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Application of indegenous space technology to land use/cover mapping for cassava yield prediction in Nigeria

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ABSTRACT

Nigeria is a nation who abandoned agriculture for oil earnings. This action resulted in food exports and thus food insecurity in the country. Agriculture has been the main source of foreign earnings for the nation before the discovery of oil, and can still be if enough attention is paid to the sector.

One of the crops that can eradicate food insecurity in Nigeria and also earn foreign exchange is cassava. Cassava is the most consumed crop in Nigeria, and a crop whose products can be exported for foreign earnings. The Obasanjo government revived agriculture in Nigeria and especially paid attention to cassava cultivation for both national and international consumption; it also initiated and promoted the importance of space technology to economic development.

NigeriaSat-1, a Nigeriansatellite has a lot of application areas, one of which is precision agriculture. As part of the effort to increase cassava production in Nigeria, the use of space tools (use of NigeriaSat-1 images and other satellite images) has been considered and adopted. This paper is on predicting cassava yield using NigeriaSat-1 images to create a land use/cover map on an eight hectares cassava farm in Kwali local government of the Federal Capital Territory of Nigeria.

KEY WORDS: *Space Technology, Satellite imageries, Cassava yield, Land use/cover map, Crop yield prediction*

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AGRICULTURE IN NIGERIA

Agriculture has been defined by the Microsoft Encarta dictionary as the occupation or business of cultivating the land, producing crops, fishing and raising livestock. Agriculture is the largest sector in the Nigerian economy accounting for nearly 35% of GDP and providing employment for the bulk of the labour force (Chigbu, 2005).

Okuneye, (2006) states that agricultural production in Nigeria comprises crop farming, fishing, livestock and forestry. The agricultural sector was the largest earner of foreign exchange during the first decade of independence, but its role has since been overtaken by crude oil exports, which presently account for about 95% of export earnings.

Agriculture is not only an important occupation of Nigerians, but also a way of life, culture and custom. The Nigerian civilization began with agriculture, when their nomadic ancestors began to settle and grow their own food, human society was forever changed. Not only did villages, towns and cities begin to flourish, but so did knowledge, the arts and the technological sciences (Chigbu, 2005).

Akande (1998) further explained that for most of Nigerian history, the society has an intimate connection to the land. Nigerian communities, no matter how sophisticated or varied, couldnot ignore the importance of agriculture because to be far from dependable sources of food was to risk malnutrition and starvation. Nigerians depend on a wide range of agricultural products in almost all aspects of life, e.g.

- Nutritional food is a key determinant of human health
- Fiber and clothing to keep warm
- Water - agricultural crops are the largest user of fresh water.
- Energy- fuel wood is a major source of energy and modern biomass plantations have significant potential to provide clean energy and stimulate economic growth.
- Health (Medicinal plants) - nutrition is a key factor in human health

• Agricultural practices play a critical role in destroying, maintaining or developing biodiversity. Ecological services are critical for sustainable development and planetary health.

Nigerian Crops
Agricultural crops in Nigeria are grouped into the following:
Cereals (guinea corn "Sorghum spp", millet, maize "Zea mays" and rice "Oryza sativa")
Root and tuber crops (cassava "Manihotesculenta", yam "Dioscoreaspp", cocoyam, and potatoes (sweet and irish))
Grains legumes and other legumes (cowpeas "Vignaunguiculata", locust bean "Parkiaclappertoniana", soyabean "Glycine max" and other beans such as groundnut "Arachishypogeae", pigeon pea "Cajanuscajan", bambara nuts "Voandzeia subterranean")
Oil seeds and nuts (melon "Cococynthyscitrullus", benniseed "Sesannumorientae or S indicum", kolanut "Cola nitida or C. acuminata", coffee "Coffee Arabic")
Tree crops, (cocoa "Theobroma cacao", oil palm "Elaeisguineensis" and rubber "Heveabrasiliensis")
Vegetables and fruits (vegetables: onions "Allium cepa", African spinach "Amaranthusspp", Indian spinach "Basellarubra", Pumpkin "cucurbitapepo", Sweet pepper "Capsicum annum", Hot pepper "Cinetumafricanum", Water leaf "Talinumtriangulare", Carrot "Daucuscarota" and Lettuce "Lactuaca sativa"; fruits: pineapple "Ananascomosus", Pawpaw "Carica papaya", Mango "Magniferaindica", Banana/plantain "Musa spp", Citrus "Citrus spp" and Guava " psidiumguajava")

