Spatial distribution of planosols environmental sciences essay

Modeling the spatial distribution of PLANOSOLS and their landuse dynamics in the Gilgel Gibe catchment, Southwest Ethiopia.

Introduction

Planosols have bleached, light colored eluviated surface horizons that shows signs of periodic water logging on account of the immediate subsoil being significantly more clay rich and hence less permeable and abruptly over lie dense, slowly permeable subsoil with significantly more clay than the surface horizon. This article is based on the description in FAO (2001). Planosols are characterized by a subsurface layer of clay accumulation. They occur typically in wet low-lying areas that can support either grass or open forest vegetation. They are poor in plant nutrients, however, and their clay content leads to both seasonal water logging and drought stress. Under careful management they can be cultivated for rice, wheat, or sugar beets, but their principal use is for grazing. The characteristic clay-rich layer of Planosols can form from a downward translocation (migration) of clay particles under the action of percolating water, from burial of a clay-rich layer by over-washed coarse material, or from seasonal destruction and translocation of clay (a process known as ferrolysis). The clay layer thus may lie under an extensively leached (and hence nutrient-poor) layer. Planosols are related to the Alfisols and Ultisols of the U. S. Soil Taxonomy. Related FAO soil groups also exhibiting clay migration are Luvisols and Albeluvisols. (http://www. britannica. com/EBchecked/topic/463187/Planosol) March 9, 2013, 11: 52 AM.)Planosol areas of the earth can be found mainly in subtropical and temperate regions with clearly alternating wet and dry seasons. Their global coverage is estimated at around 1. 3 million km2. Planosols are soils with bleached, light-coloured, eluvial surface horizons that show signs of periodic water stagnation and abruptly overly dense, slowly permeable subsoil with significantly more clay than the surface horizon. They develop mostly on clayey alluvial and colluvial deposits, predominantly in flat lands but can also be found in the lower stretches of slopes, in a strip intermediate between uplands, e. g. with Acrisols or Luvisols, and lowland (plain or basin) areas, e. g. with Vertisols. Soilscapes with associations of Planosols and Vertisols are very common throughout the Ethiopian highlands, all developed from massive occurrences of Tertiary flood basalts under a sub-humid moisture regime. Understanding how these soils have formed is a key step in understanding how the entire Ethiopian highlands have evolved over time. The Vertic Planosols of the south-western Highlands are typical examples of duplex soils, characterized by a bleached, silty top horizon abruptly overlying heavy clay subsoil. The bleached topsoil material is of local economic importance as it is extensively used for brick making. Land use/cover change has for several decades become a global concern for researchers, given its complexity that requires a deeper understanding of the extent and intensity of the changes, the causes and impacts of such changes on ecosystem goods and services. The concerns arose from the realization that land surface pro-cesses and transformations influence climate change and reduce biotic diversity, but in the process, it came to be realized also that land use/cover changes determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations (Lambin et al., 2006; Lambin et al., 2003). In recent years, the numerous researches that have been undertaken have shown that land use/cover change is a much complex process involving situation specific interactions among a large number of factors at different spatial and temporal scales (Lambin et al., 2006; Lambin et al., 2003). Current rates, extents and intensities of land use and cover change, however, are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales (Ellis, 2010). In fact, their role in environmental change overrides natural changes to ecosystems brought about by climate variations of the past few thousand years (Turner et al., 1990). These land use/cover changes have accelerated in the 20th Century, both in pace and intensity, because of increased intensity of human activities (Ramankutty et al., 2006). Therefore, the need for rational planning of land use/cover development and optimal use of the land resources is evident. That's why precise and credible data on land use/cover change and their trends are necessary for understanding global, regional and local environmental problems (Milanova and Telanova, 2007). Although a number of studies have been conducted on land use/land cover changes, it is still crucial to generate site-specific information on land use/cover dynamics to ensure planning of sustainable and integrated management of the land resources. Researches indicate planosols occupy considerably large areas in the Gilgel Gibe catchment but their spatial distribution and landuse dynamics on this soil is not known. The objective of this thesis is to provide a predictive model of the distribution of planosols in the catchment based on topography and to investigate the landuse dynamics over the period of three decades.

Study objectives

Overall objective:

The main objective of this study is to provide a predictive model of the distribution of planosols in the catchment based on topography and to investigate the landuse dynamics over the period of three decades.

