**LAND COVERS**

**GLOBE RESEARCH REPORT**

**ABSTRACT**

This paper presents a systematic methodology to derive land-use classes from a remotely sensed data derived land cover map at a scale of 1:200,000. The aim of the study is to better understand the land cover/land-use relationship and to enhance the value of a land cover mapping product for the planning and management of natural resources and/or environmental change studies. In the case of the study, the land cover product is generated using the **GLOBE OBSERVER** “land cover classification system”. The methodology is heavily determined by the spatial resolution of the satellite imagery, the classification system used and the expert knowledge of the study area. For any given land cover, the associated land-uses are identified as well as the land cover/land-use relationship. It is assumed that these relations can be of four types: one to one, one to many, many to one or a combination of any of the aforementioned possibilities. The land cover/land-use relation need not be consistent across the study area. The parameters used for land-use classification are based on a comprehensive review of the literature, in which land cover and land-use are usually amalgamated. A set of decision rules was established to define land-use classes. These decision rules were tested during the field survey, after which they were applied to the whole study area. The concurrence of land cover and land-use delineations is discussed for the classes identified. The result of the study is a detailed, flexible land-use data set in which the various parameters used for classification can be re-grouped according to user needs.

**UNDERSTANDING THE LAND COVER/LAND-USE RELATIONSHIP AND TO ENHANCE THE VALUE OF A LAND COVER MAPPING PRODUCT FOR THE PLANNING AND MANAGEMENT OF NATURAL RESOURCES AND/OR ENVIRONMENTAL CHANGE STUDIES**

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**STUDENTS:**

1. **SANNI ALIYAH AYOMIDE**
2. **IDRIS RAHMAN**
3. **IDRIS RAHEEM**
4. **RAFIU AZEEZAT**
5. **DOTO SEKINAT**
6. **BAMGBOYE SAMUEL**

**SCHOOL / ORGANIZATION:**

***EBENEZER AFRICAN CHURCH PRIMARY SCHOOL 1, IFAKO IJAIYE, LAGOS STATE, NIGERIA***

**GLOBE TEACHER:**

***MR. NOJEEM OLANREWAJU SANNI***

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**RESEARCH QUESTIONS**

1. What are significant rationales of studying land covers in Lagos State, Nigeria?
2. What are the useful resources natural resources covered up by land?
3. What are the likely environmental changes that affect the production of farm produces?

**RESEARCH HYPOTHESIS**

H1: there are significant rationales for studying land covers in Lagos State, Nigeria.

H2: there are useful natural resources covered by lands.

H3: there are significant changes in the global environment that is likely to affect farm produces.

**GENERAL CONTEXT AND RATIONALE OF THE STUDY**

The availability of timely, reliable land-use information is becoming more important than ever in decision supporting processes at various levels, both within a country and between countries. Understanding the role of land-use in natural resource management and environmental change studies requires the availability of spatial land-use data. At the local scale, historical aerial photographs and farming systems studies may help to generate these data, at a national or regional scale the collection of land-use data has to rely mainly on the availability of statistical, non-spatial data and satellite imagery. Annual estimates for most types of agricultural commodities are usually available as statistical data at (sub) country level (e.g., administrative unit). However, the user of such data remains uninformed as to where, i.e. the geographic location, these commodities are grown. The increasing availability of modern technology such as satellite imagery, geographic information and analysis systems and global positioning systems are tools that allow the production of reliable spatial (statistical) data. However, these technological advances are hampered by the lack of widely accepted methodologies for description and characterization of land-uses, which would facilitate data collection and assure harmonization between data sets in a country and between countries. The availability of advanced tools should go in parallel with enhanced methodological developments to obtain the improved data required for informed decision-making.

**Land cover** is defined as that which one can observe on the surface of the earth (Di Gregorio and Jansen, 2000), whereas **land-use** relates to the manner in which these biophysical assets are used by humans (Cihlar andJansen, 2001). Since use depends largely on the land characteristics (i.e. cover, form, position, substratum, etc.), there is a close relationship between land cover and land-use. However, land cover observation does not automatically mean land-use definition because land cover and land-use, though interrelated, are not identical.