Cassava

Cassava (Manihotesculenta) originated in the Americas specifically in Brazil and Paraguay. It is a shrub with an average height of one meter, and has a palmate leaf formation. Cassava belongs to the family of rubber plants with white latex flowing out of its wounded stem and leaf stalk (Cock, 1985).

Cassava is a tropical root crop, requiring at least 8 months of warm weather to produce a crop. It is traditionally grown in a savanna climate, but can be grown in extremes of rainfall. In moist areas it does not tolerate flooding and loses its leaves to conserve moisture in drought areas, producing new leaves when rains resume (Tewe, 2007). It takes 18 or more months to produce a crop under adverse conditions such as cool or dry weather. Cassava does not tolerate freezing conditions. It tolerates a wide range of soil pH 4.0 to 8.0 and is most productive in full sun.

Because of its massive leaf production which drops to form organic matter thus recycling soil nutrients, Tewe (2007) said cassava requires little or no fertilization and yet will maintain a steady production trend over a fairly long period of time in a continuous farming system. With its ability to suppress weeds particularly the improved varieties which develop many branches early enough to form a canopy shading weeds from solar radiation, cassava as a crop is a friend of the small scale farmer whose weeding operation is drastically reduced.

Harvesting begins 8 to 14 months after planting with the entire plant being uprooted by hand. Most cassava is harvested by hand, lifting the lower part of stem and pulling the roots out of the ground, then removing them from the base of the plant by hand. The upper parts of the stems with the leaves are removed before harvest. A mechanical harvester has been developed in Brazil. It grabs onto the stem and lifts the roots from the ground (Wagner, 2003). Care must be taken during the harvesting process to minimize damage to the roots, as this greatly reduces shelf life. During the harvesting process, the cuttings for the next crop are selected. These must be kept in a protected location to prevent desiccation. Plants can be left un-harvested for more than one season, with the roots becoming larger during the following season.

Cassava roots are very perishable with a shelf life of only a few days. Careful handling and storage in high humidity can prolong the shelf life by one or two weeks.

Whereas other crops such as yam, maize, banana and plantain, cowpea or sorghum and millet are eco-regionally specific, cassava is probably the only crop whose production cuts across all ecological zones. Talking about cassava's adaptability to the tropical African environment, Alfred Dixon, a cassava breeder at the International Institute of Tropical Agriculture (IITA, 2005) in Ibadan, Nigeria says "Cassava is to the African peasant farmers what rice is to the Asian farmers, or what wheat and potato are to the European farmers."; The stem is the planting material from which grows the roots and shoots. Cassava roots are very rich in starch, and contain significant amounts of calcium (50 mg/100g), phosphorus (40 mg/100g) and vitamin C (25 mg/100g). However, they are poor in protein and other nutrients.

Around the world, cassava is a vital staple for about 500 million people. Cassava's starchy roots produce more food energy per unit of land than any other staple crop (O'Hair, 1995).

Figure 2.1 Cassava leaf and tuber Source: IITA

Cassava; Nigeria's Staple Crop

Cassava was primarily grown in southern Nigeria during the pre-colonial period; it used to be a cheap source of food and a poor man's food. But recently, cassava products has become the most consumed food in all parts of Nigeria. According to Babaleye (2004), presently in Nigeria, about 70 percent of cassava production is used as food. The most popular processed products are commonly known as gari, lafun, foufou, attieke, kpukpuru, chickwangu,tapioca and boiled cassava (in the North). Gari, is the most popular of the products, it is a dry granular meal made from moist and fermented cassava and can be soaked in water or made into a solid food. Anywhere in Nigeria, this food can be found and it is no more a poor man's food, but a necessity in every home.