Specific objectives:

To categorize the present landuse situation in the study areaTo provide information on landuse transitions in the study area. To simulate future landuse dynamics on planosols depending on current trend

Literature review

Planosols

Planosols are soils with an elluvial horizon of loamy sand or coarser texture, with a lower boundary marked by abrupt textural change to more clay-rich composition stganic soil properties occur above this boundary and an absence of albeluvic tonguing. Formerly planosols were labeled " pseudogley soils". The USDA first used the name planosol in 1938, but the Soil Taxonomy the current usage is to include most of the original planosol in the Great Soil Groups of albaqualfs, albaquults, and argialbolls. In most soil classification system the term planosol is used. Currently in WRB the Reference Soil Group of Planosols holds soils with bleached and light-coloured surface horizons which may or may not have a stagnic colour pattern or show other signs of periodic water stagnation. They abruptly overlie dense, slowly permeable subsoil containing significantly more clay than the surface horizons (Driessen et al., 2001). Planosols have typically a weakly structured surface horizon over a horizon showing evidence of stagnating water. The texture of these horizons is markedly coarser than that of deeper soil layers; the transition is sharp and conforms to the requirements of an `abrupt textural change'. The finer textured subsurface soil may show signs of clay illuviation; it is only slowly permeable to water. Most Planosols are poor soils and are therefore not used as cropland but utilized for extensive grazing and forestry. Planosols were formerly known as pseudogley soils and today are dealt under different levels of classification hierarchies in national and international classification systems. Although the main physical and morphological characteristics of Planosols are known, there are still a lot of uncertainties about their genesis. Since one of the basic principles of WRB is to follow as much as possible a soil-genetic approach for delineating major soil groups, basic research concerning the genesis of Planosols is needed.

Genesis of planosols

Planosols have typically a weakly structured Ochric or Umbric surface horizon over an albic horizon with " stagnic soil properties". The texture of these horizons is markedly coarser than that of deeper soil layers, the transition is sharp and conforms to the requirements of an abrupt textural change. The finer textured subsurface soil may show signs of clay illuviation , it is only slowly permeable to water. Periodic stagnation of water directly above the dense subsurface soil caused the typical stagnic soil properties in the bleached, eluvial horizon (and in many soils also mottling in the upper part of the clayey subsoil). The abrupt textural change from coarse textured surface to finer subsoil can be caused by: o ' Geogenetic processes' such as sedimentation of sandy over clayey layers, creep or sheet wash of lighter textured soil over clayey material, colluvial deposition of sandy over clayey material, or selective erosion whereby the finest fraction is removed from the surface layers, and/oro ' Physical pedogenetic processes', such as selective eluviation-illuviation of clay in soil material with a low structural stability, and/oro ' Chemical pedogenetic processes' notably a process proposed under the name ' ferrolysis', an oxidation-reduction sequence driven by chemical energy derived from bacterial decomposition of soil organic matter (Brinkman 1970).

As Planosols are most extensive in relatively hot climates with a strong seasonal variation in rainfall, they are commonly occurring in association with Vertisols in presently sub-humid to semi-arid climates. In these zones all variations intermediates between Vertisols and Planosols occur such as Vertisols with a thin layer of grey or light grey, silty upper soil horizon of variable thickness, overlaying heavy clay, with silty material " etched in" along cracks into the underlying clayey material. If this layer of silty material is only few centimetres thick, the Vertisol still stands and this coarse material is tell-tale of some important pedogenetic process which is not sufficiently understood (Eric Van Ranst et. al).

Spatial distribution of planosols

Planosols are found predominantly on low, flat land forms but can also occur in the border between upland and lowland terrain. On the upland side they may be associated with Acrisols or Luvisols, and on the lowland side with Vertisols. At high topographic levels planosols occur also on terraces or plateaus, wher they may be associated with Acrisols or other soils with an argic subsurface horizon, or as in the Ethiopian highlands with Vertisols below them in the landscape and Nitisols above. Most of the world's 1. 3 million ha of planosols are in subtropical and temperate zones with alternate wet and dry seasons (Fig1). Major areas are found in Latin America (Southern Brazil, Paraguay, and Argentina), Southern and eastern Africa (Sahel, East and Southern Africa), the eastern United States, South East Asia (Bangladesh, Thailand) and Australia.

http://www. fao. org/docrep/003/Y1899E/y1899e69. gifFigure 1. Global distribution of planosols

Dynamics of landuse

Land is the major natural resource that economic, social, infrastructure and other human activities are undertaken on. Thus, changes in land-use have occurred at all times in the past, are presently ongoing, and are likely to continue in the future (Lambin et al., 2003; Moser, 1996). These changes have beneficial or detrimental impacts, the latter being the principal causes of global concern as they impact on human well-being and safety. For instance, deforestation and agricultural intensification are so pervasive when they aggregate globally and significantly affect key aspects of Earth Systems (Lewis, 2006; Zhao et al., 2006). Many research studies indicated as land use/cover dynamism is primarily associated with agricultural activity. Wright (1993) and Botkin and Keller (2005) described agriculture and settlements as the major ways in which people have changed natural landscape. Three most important human factors were recognized as change agents of land use/cover. The first is the need to provide food for rapidly growing population. This necessitates the expansion and intensification of agricultural land. The second is the provision of land for the landless in order of self sufficiency to exist and the third is to provide land for multinational companies to carry out agribusinesses. As rightly noted by Reid, Kruska, Muthui, Taye, Wotton, Wilson and Mulatu (2000), land use and land cover is an endlessly changing process taking place on the surface of the earth. Furthermore, Richards (1990) argues that the modern world has been facing massive changes in its land use patterns in the past few centuries. Williams

