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Stephen Edem Korbla Duadze

Land Use and Land Cover Study of the Savannah Ecosystem in the Upper West Region (Ghana) Using Remote Sensing

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To my parents, wife (Enyonam Agbavitor-Duadze), children (Sedor Duadze, Asiwome Duadze and Yram Duadze), primary school headteacher (Mr. Sampson K. Dzobo) and middle school headteacher (the late Mr. Charles Dotse Hodey)

ABSTRACT

Land use and land cover information constitutes key environmental information for many scientific, resource management and policy purposes, as well as for a range of human activities. It is so important that it has become a major focus for the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) at global, regional and local levels. Land use and land cover information is currently not available for many areas of the Volta Basin, which is currently undergoing rapid and wide-ranging changes in land use and vegetation due to the practice of slash-and-burn or shifting cultivation. The study of these conversions necessitates the use of remote sensing because it provides data at synoptic scales and facilitates the discerning of large-scale ecosystem patterns. Although remote sensing technology has been used for mapping in Ghana for sometime now, attempts to use unsupervised and supervised classification methods for LANDSAT images for large areas have so far yielded unsatisfactory results. Yet unsupervised and supervised classification have advantages over manual classification.

Therefore, this study was formulated as a component of the GLOWA Volta Project, the main theme of which is "*Sustainable water use under changing land use, rainfall reliability and water demands in the Volta Basin*". The project is to generate data for the development of a decision support system. This study sought to find a suitable unsupervised or supervised method of land use and land cover mapping by remote sensing, to determine land use and land cover changes and to assess the relationships, if any, between land use and land cover change on the one hand and rainfall, soil fertility and population on the other.

The objectives of the study, therefore, involved (i) the adaptation of an unsupervised or supervised classification method for land use and land cover mapping in the Volta Basin, (ii) production of land use and land cover maps of the Upper West Region, (iii) land use and land cover change assessment for the region for the periods of 1986 to 1991, 1991 to 2000 and 1986 to 2000, (iii) evaluation of the fertility status of the soils under the various land cover categories for crop production, (iv) evaluation of the rainfall regime for crop production, (v) assessment of changes in the population of the region between 1984 and 2000 and (vi) determination of the extent to which changes in soil fertility and population under rainfall variability have effects on land use and land cover change of the region during the 15-year period.

The Upper West Region was selected for this study because, being the most recently created administrative region of Ghana, it is undergoing rapid biophysical and socio-economic transformations. Situated in the north-western corner of Ghana, it covers 1,850 km^2 and falls into the Guinea savannah vegetation zone. The total population of the region in 2000 was 576,583, with a density of 31.2 km^{-2} and a growth rate of 1.7% (the relatively low growth rate being due to emigration to the south of the country).

The methodology used for image classification involved the stratification of different geocorrected LANDSAT-satellite images (1986, 1991 and 2000) and the classification of the various strata, using a classification scheme derived from the *Ghana Land Use and Land Cover Classification Scheme* (Agyepong *et al.,* 1996). The stratification procedure scaled down the complex vegetation patterns on the images and therefore improved the classification accuracy. The classified image strata were mosaicked to form a map, and the statistics of the various land use and land cover categories were generated. Prior to this, detailed analyses were made to compare visual/manual and unsupervised classification of the satellite data for land use and land cover. The results showed that visual interpretation cannot be compared with supervised and unsupervised classifications, because some of their mapping units are different. Unsupervised classification could not discriminate between water bodies and shaded closed savannah woodland and wet or dark dry riverbeds. However, unsupervised clustering was used to generate training samples, which were then used together with those collected in the field for a final maximum likelihood supervised classification. Change detection was done by comparing

the area of each land cover class over the various periods. The changes were related to soil fertility, rainfall and population of the region. Thus, the fertility of the soils under the various land cover types was evaluated for the traditional crops being grown in the region. The mean annual rainfall and mean farming-season rainfall from 1980 to 2000 were also evaluated for these crops. The change in population over the study period was also determined.

Six broad land use and land cover classes were mapped for 1986, 1991 and 2000, namely: (i) *Farmland/bare land or constructed surface*, (ii) *Closed savannah woodland or riparian vegetation*, (iii) *Open savannah woodland with shrubs and grasses,* (iv) *Mixture of grasses and shrubs with scattered trees*, (v) *Reserved woodland*, and (vi) *Water body.* The overall accuracy of the classification was 92 %. The results of the analyses showed that in 1986 and 1991, the respective extent of the various land cover categories was *Open savannah woodland with shrubs and grasses* (60% and 58.8%), *Mixture of grasses and shrubs with scattered trees* (16.8% and 17.7%), *Reserved woodland* (8.9% for both dates), *Closed savannah woodland/riparian vegetation* (7.33 and 7.32), *Farmland/bare land or constructed surface* (6.98% and 7.2%) and *Water body* (0.021% and 0.047%). In 2000, the extent of the land cover categories were *Open savannah woodland with shrubs and grasses (58.1%), Mixture of grasses and shrubs with scattered trees (19%)*, *Reserved woodland (8.9%), Farmland/bare land or constructed surface* (7.6%), *Closed savannah woodland/riparian vegetation (6.3%)* and *Water body* (0.054%). Thus, while *Closed savannah woodland/riparian vegetation* and *Open savannah woodland with shrubs and grasses* decreased in extent from 1986 to 2000, *Farmland/bare land or constructed surface*, *Mixture of grasses and shrubs with scattered trees* and *Water body* increased spatially. Reserved savannah woodland was assumed to not have changed. Based on information collected from the interview of farmers, agricultural extension workers and foresters working in the region, the dynamics of land use and land cover conversions and inter-conversions in the region were determined.