Cassava dried roots can also be milled into flour. The flour can be use for baking breads (Tewe, 2007). Industrial examples where cassava is used in the processing procedures or manufacture of products include paper-making, textiles, adhesives, high fructose syrup and alcohol.

Cassava has ethnomedical uses: the bitter variety of *Manihot*root is used to treat diarrhea and malaria, the leaves are used to treat hypertension, headache, and pain and can be used to treat Irritable Bowel Syndrome, and the paste is eaten in excess during treatment (Tewe, 2007).

Advantages of Large Scale Cassava Cultivation

Nigeria is recognized worldwide as the leading producer of cassava totaling 37 million tones cultivated on 2.5 million hectares of land, giving a national average yield of 14.8 metric tones/ hectare (IITA, 2005).

The projection of the obasanjo's initiative to attain 150 million metric tons annually is attainable by doubling the yield and hectares put to cassava cultivation in the country. Cassava is a crop that outstrips all others in its potential areas of cultivation and survival on marginal lands. It is intercropped with arable and permanent crops in heterogeneous farming systems with each small holder cultivating an average of 1.0 hectare. It is therefore a crop that lends itself to cultivation by the vast majority of Nigerians with high potentials for wealth creation of the teeming populace through the establishment of processors and marketers in many cottage industries. These can also feed large-scale industries for cassava products in demand in both domestic and export markets. The demands for cassava even domestically illustrate the vast potentials of the crop to substantially reduce the foreign expenditure on food, feed and industrial products (IITA, 2005, Babaleye, 2004).

Cassava is therefore the crop to actualize the economic rebirth if we can address its limitations particularly through a well articulated and coordinated private sector led and demand driven initiative. With the attainment of the projected 5 billion dollars annual income from cassava export, the contribution to GDP will become so significant that the focus and fight on petroleum products will be cushioned by this alternative `goldmine' that will benefit considerably more people across the country.

Limitations of Cassava production in Nigeria

Some of the limitations of cassava cultivation in the country are

1. High Cost of Production due to traditional farming practice. The high cost of labour for planting, weeding and other cultural practices brings the average cost per tonne to about N8, 000 or about US $45.00.However, studies by the IITA Ibadan on Nigeria have shown that mechanization of cassava production on medium and large-scale farms brings the production price down to the US $20.00/tonne mark particularly when the improved cassava varieties are used.

2. Cassava is uneconomical to transport on long distances due to its bulky nature. Farm gate processing is therefore advisable but this is limited by poor electricity supply and other necessary infrastructure particularly in rural areas, thus the processing to storable products is limited to traditional foods and notindustrial products that have standards and specifications. It will therefore be necessary to address the problem of providing equipment that can utilize the minimal facilities in rural areas to produce dry storable products at the farm gate for cheaper transportation to distant areas.

3. Cassava prices follow a cycle that alternate high and low prices every two to three years. In times of cassava shortage, prices go up and farmers feel motivated to plant more cassava, only to result, a year or two later, in a glut of cassava that leads to low prices and a reduction in the planting of cassava (Tewe, 2007). Cassava farmers would steadily increase their production if there were an assured demand for their crop. Expansion of cassava is therefore demand-limited. The recent observed changes in food habits of urban dwellers indicate an increased demand for cheap high calorie feeds.

4. Farmers' access to the market encompasses their ease of access to market places and to credit, and the availability of cassava marketing middlemen who would link the farmers to source of demand for farm products and supply of farm inputs. This will certainly call for a private sector partnership with farmers to effect this vital link. Presently market access for cassava farmers is poor (IITA, 2005). Nevertheless, farmers would expand cassava land area under condition of difficult access to market centers provided technologies that improve product quality, reduce bulk, extend shelf life and make it possible for quality cassava products to be transported at reduced costs over poor roads to distant urban market centers were available. Unfortunately, such facilities exist to a limited extent for processing traditional foods. Equipment for processing into intermediate or final raw materials for industries are rarely existent on or near farms, hence the difficulty and high cost of transportation of perishable cassava tubers.

