also applied image segmentation techniques to further enhance image-to-map training data and to classify landcover maps (Dey et al., 2010; Cheriguene et al., 2018).

Landcover Classification Accuracy Assessment

A vital aspect of landcover mapping is assessing the accuracy of the classification results in the final map product. Table 7 shows the result of the Kappa statistical analysis of the accuracy assessment of the thematic landcover classification map generated from orthorectified 50-70 cm resolution Astrium Pleiades satellite imagery of the study area.

Landcover thematic maps produced by classifying satellite imagery are among the most common applications of remote sensing technology. Emphasis must therefore be placed on various components of the mapping process to ensure tolerable accuracy according to Foody (2002).

Table 7: Classification Accuracy Assessment of 2016 Astrium Pleiades Imagery – Generated Landcover Map

LULC 2016		Truth						Classification Overall	Producer Accuracy
		BU	CF/P	F	MV	OS	P		
Classification	Built up(BU)	7	1	1	0	1	0	10	70%
	Crop Fields /Pasture (CF/P)	0	7	1	1	1	0	10	70%
	Forest (F)	1	0	8	1	0	0	10	80%
	Mixed Vegetation(MV)	0	1	1	7	1	0	10	70%
	Open Surfaces(OS)	0	1	0	1	8	0	10	80%
	Plantation(P)	0	0	0	0	0	2	2	100%
Truth overall		8	10	11	10	11	2	52	
User Accuracy		87.5 %	70%	72.727 %	70%	72.727 %	100%		
Overall Accuracy		75%							
Kappa		0.693							

Landcover mapping and classification accuracy in this study were assessed based on 52 (11) stratified random points, comparisons between classified images, and comparisons with a suite of Astrium Pleiades imagery. After visual and digital interpretation of the trained imagery data and supervised classification into various landcover categories, the accuracy of the landcover map was assessed using Kappa statistics, and the result is presented in Table 7 above.

The overall accuracy was 75%, and the user accuracy was 87.5%. Kappa statistics was also calculated to determine the significance of the differences between the two classifications, and the result shows a kappa coefficient of 0.693.

CONCLUSION AND RECOMMENDATIONS

This paper established the feasibility of mapping landcover patterns using a combined application of satellite remote sensing, GPS and GIS technologies. In the paper, the logistical advantages of utilising a high-resolution satellite imagery system coupled with the map generation capabilities of GIS, and with the reasonably high level of accuracy, proved to be a reliable method of landcover mapping. The resultant map serves to identify areas where the University Management's efforts might be directed or adjusted to aid present and future planning and to better conserve existing natural resources, according to Scott et al. (1993).

The resultant map can also be used for physical planning, ecological analysis, environmental management, and the assessment and modelling of development channels. It can serve as input toward improving the quality of the University's strategic and master plans. Mapping and mitigating environmental problems for disaster risk reduction is also possible.

Datasets can be automated and imported into a 'standalone' or server-based Geospatial Database to enhance the intelligent decision-making process on land-use/land-cover characteristics and change over time. The study can also assist in delineating the University boundaries and in monitoring encroachment by unauthorised land users.

Classification accuracy can be further improved by devoting special attention to training orthorectified imagery data into a landcover map format, with proper registration and georeferencing of all datasets and layers to the UTM and WGS 84 datum, and by combining basemaps, GPS, and pure pixel selection.

Acknowledgements
The authors would like to thank the French Space Agency (CNES), the French-Italian ORFEO Programme, the Astrium Geoinformation Team and GeoStore Portal, the Pleiades EoPortal Directory, and Google Inc. Maps Products and Services. These bodies graciously provided the Astrium Pleiades imagery used in this work.

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