For each plot, i.e. a contiguous tract of land, individuals choose a land-use type from which they expect to derive benefits, in the form of goods and/or services, considering their aims, available means, possible constraints and the given set of biophysical parameters. In addition, there are determining factors such as the institutional and cultural setting, the legal attributes of the plot (e.g., land tenure) and the broader socio-economic environment (Cihlar and Jansen, 2001). The land-use choices made will vary in space and time and so will the resulting land cover. Understanding these land cover/land-use changes is regarded as crucial in understanding environmental change over the next decades in order to respond in a timely manner. Land cover and land-use changes are one of four major environmental global problems, together with biodiversity, atmospheric composition, and climate change (Walker and Steffen, 1997; Walker, 1998). The need for a better understanding of the land cover/land-use relationships and their changes has been the main incentive in establishing the GLOBE and NASA. Attempts at compiling spatial land-use information have been made, though not in a very systematic manner. They resulted, more often than not, in a mixture of land-use and land cover (Jansen and Di Gregorio, 2002a). The main strategy in the past has been to design a land-use classification or legend and to distinguish land-use categories directly from remotely sensed images or other supporting data

 (Anderson et al., 1976; IGU, 1976; Kostrowicki, 1977; ECE-UN, 1989; CEC, 1995). This approach is limited to those land-use categories where the land cover/land-use relation is clear and direct, and to data types that are sufficiently detailed to contain detectable land-use information. These conditions imply constraints on the suitable data types to which, and the geographic environments in which this approach can be applied (Cihlar and Jansen, 2001).

In this paper, it is explored how a remotely sensed data derived land cover interpretation can be used as the primary data source for the collection of land-use data. The land cover interpretation is thus used as the baseline data set upon which a first land-use stratification is based.

**METHODOLOGY**

The land cover interpretation was prepared through analysis of hardcopy Land sat TM false colour composite satellite imagery (reference year 1995) and available ancillary data, such as topographic maps, soils data and relevant reports. Land cover is based primarily on the spectral data content, while land-use information benefits from aspects of the data such as pattern, shape, size, context, resolution, etc. (Lillesand and Kiefer, 2000). This contextual information may be efficiently extracted by a skilled interpreter who is also known to the study area. Consequently, one can obtain important additional land-use information and maybe able to identify land-use boundaries within the satellite image. In most cases such boundaries will concur with land cover boundaries. Because of the intricate land cover patterns in the study area and the occasionally unclear relationship between land cover and spectral response, visual interpretation was preferred. There is no standard approach to the image interpretation process. The imagery and the interpretation equipment available influence how interpretation is undertaken, in addition to the specific goals that will determine the image interpretation process employed. The delineation of discrete areal units, the polygons, containing a certain land cover or a mixture of land cover types, i.e. a mixed mapping unit, requires the interpreter to outline boundaries between areas. These boundaries are not always discrete edges but, especially with phenomena such as natural vegetation, gradual. In practice, the interpreter starts to delineate the most highly contrasting features first and then works from the general to the specific. In the case study, the major land cover categories and domains were first identified and then, through a stepwise series of classifiers, the land cover classes. The growing human and livestock populations and rainfall are exogenous factors influencing land-use allocation (St!ephenne and Lambin, 2001). The generation of fuelwood, food for subsistence household needs, cash crops for export, fallow, species protection and rangelands compete for the limited land resources. It should be noted that a land-use does not necessarily concur with a single land cover type. The identified land cover classes are defined with LCCS (see [www.lccsinfo](http://www.lccsinfo). org) that emphasises the use of quantifiable criteria to build a class rather than class names (Di Gregorio and Jansen, 2000; Jansen and Di Gregorio, 2002a). Therefore, the resulting classes are based upon observable characteristics verified in a field survey that complements the preliminary interpretation. The Africover Project established the preliminary and final legends used for the whole country. In the study area only a subset of the classes in the country legend occurs .For the identification of land-use classes, the same approach was applied. However, neither a comparable software application for land-use, nor a widely accepted classification exists. Therefore, the rules to be applied were first developed and tested in a field survey, followed by application to all the land cover polygons. The rules to assign land-use classes to the land cover polygons were developed as follows:

1. Identification of the prime land-use functions in the study area;

2. Identification and tailoring of the activity parameters to be used for identification and assignment of land use classes to the major land-use functions distinguished;

3. An inventory of local land-use activities was made to be used for making distinctions at a lower, i.e. more detailed, level;

4. Systematic ordering of the criteria to be used in the decision rules;

5. A field survey was carried out in which 105 observations were made by the Kenya Soil Survey;

6. The field observations were related to the developed decision rules; and

7. Application of the final set of decision rules to the delineated land cover polygons resulted in the land use data set.