5. The dearth of processing equipment for transforming cassava tubers into storable and acceptable products at the farm gate is a serious limitation to expansion of the cassava industry in Nigeria. Apart from the locally fabricated grater, press and fryer, rarely can one locate any other facility near the farm for cassava processing. The most critical of this equipment particularly in the more humid south is the absence of suitable and economically viable drying facilities that micro-processors can utilize for their cassava processing. A pertinent illustration in this regard is the recent legislation of 10% inclusion of cassava flour in bread. There is hardly any drier on ground that can be utilized by micro-processors at the farm gate to producewholesome and acceptable cassava flour. The method of sun-drying on raised concrete floors have been discouraged because of contamination with sand and other extraneous materials even where the solar radiation is abundant to produce a storable cassava flour.

Nigerian Space Activities

Nigeria has been a nation that strives towards science and technology advancements; as a result it has recognized early enough the importance of space programs in achieving this goal. Nigeria first showed its intention in space program during the inter-governmental meeting of the Economic Commission for Africa of the Organization of African Unity (OAU) in AddisAbaba, Ethiopia in 1976; also the Nigerian Government has earlier proposed a sum of 10 million naira (USD78, 125) in 1975 for a period of five years towards the development plan for the establishment of a Remote Sensing center (Obba, 2003).

In 1987, Food and Agriculture Organization (FAO) through a two-man committee, made a recommendation to the Nigerian Government for a need of space science infrastructure. As a follow up plan, in 1993, the National Agency for Science and Engineering Infrastructure (NASENI) set up a nine- member committee to formulate a National Space Science and Technology Policy for Nigeria. They recommend the creation of centers for the development of space science and technology in Nigeria. The centers are

1. National Center for Remote Sensing (NCRS) Jos, created in 1996
2. National Space Research and Development Agency (NASRDA), created in 1999, and approved in 2001 when the Federal Executive Council (FEC) approved its National Policies and Programmes.

The National Space Research and Development Agency (NASRDA)

NASRDA was created in 1999 under the regime of the Obasanjo’s government. This agency has been proposed since 1993 under a military government, but was established after six years of its proposal. The satellites launched by the centre are NigeriaSat-1 (2003), NigcomSat 1 (2005), NigeriaSat 2 (2011) and NigeriaSat-X (2011). NigeriaSat-1 is now out of orbit, but its images are used for this paper.

NigeriaSat-1

NigeriaSat-1 is part of the Disaster Monitoring Constellation (DMC) Satellites. The DMC is an international collaboration between 5 countries: Nigeria, Algeria, Turkey, United Kingdom, and China with the aim of addressing the need for daily revisit and global coverage using EO (Earth Observation) satellites to monitor natural disasters.

The five satellite owners have established a "DMCII Consortium" to derive maximum mutual benefits through exchange of their DMC satellites resources daily for monitoring of disasters and other dynamic phenomena. NigeriaSat-1 has the advantages of frequent revisits and is locally available and free of foreign exchange transaction problems. It has been providing services which have greatly improved the response time, aid -environmental monitoring and the management and mitigation of disasters wherever and whenever they occur.

The various applications of NigeriaSat-1 Images

NigeriaSat-1 is a remote sensing satellite with the following areas of application (NASRDA, 2003):

1. Disaster Management
2. Agriculture
3. Water resources development and management
4. Solid Mineral Exploration/Exploitation
5. Ecosystems Management with Associated Goods and Services
6. Demographic and Cadastral
7. Transportation and Utilities
8. Environmental Management
9. Defense and Security
10. Health and Public Health Delivery
11. Education and Capacity Building

Application of NigeriaSat-1 to Precision Farming in Nigeria

Precision farming is an integrated agricultural management system incorporating several technologies. The technological tools often include the GPS, GIS, yield monitor, variable rate technology, and Remote Sensing (Foreign Agricultural Service, 1998).