The soils under *Closed savannah woodland* were more fertile than those under *Open savannah woodland*, which, in turn, were more fertile than those under *Mixture of grasses and shrubs with scattered trees*. The *Farmland* soils were the lowest in fertility. The soils of the region are generally low in fertility and *marginally suitable* to *suitable* for millet, sorghum, groundnut, rice, legumes, maize and cotton. The rainfall pattern is erratic, variable and unreliable, sometimes causing reduction in yield or total crop failure and imposing restriction on the choice of crops. The rainfall is *moderately suitable* to *suitable* for these crops. About 75% of the economically active population are farmers. The population increased from 1984 to 2000 by 32%. Obviously, given that such a high proportion of the population is in agriculture, an increase of 32% in population has serious implication for the degradation of the woodland, which is known to be more fertile. Declining soil fertility in the farmlands and increasing population, therefore, cause pressure on land, which leads to land degradation. This, in turn, causes the farmers to move to other areas to farm. This practice results in the progressive loss of woodland.

The study shows that (i) supervised classification can be applied to derive accurate land use and land cover maps for the savannah ecosystem in the Volta Basin of Ghana, (ii) generally, supervised maximum likelihood classification of LANDSAT images for a large area can be done successfully with a high level of accuracy and, more important, (iii) this is the first time sit has been carried out for a large area in the complex savannah ecosystem in Ghana, (iv) land use and land cover of the region have changed over the past 15 years, and (v) changes in land use and land cover in the Upper West Region are related to the driving forces of declining soil fertility and increasing population under rainfall variability.

Landnutzung und Landbedeckung im Savannenökosystem der Upper West Region (Ghana) unter Verwendung von Fernerkundung

KURZFASSUNG

Informationen zu Landnutzung und Landbedeckung bilden die entscheidenden Umweltinformationen für zahlreiche Zwecke der Wissenschaft, des Ressourcenmanagements und der Politik sowie für einige menschliche Aktivitäten. Diese Informationen sind so wichtig, dass sie zu einem Schwerpunkt des Internationalen Geosphären-Biosphären-Programm (IGBP) und des International Human Dimensions Programme (IHDP) auf globaler, regionaler und lokaler Ebene geworden sind. Informationen zu Landnutzung und Landbedeckung sind z.Zt. für viele Gebiete des Voltabeckens nicht verfügbar. Das Voltabecken erlebt gegenwärtig schnelle und weit reichende Veränderungen in der Landnutzung und der Vegetationszusammensetzung als Folge des Brandrodungsfeldbaus. Die Untersuchung dieser Veränderungen macht die Anwendung der Fernerkundung erforderlich, da diese Daten in synoptischen Maßstäben liefert werden können und sie die Erkennung von großräumigen Ökosystemmustern erleichtern. Obwohl die Fernerkundungstechnologie in Ghana seit einiger Zeit zur Kartierung eingesetzt worden ist, haben Versuche, rechnergestützte Klassifizierungsmethoden für LANDSAT-Bilder von großen Gebieten zu nutzen zu unbefriedigenden Ergebnissen geführt. Die rechnergestützte Klassifizierung hat jedoch Vorteile gegenüber der manuellen Klassifizierung.

Diese Studie wurde daher als Teil des GLOWA-Volta Projektes „*Nachhaltige Wassernutzung bei Veränderungen in Landnutzung, Niederschlagsbeständigkeit und Wassernachfrage im Voltabecken*“ durchgeführt. Dieses Projekt wurde konzipiert, um Daten für die Entwicklung eines „decision support system“ zu entwickeln. Die vorliegende Studie sucht nach einer geeigneten rechnergestützten Methode zur Kartierung der Landnutzung und -bedeckung und zur Bewertung der Beziehungen, wenn vorhanden, zwischen Änderungen der Landnutzung und Landbedeckung auf der einen Seite und Niederschlag, Bodenfruchtbarkeit und Bevölkerung auf der anderen.

Die Ziele dieser Studie umfassten daher (i) die Entwicklung einer geeigneten rechnergestützten Methode zur Klassifizierung der Landnutzung und Landbedeckung der Savanne des Voltabeckens in Ghana, (ii) Erstellung von Karten über Landnutzung und Landbedeckung im Maßstab 1:250,000 (iii) Bewertung der Veränderungen in der Landnutzung/Landbedeckung in der Upper West Region für die Jahre 1986, 1991 und 2000, (iii) Bewertung des Fruchtbarkeitsstatus der Böden unter den verschiedenen Landbedeckungskategorien für die Produktion der angebauten Kulturpflanzen, (iv) Bewertung des Niederschlagregimes in Beziehung zur Produktion der angebauten Kulturpflanzen, (v) Bewertung der Bevölkerungsveränderungen zwischen 1984 und 2000 und (vi) Bewertung der Veränderungen in der Bodenfruchtbarkeit und Bevölkerung unter Berücksichtigung der Niederschlagsvariabilität; dabei wird untersucht, ob diese Auswirkungen auf die Landnutzung/Landbedeckung der Region während in den letzten 15 Jahre hatten.

Die Upper West Region wurde für die Studie ausgewählt, da sie erst vor Kurzem als Verwaltungsregion definiert wurde und einer sehr schnellen biophysikalischen und ökonomischen Wandlung erfährt. Die Upper West Region umfasst ca. 1.850 km^2 und liegt in der nordwestlichen Ecke von Ghana in der Vegetationszone Guinea-Savanne. Die Gesamtbevölkerung der Region beträgt 576.583 (2000 Zensus) mit einer Dichte von 31.2 Personen km^{-2} und einer jährlichen Zunahme von 1.7% (die relativ geringe Wachstumsrate ist die Folge der Emigration der Menschen in den Süden des Landes).

Die Methode umfasst die Interpretation von geometrisch korrigierten LANDSAT-Satellitenbilder (1986, 1991 und 2000) und die Klassifizierung der verschiedenen Schichten auf der Grundlage des *Ghana Klassifizierungsschema für Landnutzung und Landbedeckung*.