The land cover and land-use activities took place in parallel and thus cover the same timeframe. The LCCS approach has been previously tested and applied in national data collection efforts by the Africover Project (see www.africover.org). Furthermore, the design of the land-use data collection is based upon identification of parameters for the detection of occurring land-uses. Thus, during the field survey a certain land-use was not identified by a name but by a set of characteristics. Not only the dominant land-use was considered but also secondary land-uses (up to a maximum of three classes identified in a single mapping unit). In an earlier case study in Lebanon (Jansen and Di Gregorio, 2002b), only the dominant land-use was reported. The individual land-uses within the land cover mapping unit are not further specified in their spatial extent, i.e. the land cover polygon has not been subdivided.

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**PRELIMINARY LAND-USE CLASS PARAMETERS**

The developed methodology to characterize land-uses is based upon the identification of a series of parameters. This method differs from earlier proposed land-use classifications (Anderson et al., 1976; Kostrowicki, 1983; ECE-UN, 1989;M.ucher et al., 1993; UNEP/FAO, 1994; CEC, 1995) because the classes are defined by a set of systematically applied criteria (Jansen and Di Gregorio, 2002b). The first step is the recognition of broad human activities related to the use of the land cover type for a specific function. The second step involves the subdivision of the major functional categories according to criteria based on economic activities and/or local socio-cultural considerations, whichever is the most suitable criterion. These are then further subdivided according to the production environment, in the case of agriculture, and are again further subdivided according to production purpose followed by crop type at the most detailed level. This sequence offers an opportunity for a structured, though flexible, hierarchical system with which it is possible to characterize and describe any portion of land according to the human activities carried out on the land. Description can be carried out at any of the identified levels depending on the existing information resulting in a set of classes containing the maximum available level of information, but this level is not necessarily equal among classes or within classes. The following is a description of each of the major land-use categories and accompanying hierarchies with the criteria used for distinction. The methodology has two phases: a first phase where land-use categories are defined using major economic function as the criterion:

1. ‘‘Agriculture’’, where food and fibres are produced (excluding wood and timber products);

2. ‘‘Forestry’’, where wood and timber products are produced;

3. ‘‘Urban Area Uses’’, where people live and where a wide range of economic activities take place that are largely related to buildings;

4. ‘‘Water Reservoirs’’, where water is stored for specific uses in a construction.

A lower, i.e. more detailed, second phase is distinguished in which the creation of a land-use class is based on a combination of a set of selected parameters that are tailored to each of the major land-use categories defined above. The main governing criterion is economic activity.

**Agriculture**

‘‘Agricultural land-uses’’ cover all areas where the function of human activities includes plant and/or animal production. Cultivated field areas and fallow fields are included as well as (semi-) natural vegetated areas and buildings where animals are kept or crops grown. It should be clear that these land-uses comprise a range of different land covers that do not fall into a single, major land cover category. Areas under (semi-) natural vegetated cover (e.g., parks and reserves) are excluded from this class, as these systems do not have a production function.

Further subdivisions are made according to the nature of the production system and the aim of the economic activity into commercial and subsistence production systems.

**DECISION RULES**

**The decision rules**

The criteria used in the set of decision rules are tailored to the main land-use category and related to the

land-use function(s) and activities identified and described above. The decision rules are discussed in more detail below. These rules are arranged so that with each step in the interpretation process, all features and conditions are eliminated except the one being identified.