The goal of precision farming is to gather and analyze information about the variability of soil and crop conditions in order to maximize the efficiency of crop inputs within small areas of the farm field. To meet this efficiency goal the variability within the field must be controllable. Efficiency in the use of crop inputs means that fewer crop inputs such as fertilizer and chemicals will be used and placed where needed. The benefits from this efficiency will be both economical and environmental (Ames Remote 2007). Environmental costs are difficult to quantify in monetary terms as the reduction of soil and groundwater pollution from farming activities has a desirable benefit to the farmer and to society.

The various applications of NigeriaSat-1 in Precision Agriculture are listed below (NASRDA 2003)

- Soil and Drainage Maps
- Land use maps
- Variable Rate Technology
- Monitor Crop Health
- Yield Forecasting

Study Area

Abuja is the capital city of Nigeria, located in the center of the country in the Federal Capital Territory (FCT). Abuja is Nigeria's most planned city with an average population of 405,000. It was built as the FCT in the 1980s and officially became Nigeria's capital on 12 December 1991 (African Cities, 2005). The city is divided into five (5) districts: Central, Garki, Wuse, Maitama and Asokoro. The sub-urban districts are Nyaya, Karu, Gwagwalada, Kubwa, Jukwoyi, Kwali, Lugbe and other developing districts

Abuja and the FCT have experienced a huge population growth; it has been reported that some areas around Abuja have been growing at 20-30%. Squatter settlements and shanty towns have spread rapidly in and outside the city limits. One of such settlement is the Lailai village in Kwali local government areas of the FCT. This is the where the cassava farm under study is located.

The Mohammed Abubakar Farms, Lailai village has been operational since the 1990s. The farm size is 8.94 hectares and mixed cropping is practiced on the farm. The farmer mainly cultivates maize and cassava, but other crops like melon, garden egg, onions and potatoes are also grown in the farm.


Figure 3.1 Muhammad Abubakar Farm, Kwali LGA, FCT .

Methodology

Application of Remote Sensing and Geographic Information System on NigeriaSat-I imagery for land cover mapping for potential expansion of cassava cultivation and to model the physical features- topography, soils: - type, moisture content, location etc for predicting cassava yield.

Apart from NigeriaSat-1, Landsat images will be used.Landsat images are chosen because they provide high-quality, multi-spectral imagery of the surface of the Earth which contains many layers of data collected at different points along the visible and invisible light spectrum. No other satellite imagery has that combination of attributes, which makes Landsat imagery of particular value to the global community.

Acquisition of Data

The NigeriaSat-1 and Landsat images used for the study were obtained directly from the Mission Control and Data Management Department of NASRSDA.

Data Processing

The raw images are first processed using Idris remote sensing software. This software is used to perform the following.

a. Geometric correction (Georeferencing and Geocoding): are made to correct the inaccuracy between the location coordinates of the picture elements in the image data, and the actual location coordinates on the ground.

b. Atmospheric correction: is to retrieve the surface reflectance (that characterizes the surface properties) from remotely sensed imagery by removing the atmospheric effects. It has been shown to significantly improve the accuracy of image classification

c. Radiometric correction: Made to correct for brightness values, of the object on the ground, that have been distorted because of sensor calibration or sensor malfunction problems.

d. Mosaic - the gluing of the various scenes of the images used.

e. Clipping and sub setting: Cutting the image to a desired size

f. Image enhancement: include contrast stretching, spatial filtering, and rationing.

g. Image Classification: groups pixels into classes or categories. This image classification process may be unsupervised or supervised.

Interpretation/Analysis of Data

This involves the interpretation of the processed data into classes either visually or by automation (by training the software to classify the image on the bases of the information provided). The former is done by studying the processed image and by what is seen, classification is made. This is possible where the resolution of the image is high or medium and most features are recognizable. For low resolution images, trained and experienced personnel can still use the visual mode of classification.