Im Stratifizierungsverfahren wurden die komplexen Vegetationsmuster in den Bildern zur Verbesserung der Klassifizierungsgenauigkeit reduziert. Die einzelnen Schichten wurden dann in Mosaiken überführt, Statistiken wurden generiert und Karten entwickelt. In einem zweiten Schritt wurden detaillierte Analysen durchgeführt, um die visuelle/manuelle und nicht-bewachte Klassifizierung der Satellitendaten für die Landnutzung und Landbedeckung zu vergleichen. Die Ergebnisse zeigen, dass die visuelle Interpretation aufgrund der Unterschiede in einigen der Landnutzungs-/Landbedeckungseinheiten nicht mit der der nicht-bewachten bzw. bewachten Klassifizierung verglichen werden können, da sich einige der Karteneineiten unterscheiden. Die nicht-überwachte Klassifizierung war nicht in der Lage, zwischen Gewässer, beschattetem, geschlossenem Savannenwald und nassen bzw. dunklen trockenen Flussbetten zu unterscheiden. Jedoch wurde die nicht-bewachte Klassifizierung eingesetzt, um Trainingsgebiete zu bestimmen, die dann zusammen mit den Felddaten zur abschließenden „größte Wahrscheinlichkeit"-Klassifizierung eingesetzt wurden. Die Ermittlung von Veränderungen wurde durch einen Vergleich der räumlichen Statistiken der verschiedenen Landbedeckungsklassen über die einzelnen Zeiträume in bezug auf Bodenfruchtbarkeit, Niederschlag und Bevölkerung durchgeführt. Die Fruchtbarkeit der Böden bei den verschiedenen Landbedeckungstypen wurde außerdem für die traditionellen Kulturpflanzen in der Region bestimmt. Der mittlere Jahresniederschlag und mittlere Niederschlag der Anbausaison von 1980 bis 2000 wurden hinsichtlich der dort angebauten Kulturpflanzen bestimmt.

Insgesamt wurden sechs Landnutzungs- und Landbedeckungsklassen für die Jahre 1986, 1991 bzw. 2000 kartiert. Diese waren: (i) *landwirtschaftliche Anbaufläche/bewuchsfreies Land oder bebaute Oberfläche,* (ii) *geschlossener Savannenwald oder Ufervegetation*, (iii) *offener Savannenwald mit Sträuchern und Gräsern,* (iv) *eine Mischung von Gräsern und Sträuchern mit vereinzelten Bäumen*, (v) *geschützte Waldflächen* und (vi) *Gewässer*. Die Gesamtgenauigkeit der Klassifizierung betrug 92 %. Die Ergebnisse der detaillierten Analysen zeigen für die Jahre 1986 bzw. 1991 den Anteil der Landbedeckungskategorien als *offener Savannenwald mit Sträuchern und Gräsern* (60% bzw 58.84%), *eine Mischung von Gräsern und Sträuchern mit vereinzelten Bäumen* (16.8% bzw. 17.7%), *geschützte Waldflächen* (8.9% für beide Jahre), *geschlossener Savannenwald oder Ufervegetation* (7.33 bzw. 7.32%), *landwirtschaftliche Anbaufläche/bewuchsfreies Land oder bebaute Oberfläche* (6.98% bzw. 7.2%) und *Gewässer* (0.021% bzw. 0.047%). In 2000 betrugen die Anteile *offener Savannenwald mit Sträuchern und Gräsern* 58.13%, *eine Mischung von Gräsern und Sträuchern mit vereinzelten Bäumen* 19%, *geschützte Waldflächen* 8.9%, *landwirtschaftliche Anbaufläche/bewuchsfreies Land oder bebaute Oberfläche* 7.6%, *geschlossener Savannenwald oder Ufervegetation* 6.30% und *Gewässer* 0.054%. Folglich nahm der Anteil *geschlossener Savannenwald oder Ufervegetation* und *offener Savannenwald mit Sträuchern und Gräsern* von 1986 bis 2000 ab, während die Kategorien *landwirtschaftliche Anbaufläche/bewuchsfreies Land oder bebaute Oberfläche, eine Mischung von Gräsern und Sträuchern mit vereinzelten Bäumen* und *Gewässer* zunahmen. Es wird angenommen, dass sich der Anteil des geschützten Savannenwaldes nicht verändert hat. Auf der Grundlage der Informationen aus den Interviews mit den Farmern, der landwirtschaftlichen Berater und den Förstern aus der Region wurde die Dynamik der Landnutzungs- und Landbedeckungsänderungen bestimmt.

Die Böden unter *closed savannah woodland* waren fruchtbarer als die unter *open savannah woodland*, die wiederum fruchtbarer waren als die unter *mixture of grasses und shrubs with scattered trees*. Das *farmland* zeigte die geringste Fruchtbarkeit. Die Böden in der Region sind im Allgemeinen von geringer Fruchtbarkeit und *geringfügig geeignet* bis *geeignet* für den Anbau von Hirse, Sorghum, Erdnuss, Reis, Hülsenfrüchte, Mais und Baumwolle. Der Niederschlag zeichnet sich durch Unbeständigkeit, Variabilität und Unzuverlässigkeit aus; dies führt oft zu Ertragsminderung oder kompletten Ernteausfällen und beschränkt die Auswahl der Kulturpflanzen. Der Niederschlag ist *mäßig geeignet* bis *geeignet* für diese Pflanzen. Ca. 75% der wirtschaftlich aktiven Bevölkerung sind Bauern. Die Bevölkerung nahm von 1984 bis 2000 um 32% zu. Die nachlassende Bodenfruchtbarkeit und wachsende Bevölkerung führen zu einem

verstärkten Landdruck, der wiederum zur Landdegradation führt. Als Folge ziehen die Farmer in andere Gebiete. Diese Praxis führt zu einem fortschreitenden Verlust von Waldgebieten.