The presence of a cultivation pattern and field boundaries are the two decisive indicators for agricultural cropping systems. Even if a crop is absent, signs of cultivation remain present. These signs remain present for several years. Distinction between long fallow and natural vegetation may be quite difficult if only satellite imagery is used. However, due to increasing population pressure long fallow is becoming rare. The field size may provide indications on the type of cropping system. Two major production environments are distinguished in the land cover category Cultivated and Managed Terrestrial Areas in which the field size plays a determining role: large-sized fields correspond in the study area with life form of the plants grown, whereas medium to small-sized fields correspond with subsistence or commercial cropping systems. The corresponding crop types, especially the temporary life forms, result from the field inventory and ancillary data, such as crop calendar and local growing conditions. Cash crops, such as tea and coffee, require a high level of inputs. Hence, the experienced interpreter and field surveyor uses the process of convergence of evidence to successively increase the accuracy and detail of the interpretation (Lillesand and Kiefer, 2000). For crop identification, better results would have been achieved by obtaining several images during the growing season. However, this was impossible within the context of the project. Animal production systems related to a field pattern can be easily distinguished. Such fields are generally managed well. However, in Kenya this is not always the case. In the absence of field boundaries, the vegetation may provide indications, especially of the type and extent of herbaceous and shrub layers. The presence and type of built-up structures may provide indications of the type of inputs used. Two major environments are distinguished that correspond with a difference in land cover: free versus confined grazing. Confined grazing coincides with a high level of management. The herbaceous species composition and the presence of animals give further information on the type of production system, in addition to the location of the area with respect to densely settled areas and market places. An important criterion in the (semi-) natural environment is the height of the vegetation. In the absence of animals, height may provide an indication of the type of animals grazing in the area. Certain plant species take preference in grazing because they are more palatable, but only a rangeland expert can identify such cases. This implies that grazing intensity is not equally spread across an area and that only part of an area may be grazed. The relation between land cover and land-use is more complicated in the case of forestry. The tree stands do not necessarily clearly indicate their use(s). The regular shape of land cover polygons may point towards commercial production systems, whereas forms that are more irregular may indicate protective and conservation uses (e.g., nearby gullies). The contextual information, i.e. landform and position, usually provides more clues as to the use of these areas. In practice, all land cover polygons need to be checked during the field survey as to their uses if no additional information is available in the form of maps and/or reports, or if the information available is not very reliable.

**Results and discussion**

The land cover mapping unit is relatively limited in areal extent and does not occupy more than 8 percent of total area. The dominant land cover category is (Semi-) Natural Vegetation occupying 51.2 percent of total area, whereas Cultivated Areas and Built-up Areas occupy 35.7 and 10.7 percent, respectively. These land cover units form the baseline data. This implies that the accuracy of the

land-use interpretation is at best identical to that of land cover. Each land cover unit is associated with a maximum of up to three land-use classes. The land-use classes are ordered according to dominance, i.e. the first land-use class mentioned is dominant in areal extent over subsequent land-uses, if any.

Economic criteria have not been used in this study, whereas cultural or historical values cannot be expressed in monetary terms. The limited areal extent of the land cover types implies a similar pattern for land-uses. This figure clearly shows the importance of Agriculture (all classes with an the areasl) in the study area, occupying 74.4 percent of the territory, whereas the land-use categories Urban Area Uses, Forestry and Water Reservoirs occupy 13.8, 9.1 and 0.6 percent, respectively (2.2 percent of total area is unused). This means that Agriculture, especially animal production, is not limited to the land cover types of the Cultivated Areas but is also related to (Semi-) Natural Vegetation types. The Urban Area Uses comprise a substantial area because Ifako Ijaiye, Lagos State is part of the study area.

The numerous cultivated area classes are all closely correlated to various forms of commercial and subsistence agriculture. The same crop type can be grown for commercial as well as subsistence purposes. A large number of crops are perennial. Imagery and additional information were used to separate these different crop types (e.g., coffee, tea, passion fruits and pineapples). In few cases, the crops were not further divided according to crop type. It is clear that most land cover classes defined until the crop type level, are related to a single land-use, a so-called ‘‘one-to-one’’ relationship.

The use of more general land cover terms, such as ‘‘herbaceous crops’’, without crop type specification, results in a relation to more than one land-use. Furthermore, it can be observed that if the land cover is related to more than one land-use, these land-use classes generally belong to the same category (e.g., Agriculture).