The automated classification is done by the software and can be supervised or unsupervised. When the software is trained to do the classification based on spectral reflectance and each class named in accordance to what is observed by ground truthing, then it is unsupervised. The classification is supervised when the user instruct the software on what classes to produce and what those classes stand for. Such information is obtainable only by ground truthing.

Ground truthing is thus a very important part of data interpretation and analysis. Even in visual classification, a good knowledge of the area is needed and such information is provided when the study area is visited.

The software used for data interpretation and analysis, is the Arc View GIS software.

Product

The products of these processes are two land use maps of the study area. The first map is produced from NigeriaSat-I images and the second from Landsat images; this is to compare the result and what product each images is capable of producing. The location of the farm isalso identified on the map using the coordinates obtained from the field trip to the farm. The land use/cover maps are classified into four classes: the minor urban, montane vegetation, farms and extensive grazing and bare surfaces.

Result- Land Use/Cover Map ofKwali Local Government

The first land use/cover map for Kwali local government area of the FCT using NigeriaSat-1 images and Landsat images are achieved usinga 2008 image of NigeriaSat-1 captured during the raining season. The farm was also visited during the raining season in consistency with the acquired image.

Visualized classification was then carried out on the processed image to achieve the image result below.

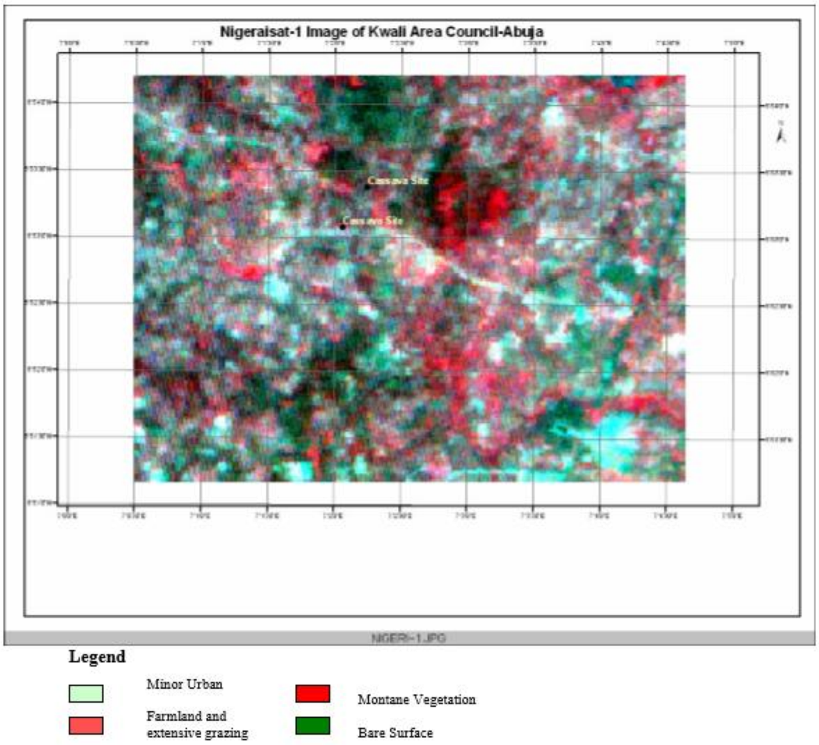

Figure 1 NigeriaSat-1 Land use/cover map of Kwali Area Council Source: Ogunade

The two black dots on the image signify the location of the farm on the image. Due to the low resolution of NigeriaSat-1, not much classification or detail could be obtained from the result.

In order to present a much clearer picture of the land use/cover map of the area, 2006 Landsat images captured at the same season as farm visit was used to produce another land use/cover map. Below is a supervised classification of the study area's land use/cover map using Landsat images. The two dots on the map also show the location of the farm on the image.

The picture is much clearer here, the "Y" shaped linear green lines depicts the two roads that led to the farm. The brownish area between the two black dots is the farm and the light green areas are bare grounds around the farm.