(1990) clearly stated that in the last few decades' conversion of grassland, woodland and forest into cropland and pasture has risen dramatically in the tropics. Land in Ethiopia is being used to grow crops, trees, and animals for food, as building sites for houses and roads, or for recreational purposes. Most of the land is being used by smallholders who farm for subsistence. With rapid population growth and in the absence of agricultural intensification, smallholders require more land to grow crops and earn a living it results in deforestation and land use conversions from other types of land cover to cropland. As a consequence, considerable land use/cover changes have occurred in Ethiopia during the second half of the 20th century (Solomon, 1994; Gete, 2000; Kebrom and Hedlund, 2000). The results of these studies have identified deforestation and encroachment of cultivation into marginal areas as the main agents of land use/cover change and land degradation in the highlands of Ethiopia. Numerous studies (e. g., Gete, 2000; Kebrom and Hedlund, 2000; Belay, 2002; Woldeamlak, 2002; Kahsay, 2004; Tsegaye, 2009; Behailu, 2010; Efrem, 2010; Eyayu, 2010) conducted in different parts of Ethiopia have indicated the existence of considerable change in land use/cover over the past 30 to 50 years. Kebrom and Hedlund (2000) reported increases in cultivated and settlement land use at the expense of shrub lands and forests between 1958 and 1986 at Kalu area, north-central Ethiopia. Gete (2000) reported a significant increase in cultivated land at the expense of shrub lands and forests between 1957 and 1995 in the Dembecha area, northwestern Ethiopia. Similarly, Birru (2007) indicated that the grassland cover of the Lake Tana Basin declined continuously over the last 40 years. Tsegaye (2009) reported a considerable increase in agricultural land at the expense of dense forest land in Adaba

Dodola, southern Ethiopia. A 90. 6% increase in cultivated land between 1957 and 2003 at Tara Gedam, northwestern highlands of Ethiopia was reported by Eyayu (2010). Likewise, a study made by Abiy (2010) indicated a 44. 53% increase in cultivated land at the expense of other land uses/land covers in the Antsokia-Gemza District, north-central Ethiopia. In line with this, Belay (2002) reported a serious trend in land degradation resulting from the expansion of cultivated land at the expense of forestlands in the Derekoli Watershed in South Wollo. In contrast, Woldeamlak (2002) and Muluneh (1994) reported increments in wood lots (Eucalyptus tree plantations) and cultivated land at the expense of grazing land in both Sabat-bet Gurageland in south-central Ethiopia, and in the Chemoga River Watershed in north-western Ethiopia. Land use/land cover changes that occurred from 1971/72 to 2000 in Yerer Mountain and its surroundings indicated an increase in cultivated land leading in to a simultaneous reduction in the grassland areas (Kahsay, 2004). In the semi-arid areas of the central Rift Valley of Ethiopia, in Keraru and Gubeta-Arjo, cropland area coverage has increased and woodland vegetation cover lost during the period from 1973-2000 (Efrem, 2010). According to the Swiss National Centre of Competence in Research (NCCR) North-South Syndrome Pre-Synthesis Project; SPSP (Hurni et al., 2004), the highland areas of the Horn of Africa have for centuries been favourable places for settlement and agriculture, as the ecological environment is more favourable than in the surrounding lowlands. However, as time goes by, intensive agricultural use and expansion of cropland into marginal areas have led to severe degradation of the natural resource bases in large areas of these zones. Land is very scarce in many highland areas, leading to unsustainable land use practices. Research findings by Gete

(2000), Amare (2007), Birru (2007), and Hurni et al. (2010), under the NCCR North-South Research framework that is the conflicting use of land resources in the highland-lowland problem context and/or upstream-downstream resource use, have indicated that dramatic land degradation has been recorded in the highlands of Ethiopia due to land use/cover changes. Information on land use/land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban, industrial, environmental protection, economic production, etc. Furthermore, documentation of the land use/cover change provides information for the better understanding of historical land use practices, current land use patterns and future land use trajectory. Therefore, identifying, delineating and mapping of the types of land use/cover are important activities in support of sustainable natural resource management (Zhang et al., 2004).

Why to Study Landuse Change?