Die Studie zeigt, dass (i) die rechnergestützte bewachte Klassifizierung zur Erstellung von genauen Landnutzungs- und Landbedeckungskarten für die Upper West Region eingesetzt werden kann, (ii) im Allgemeinen kann die bewachte „größte Wahrscheinlichkeit"-Klassifizierung von LANDSAT-Bildern für ein großes Gebiet erfolgreich durchgeführt werden und, noch wichtiger, sogar in einem komplexen Savannenökosystem; dies ist das erste Mal, wo diese Klassifizierungsmethode in einem großen Gebiet in Ghana eingesetzt wurde, (iii) die Landnutzung und Landbedeckung der Region haben sich in den vergangenen 15 Jahre verändert und (iv) Veränderungen in der Landnutzung/Landbedeckung in der Upper West Region hängen mit abnehmender Bodenfruchtbarkeit und zunehmendem Bevölkerungswachstum unter variablen Niederschlagsbedingungen zusammen.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Background of the study

This study is an integral part of an on-going GLOWA-Volta Project, the main theme of which is *'Sustainable water use under changing land use, rainfall reliability and water demands in the Volta Basin"*. The Volta Basin, which spans across six countries in West Africa (Figure1.1) and covers some 400,000 km^2, lacks biophysical and socio-economic information for effective environmental and socio-economic management (GLOWA Volta, 1999). The project has, therefore, been designed to generate data for the creation of a decision support system that will provide a comprehensive monitoring and simulation framework to enable decision makers to evaluate the impact of manageable systems, such as irrigation, primary water use, land use change, power generation and trans-boundary water allocation, as well as the less manageable attributes, such as climate change, rainfall variability and population pressure on the social, economic, and biological productivity of water resources. Thus, the project is expected to equip decision makers with the ability to weigh alternative development strategies and answer questions such as: (1) Is there an increase in rainfall variability, and if yes, what would be the economic and ecological consequences? (2) How can the present population growth be reconciled with water resource management? (3) What are the feedback loops between land use intensification, reduced rainfall and soil fertility? (4) What are the returns in terms of productivity and downstream availability of water

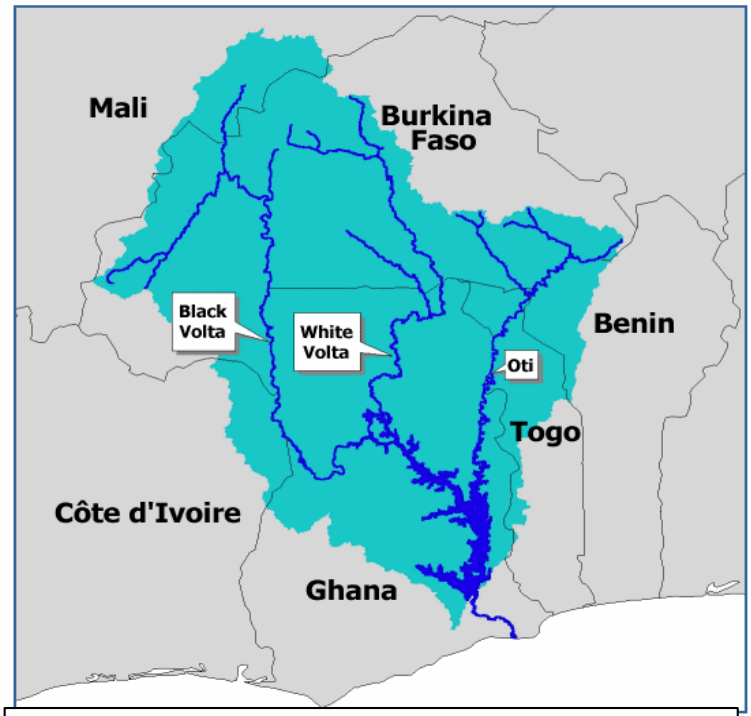

Figure1.1: The Volta Basin, showing the various countries it covers (*Source: GLOWA Volta, 1999*)

resources yielded by large-scale irrigation schemes along major rivers or hydraulic development of small valleys in the upper reaches? and (5) what are the trade-offs between increased hydro-power production (helping industries around Accra) and agricultural productivity through irrigation in the North (reducing rural poverty)?

The GLOWA-Volta Project is being implemented through research, the activities of which focus on data collection, monitoring methodologies, data standardization, information institutionalisation, and model selection. The research is being organized in three clusters, each covering one theme associated with a complex set of interactions (Figure 1.2). The first cluster, "*Rainfall and Climatic Change*", deals with atmospheric redistribution of moisture and heat. The second cluster, "*Land Use and Land Cover Change*", seeks to analyse the multiple feedback loops between population pressure, agricultural development, soil degradation, and land cover and the consequences for the distribution of rainfall between actual evapotranspiration (ETa) and aquifer recharge. The third cluster, "*Water Use and Institutional Change*", is to project future water supply and demand under different policies and institutional arrangements. The clusters have been chosen in such a way that their interfaces have a relatively simple structure.

Together, these structures are expected to provide inputs into a basin model, which will be able to play out dynamic interactions and feedback loops. These will, as a final objective, lead to the development of a management system, which will allow the extrapolation of rainfall and population trends as well as the consequent change in land pressure, agricultural productivity and water demands, which in turn translate into migration patterns and changes in land cover. The scientific innovation of the model lies in the fact that none of these "global change factors" (rainfall patterns, land cover, population and hydrologic cycle) are taken as an entity, but rather treated as being dependent on internal dynamics as well as on boundary conditions.

This study falls within the *Land Use Cluster* (Figure 2.1), and it is being handled by the Remote Sensing Research Group (RSRG) of the Geography Institute, University of Bonn. The study has sought to adapt commonly used computer-based methods of land use and land cover classification, using remote sensing, to produce historical and current land use and land cover information of the Basin and to determine whether there have been land use and land cover changes over the past fifteen years (1986-2000).