The Role of Land use/cover map in Predicting Cassava Yield

The purpose is to provide an overall picture of what land is used for in the study area. As seen from the above maps, one can depict which area is bare land, which is thick forest, which is under cultivation, etc. this can be achieved by low resolution satellites like NigeriaSat-1 of 32m resolution and Landsat of 28m resolution as used in this study. However, this task can be easier performed using higher resolution images like NigeriaSat-2 and SPOT images which will enhance the result and get much more accurate picture.

To provide a complete map, a radar remote sensing satellite images like the Radarsat l and 2 in conjunction with a metrological, vegetation and soil maps of the area are to be interpolated with panchromatic images used above. The images taken from an active remote sensing satellite with radar payload are more detailed as radar penetrated the clouds to show the reflectance and signature of each crop. Cassava farm can easily be differentiated from a maize farm because the reflectance will be different. The reflectance can also show how healthy the crops are.

The use of meteorological map of the area in conjunction with the vegetation and soil map will lead to the yield prediction of the crop. This will be enhanced by visiting the farm with a ground spectrometer to correlate the ground reflectance of the crop with that seen on the map. Also the cassava yield data of the farm for at least twenty- five years will be needed in making the prediction.

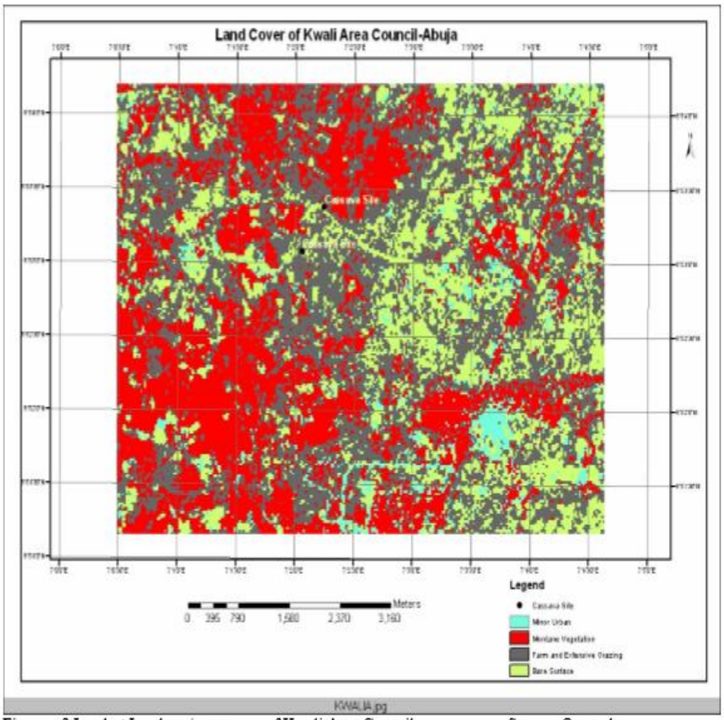

Figure 2 Landsat Land use/cover map of Kwali Area Council Source: Ogunade

CONCLUSION

As Nigeria is reawakening its agricultural sector, the nation is on the right path in adopting space tools in achieving great yields, and thus securing food security. Unfortunately, only few Nigerians know the importance of space to agriculture and fewer people know how to apply space tools in enhancing agriculture. Also the farms under study using space tools are modernized farms and not the local farms which are the major producers of cassava (and food) in the country.

The Nigerian government still has a long way to go in the application of space tools to agriculture. This can be achieved through agricultural extension; the training of the rural farmers on what it entails. These rural farmers also need assistance on their farms; they need those who can help them in reading the market, and thus help in advising them on how much to produce yearly. This will minimize post harvest wastage and serve as an incentive to the farmer. There is also room for detecting crop health and the amount of fertilizers needed by knowing the crop reflectance and the soil health respectively. This can also be achieved through space technology in the production of soil and vegetable maps.

In conclusion, with the launch and use of NigeriaSat-I as well as NigcomSat2 and X, Nigeria has gained international recognition in technology development. The nation is making use of these technology advantages in advancing the country's infrastructure and economy. The nation is targeting to be one of the world's first twenty countries with the best economy in year 2020.

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