The need for optimal use of the land resources and for balance of Land-Cover capability with anthropogenic stress is one of the mega-scale issues of mankind. The way people use the land has become a source of widespread concern for the future of the world. The inability of many countries to balance environmental and production needs, as well as Land- Cover capability and anthropogenic stress, emphasize these mega-scale issues. More than ever, therefore, the need for rational planning of landuse/landcover development and optimal use of the land resources is evident. That's why precise and credible data on landuse/landcover change and their trends are necessary for understanding global, regional and local environmental problems (Milanova et al., 2007). Land use data are also needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels. One of the prime prerequisites for better use of land is information on existing land use patterns and changes in land use through time (Anderson et al., 1976). Information on landuse/ landcover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban industrial, environmental studies, economic production, etc. Today, with the growing population pressure, low man-land ratio and increasing land degradation, the need for optimum utilization of land assumes much greater relevance (Roy et al., 2008). Documentation of the land use and land cover change provides information for the better understanding of historical land use practices, current land use patterns and future land use trajectory. LUCC contributes significantly to earth atmosphere interactions, forest fragmentation, and biodiversity loss. It has become one of the major issues for environmental change monitoring and natural resource management. Identifying, delineating and mapping of the types of land use and land cover are important activities in support of sustainable natural resource management (Zhang et al, 2004). Generally, determining the effects of land-use and land-cover change on the earth system depends on an understanding of past land-use practices, current land-use and land-cover patterns, and projections of future land use and cover, as affected by human institutions, population size and distribution, economic development, technology, and other factors. Landuse and land cover assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Kiros, 2008).

GIS in landuse dynamics

Proper organization and monitoring of land resources requires not only an understanding of the spatial and temporal patterns of resources but also insight in to the spatial and temporal process governing their availability. Such analysis demand timely repetitive and continuous spatial data. Ground surveying of such data is difficult and often expensive and such problem is a significant feature of developing countries with agricultural economy like Ethiopia (Wall et al., 1982). Land use/land cover and soil degradation study requires analysis of an interlinked physical and socio-economic factors. With in such an interlinked environmental system, modeling and predicting uncertainty of the factors can help us to manage land resources appropriately. This in turn requires analysis and manipulation of large volume of different kinds of datasets with respect to their geographic location. It is GIS and its data source (remote sensing) technology that can manipulate such interlinked system datasets (Vieux, 1995).

Material and methods

Study area

The Gilgel Gibe catchment, covering an area of 5500 km2, is located in south-western Ethiopia, in the Oromiya region, about 260 km of Addis Ababa (Fig. 2). The Gilgel Gibe, the main river of the catchment, is a tributary of the Gibe river which on its turn is a tributary of the Omo River. The geology of the catchment is very complex and is dominated by Eocene and Paleocene volcanic rocks, related to the East African rift valley (Tadesse et al., 2003). Many remnant volcanic landforms, such as cone structures, lava flows, mudflows, plugs, etc. can readily be recognized in the landscape. The volcanic rocks and materials identified in the field include basalts (hawaiites), trachytes, rhyolites, tuffs, ignimbrites and ash deposits. The altitude in the catchment varies between 1096 and 3259 m. a. s. l. The lower valley areas along the river are filled up with alluvium and lacustrine sediments. The climate of the Gilgel Gibe area is sub-humid. The main rains fall between May and September. The mean annual rainfall in the catchment increases from 1300 mm in the lower valley areas to 2000 mm in the highest regions. Temperature is fairly constant throughout the year, with the mean minimum, maximum and average temperatures at 1800 m altitude (Jimma station) being 11 °C, 25 °C and 17 °C, respectively. The major reference soil groups in the catchment are Nitisols, Acrisols, Ferralsols, Vertisols and Planosols. The soilscapes, with associations of Planosols and Vertisols, are mainly used for grazing. In the study area, almost all the land has been taken into cultivation. The main land use type in the study area is agricultural cropping, mainly wheat, teff, barley, faba bean, sorghum and maize. Next to these cropping activities, the farmers keep certain plots as grazing land for their livestock. The plots are mostly small and enclosed by hedges or tree rows. Total forest cover in the study area is ca. 11%, however this is mainly bush vegetation which is extensively used by the farmers. Only the highest parts of the study area are still covered by forest.

Method of data collection

Data will be collected by auguring along topographic transects in various topographic locations at representative sites in the catchment from stream to hill. For the delineation of boundaries, general morphology of the terrain land forms, relief form, slope, drainage pattern individual rivers and streams will be used. The physiographic units will be further subdivided into different mapping units on the basis of slope. Changes in landuse will be examined through analysis of time series aerial photos and satellite images. Digital Elevation Model of the study area will also be created by GIS software using digitized data of contour lines of the topographic maps and landuse and land cover maps can also be used for mapping the landuse dynamics.