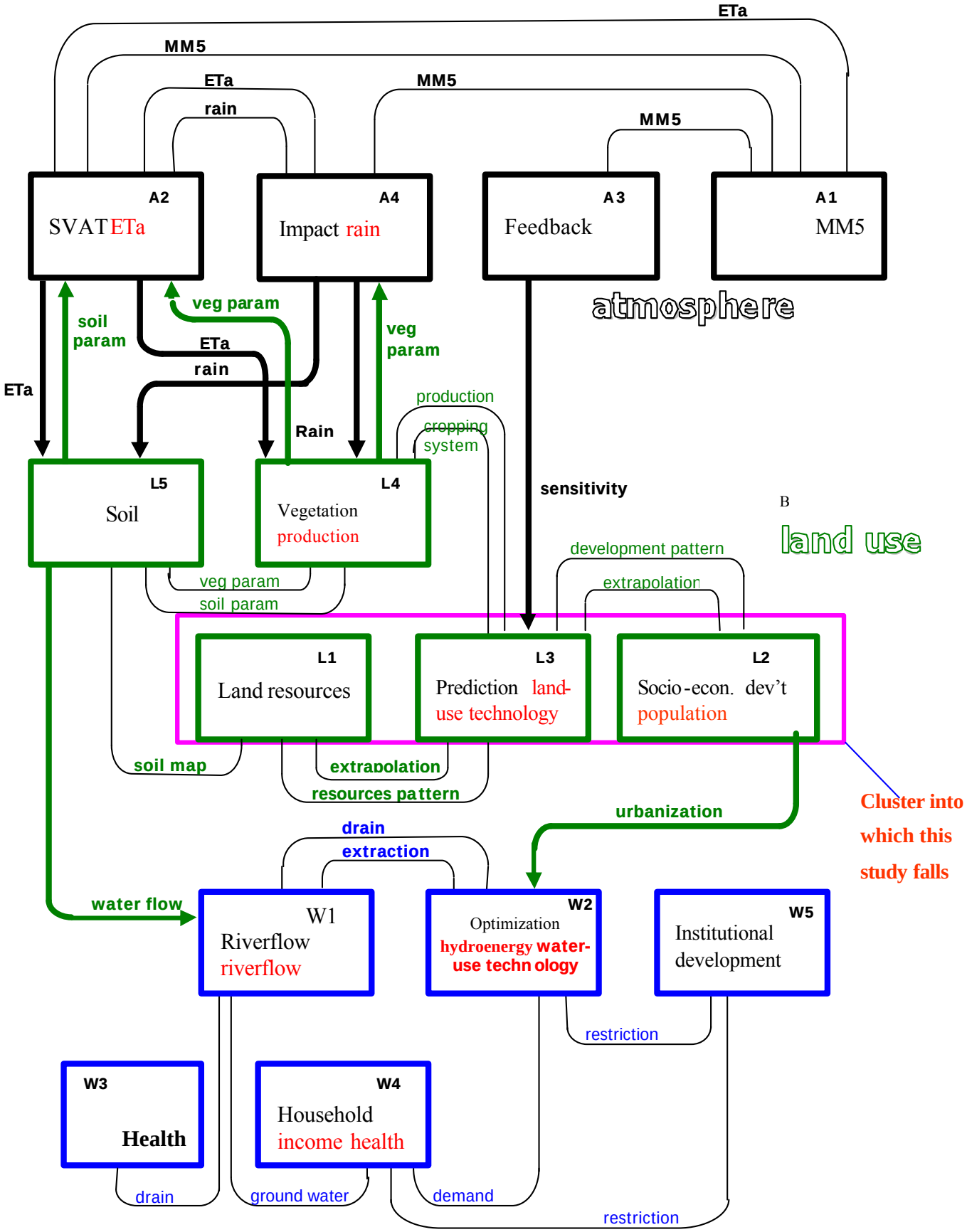

Figure 1.2: Overview of GLOWA-Volta project structure with sub-project names and codes, information exchange and state variables (GLOWA-Volta, 1999)

and assess the relationships, if any, between the changes in land use and land cover with rainfall, soil fertility and population.

1.2 Land use and land cover: definitions and concepts

In order to appreciate the definitions and concepts of land use and land cover, it may be necessary to, first of all, define the term "land". According to the FAO (1998), "*land*" is any delineable area of the Earth's terrestrial surface involving all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), near-surface layers and associated ground water and geo-hydrological reserves, plant and animal populations, human settlement patterns and physical results of past and present human activities (terracing, water storage or drainage structures, roads, buildings, etc.). Land is the basic life supporting system that supplies the majority of living forms with space, energy and nutrients that are essential for all biochemical metabolisms occurring in any organism. Land plays a key role in major biogeochemical cycles both within ecosystems and globally (FAO, 1998). Generally, land can be considered in two domains: (1) land in its natural condition and (2) land that has been modified by human beings to suit a particular use or range of uses. The natural capability of land to meet a certain anthropogenic activity in a broad sense is referred to as *land quality*, and this is traditionally interpreted in terms of land resources, which determine land use. Historically, land has been exploited in different ways, from a simple watching of landscapes and primitive collection of herbs to intensive land management based on massive distortion of land by heavy machinery and artificially generated industrial areas (Stolbovoi, 2002). In these ways, humans are adapting to land capacity or rebuilding land to fit their demands.

Many authors or groups have defined "**land use**" and "**land cover**". The UNEP-WCMC (2001) have concisely defined "**land use**" as the human activity carried out to obtain goods or benefits from the land, and "**land cover**" as the vegetation or the construction, that cover the Earth's surface. Cracknel and Hayes (1993) have referred to "**land use**" as the current use of the land surface by man for his activities, and "**land cover**" as the state or cover of the land. Smits *et al.* (1999) have used the term "**land cover**" to refer to any type of feature present on the surface of the Earth, such as trees,

grasses, open water, and wetlands, but does not assume the specific use of land. They have used the term '**land use"** to refer to a human activity associated with a specific piece of land, which may include characteristics that often cannot be inferred directly from the remote-sensing data alone.

The International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP) and the Land Use and Land Cover Change Project (LUCC) have referred to '**land use and land cover change"** as follows (IGBP/IHDP, 1999):

Land cover refers to the physical or biophysical characteristic or state of the Earth's surface and the immediate subsurface, captured in the distribution of vegetation, water, desert, ice, and other physical features of the land, including those created solely by human activities such as mine exposures and settlement.

Land use is the intended use or management of the land cover type by human beings. Thus, land use involves both the manner in which the biophysical attributes of the land are manipulated and the intent underlying that manipulation (the purpose for which the land is used, e.g., logging, ranching, agriculture, wildlife reservation, etc.). The biophysical manipulation refers to the specific way in which the resources (e.g., vegetation, soil, and water) are used for a particular purpose, for example, logging, the cut-burn-hoe-weed sequence in many slash-and-burn agricultural systems, the use of fertilizers, pesticides, and irrigation for mechanized cultivation on arid lands; or the use of an introduced grass species for pasture and the sequence of movement of livestock in a ranching system. Biophysical manipulation can be seen as the techno-managerial system.