There are only a few cases where the land cover is related to land-uses belonging to different categories and when this occurs it mainly concerns animal production— free grazing. In the latter case, one can speak of a ‘‘many-to-one’’ relation between the land covers and a single land-use. Subsistence free grazing is a land-use that is related to various types of (semi-) natural vegetation, e.g., shrub lands and herbaceous vegetation types. If the herbaceous stratum is dominant, the land cover could also indicate a type of subsistence agriculture for cereals production where animals graze the stubble or a fallow field where animals browse the re-growth. Most agricultural land-uses are confined to fields that are clearly distinguishable with the human eye and on the satellite imagery. The same for commercial forest stands. Both types of land cover have quite homogeneous stands that are being managed until harvest.

(Semi-) natural vegetation is characterized by gradients and less sharp boundaries. Grazing may take place where the species composition is most nutritious and palatable and the boundaries of the land cover unit do not necessarily concur with its use. In most cases, the area delineated will be bigger than that actually used for grazing. This means that under the assumption that delineations concur, the extent of the rangeland area is bigger and contains ‘‘probable’’ grazing areas.

The identified forested areas are used for a variety of forest uses that may occur in parallel or alongside free grazing. This mixture of uses occurs especially when the identified tree cover includes a shrub stratum at a height that cattle, sheep or goats can reach. Urban Area Uses and Water Reservoirs are related to specific structures and thus have clear boundaries. These types of structures are characterized by multiple uses; this means that the land cover/land-use relation is of the type ‘‘one to many’’. The Built-up Area land cover classes are associated with the use of certain types of buildings. However, these land covers are sometimes also associated with free grazing as animals may browse the lawns next to the tar roads as can be widely observed in Ifako Ijaiye, Lagos State Nigeria. For identification of the use of artificial water bodies, the location and proximity of farm buildings is decisive in assigning a land-use.

The complexity of certain land-use types is only partially captured in the present study. Associated crops within the same field have not been considered because they did not appear in the land cover classes but they do occur on the fields. Having a time-series of images throughout the seasons would be an aid to better describing the cropping pattern and mixture of crops. With only one image available, such a level of accuracy cannot be achieved. Another aspect, which occurs throughout Africa, is the presence of multi-purpose trees on cultivated fields. These trees are widely scattered and difficult to identify on the imagery because of the sparse canopy cover. In practice, the land cover interpretation did not recognize the presence of such trees and consequently they do not appear in the resulting land-use classes.

The use of the crops has been simplified in the decision rules. The authors are aware that it is customary to use the crops and remaining stubble for various purposes. In the study, only the main purpose is described because there is insufficient evidence to draw any conclusions with regard to secondary uses. A much more detailed scale would be needed, implying more field observations and additional and more complex decision rules.

**Conclusion**

A set of decision rules was specifically developed to generate land-use information from a land cover interpretation of satellite imagery at a scale of 1:200,000 using LCCS. The decision rules are area specific; they were tested in a field survey. Some of the parameters used for land cover classification can be easily linked to land-use characteristics. The approach results in 48 land cover types associated with one, or more than one, of 55 land-use classes. The level of detail varies between the classes but each class contains all the information available. The main characteristic of the approach lies in the use of parameters to define land-use and understanding the land cover/land-use relationships in the study area. The decision rules eliminate all irrelevant options one by one. In most cases the land cover and land-use boundaries coincide but some particular land-uses, such as free grazing, tend to have boundaries that do not necessarily concur. An important point in this case study is the validation of concurrence of land cover and land-use boundaries. Land-uses related to a field pattern tend to concur with the identified land cover, but areas identified as used for free grazing purposes may be larger in extent than that which is actually used by the animals. The vegetation in these cases represents more of a ‘‘probable’’ than an actual land-use. The term ‘‘potential’’ is avoided in this context because it is used in land evaluation (FAO, 1976, 1984). The identification of probable free grazing areas is based upon actual land cover and inferred land-use and not on the potential of an identified agro-ecological unit. Therefore, it is more accurate and may be more useful in natural resources planning and management. Land cover types with a herbaceous stratum and no clear field boundary pattern introduce uncertainties. In addition, forested areas may be subject to various uses that cannot exclusively be inferred from the available land cover information. Contextual information is decisive to determine the land-use(s) associated with built-up areas and water bodies. Both the land cover and land-use data follow a parametric approach, consequently the data can be regrouped according to any selection of parameters used. This results in a flexible data set that may be useful to a range of disciplines.

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