***Land cover and land use changes*:** Shifts in intent and/or management constitute land-use changes. Land cover and land use changes may be grouped into two broad categories: (1) *conversion or (2) modification* (Stolbovoi, 2002). Conversion refers to changes from one cover or use type to another. For instance, the conversion of forests to pasture is an important land use and la nd cover conversion in the tropics. The abandonment of a piece of land that has been permanently cultivated over a period in the past to regenerate to forest is a land use and land cover conversion. Land use and land cover modification, on the other hand, involves the maintenance of the broad cover or use type in the face of changes in its attributes. Thus, a forest may be retained while

significant alterations take place in its structure or function (e.g., involving biomass, productivity, or phenology). Likewise, slash-and-burn agriculture, a use, may undergo significant changes in the frequency of cropping, and use capital and labour inputs while retaining the rotation, cutting, and burning that constitute such uses.

Land use class is a generalized land use description, defined by diagnostic criteria that pertain to land use purpose(s) and the operation sequence followed; it has no location or time indications (de Bie, 2000).

Land use classification is the process of defining land use classes on the basis of selected diagnostic criteria (de Bie, 2000).

Land use type is a use of land defined in terms of a product, or products, the inputs and operations required to produce these products, and the socio-economic setting in which production is carried out (FAO, 1998).

Notwithstanding these definitions, it is sometimes difficult to differentiate between land cover and land use. Therefore, Stolbovoi (2002) stated that land use is closely interrelated with land cover in the sense that land cover provides additional information on human activity and specifies this activity in terms of commodity identification, timing, etc. This information, when spatially explicit, may lead to the breakdown of land cover categories into sub-entities, which under various conditions can facilitate further linkages of land use data with other natural characteristics. Land use encompasses a wide range of natural and socio-economic aspects and their interrelations (Stolbovoi, 2002). Land use and land cover information has become so important that it is often parts of studies relating to the environment.

1.3 Importance of land use and land cover

Land use and land cover information is important for many planning and management activities concerned with the surface of the Earth (Smits *et al.*, 1999; Lillesand and Kiefer, 1994), because it constitutes a key environmental information for many scientific, resource management and policy purposes, as well as for a range of human activities. This information is significant to a range of themes and issues that are central to the study of global environmental change. For example, alterations in the Earth's surface hold major implications for the global radiation balance and energy fluxes, contribute to changes in biogeochemical cycles, alter hydrological cycles, and influence

ecological balances and complexity. For example, large-scale deforestation increases the atmospheric carbon level (IPCC, 2001). Through these environmental impacts at local, regional and global levels, land use and land cover changes, driven by human activity and biophysical factors, have the potential to significantly affect food security and the sustainability of the world agricultural and forest product supply systems (Mas and Ramirez, 1996 and IIASA, 2001). Land cover is an important determinant of land use and hence the value of land to society (Mucher *et al.*, 2000). Therefore, with the need for environmental planning and management becoming increasingly important, the need for land cover information has emerged parallelly (Cihlar, 2000) at local, regional and global levels. It is, therefore, generated on global, regional and local scales. Figure 1.3a shows a global land cover map and Figure 1.3b its legend. Figures 1.4 and 1.5 show historical land use and land cover information for Ghana.

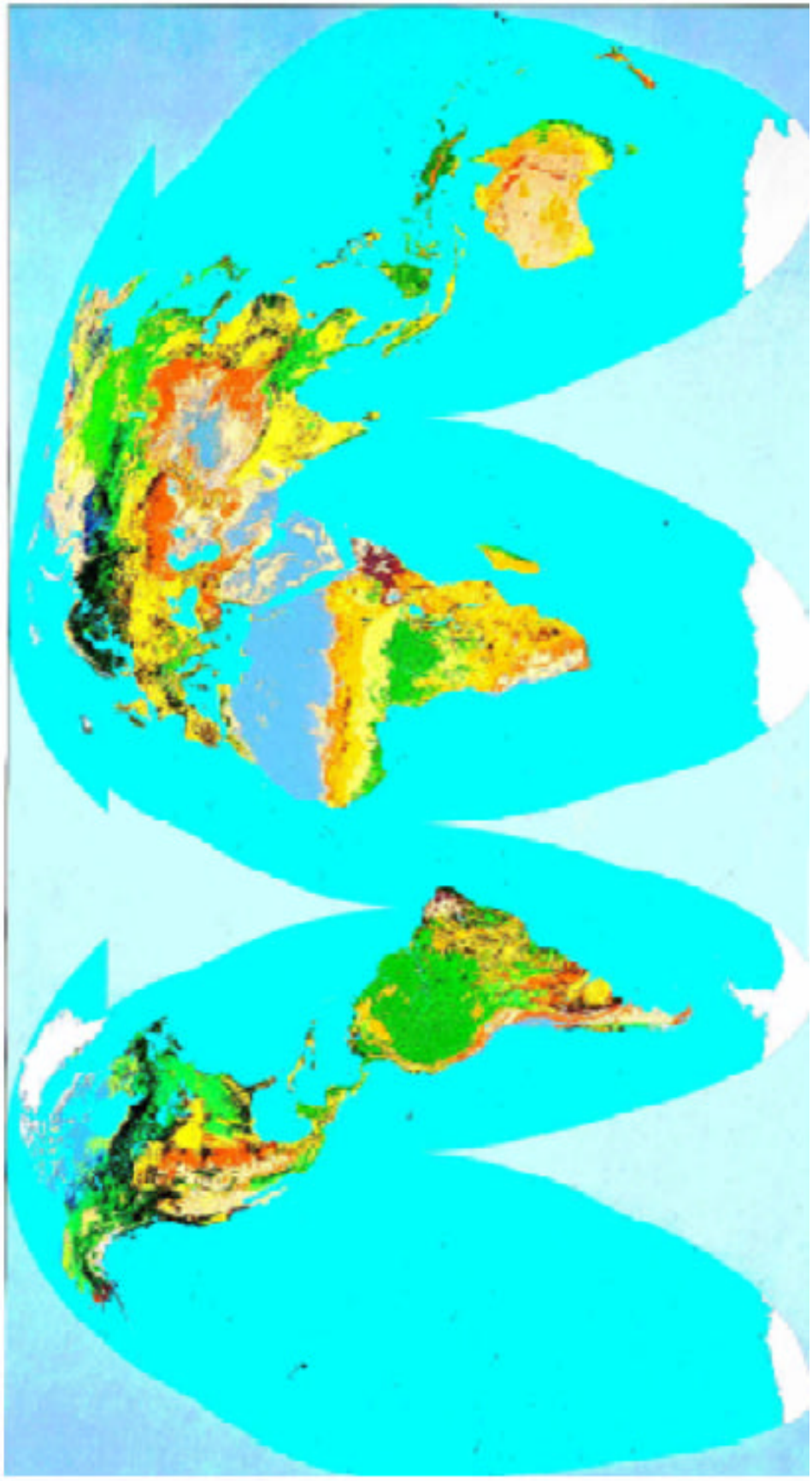

Figure 1.3: Global land cover characterization map (Loveland *et al.,* 2000)

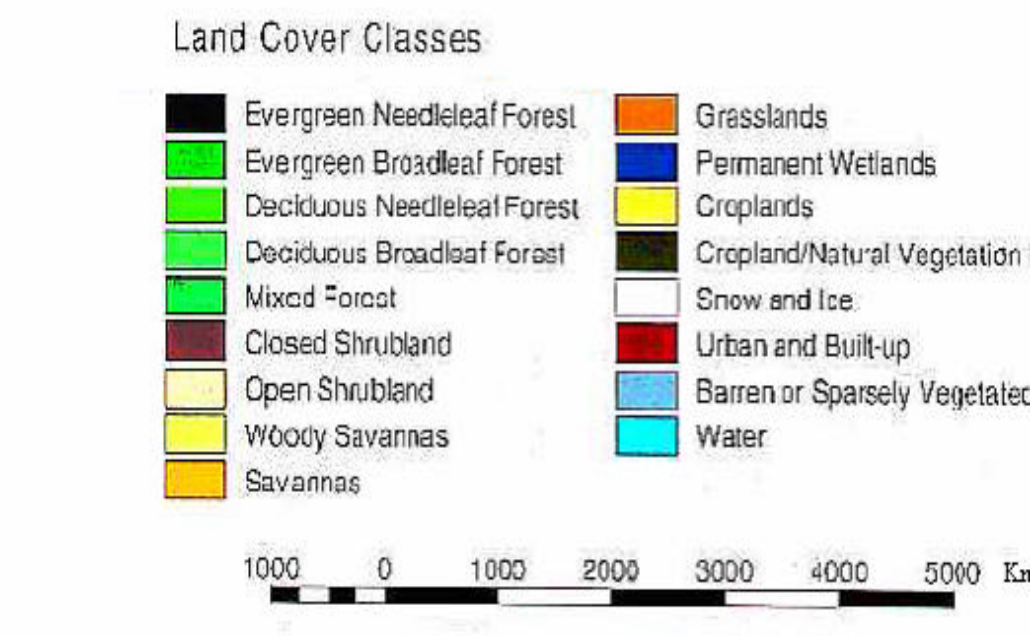

Figure 1.3b: Legend to the Global land cover characterization map by Loveland *et al.* (2000)

KEY

Interior savannah

1. *Compound farming area.1 & 3. Compound farming mixed with land rotation cultivation as in 3.*
2. *Grazed grassland with rare land rotation cultivation*
3. *Land rotation with grazed tree savannah regrowth fallow*
4. *Less intensive land rotation with sparsely grazed tree savannah regrowth fallow and scattered patches of 5*
5. *Little-cultivated ungrazed tree savannah, including forest reserves*

Derived savannah

6. Land rotation with cocoa in forest outliers mixed with less intensive land rotation in more *extensive patches of savannah*
7. ***Less intensive land****rotation with tree savannah regrowth fallow and some small cultivated forest outliers*
8. ***Little cultivated,*** *ungrazed tree savannah mixed with occasional patches of incompletely developed closed forest or secondary forest*

Forest zone

9. ***Intensive land rotation*** *with negligible forest remaining: area of most commercialised food cropping*
10. *Land rotation with a small percentage of forest remaining: area of most extensive cocoa, including area of newest cocoa planting, especially in the northwest.*
11. *Less intensive land rotation with much forest remaining.*
12. *Little-farmed closed forest, including forest reserves: area (outside the reserves) of most active timber exploitation. (owing to limitations of scale 11 and 12 have been mapped together over much of the zone.*

Coastal thicket and sav. zone

Coastal thicket; 14. Grass savannah, 15. Tree savannah, 16. savannah-thicket transition, 7.Lagoons and marshes

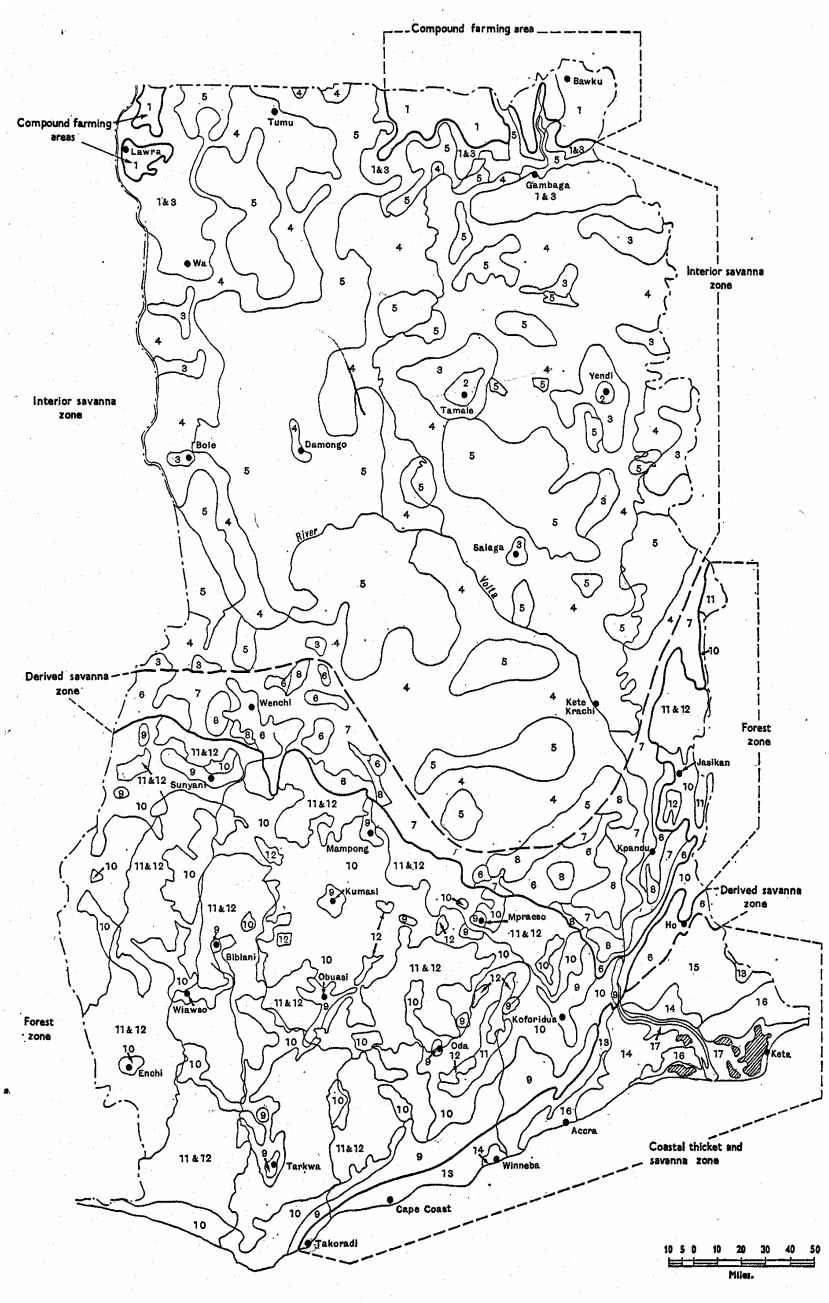

Figure1.4: Land use and land cover map of Ghana (Wills, 1962)

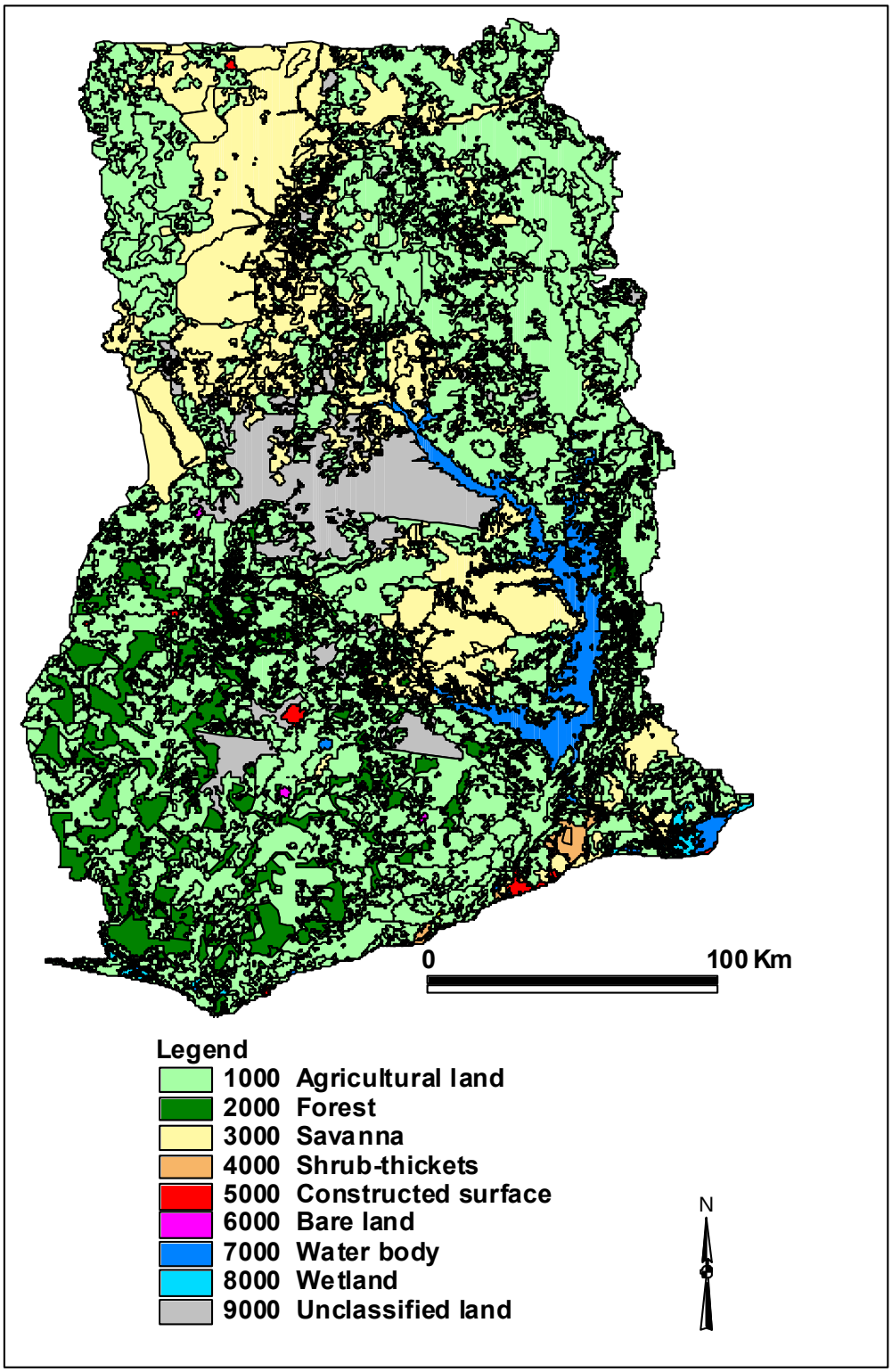

Figure 1.5: Land use and land cover map of Ghana (Level I), 1990/1991
Source: Agyepong et al. (1999) (Dark areas are vector layers of higher land use and land cover levels (Levels II-IV) of Level I classes)