# Land Cover Changes Between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia

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*This paper evaluates changes in land use/land cover (hereafter land cover) in a specific area in Kalu District, Southern Wello, Ethiopia, by comparing two aerial photographs from 1958 and 1986. An attempt is also made to discuss possible implications of these land cover changes for land degradation. By applying Geographic Information Systems (GIS), two maps of the study area (for the years 1958 and 1986) were produced. The maps show a decrease in coverage by shrublands, riverine vegetation and forests, and an increase in remaining open areas, settlements, floodplains, and a water body. The areal extension of nine categories of land cover was calculated and, by overlaying the two maps, the percentage of each type of land cover that was converted into other categories was computed. Land cover changes were most noticeable for shrublands, with a decrease of 15.5 km$^2$ (–51%), and for remaining open areas (ie, excluding cultivated areas and settlements), with an increase of 14.3 km$^2$ (+333%). Areas under cultivation remained more or less unchanged. By and large, land cover changes observed in this study were the result of clearing of vegetation for fuelwood, grazing lands, new cultivation areas, etc., thus contributing to the current problem of land degradation in the country. If coordinated efforts are not made to rehabilitate degraded hillslopes, further deterioration of shrublands, forests, and riverine vegetation into areas with little or no plant cover will adversely affect the hillslopes and eventually those areas that are currently used for crop production.*

***Keywords:*** *land degradation; land use changes; GIS; remote sensing; Ethiopia.*

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## Introduction

Repeated aerial photographs and/or satellite images play a major role in setting up inventories of natural resources because they give a visual assessment of land cover changes over a period of time and provide quantitative information on the trade-offs between different land cover categories. Historical investigations of land cover changes have helped to acquire information on salt marsh vegetation and wetlands (Larson et al 1980; Civco et al 1986; Jean and Bouchard 1991), mountainous regions (Schreier et al 1994; Schweik et al 1997), dry lands in the tropics (Mwalyosi 1992), coastal sage scrub (Davis et al 1994), and vegetation succession on dunes (van Dorp et al 1985). In these and other studies, most results are in line with general assumptions about land cover changes. Some, however (eg, Pandee and Chapman 1983), have shown that land cover changes based on estimates, interpolations, etc., and those based on historical data sets such as aerial photographs do not concur.

In many developing countries, agricultural production has not kept pace with population increase due to such factors as land tenure systems, political insecurity, and wars. Empirical evidence of land cover changes delivered by repeated aerial photographs and/or satellite images can greatly contribute to planning more appropriate management of available resources, especially in developing countries, where other kinds of background data are often lacking. However, to come up with fruitful recommendations, studies on land cover changes have to be supplemented by investigations of their causes and effects.

This study is part of a project on "Natural regeneration of degraded hillslopes in Wello, Ethiopia." An initial reconnaissance survey was conducted before the study area was selected. The study area was chosen mainly because (1) it had undergone substantial land cover changes, especially since the early part of the century, (2) it included a variety of physiographic features (highlands, plains, steep and gentle slopes, river valleys, etc.), each of which influences land cover categories in a different way, and (3) it was subjected to high population pressure. Within the broader context of understanding and describing landscape dynamics, the specific objectives of the present paper are (1) to identify and determine overall trends of major land cover changes over a period of 28 years (1958–1986) and (2) to relate these changes to physiographic and socioeconomic processes.

## Description of the study area

The study area covers about 110 km$^2$ and features altitudes between 1705 and 3000 m. Geologically, the region belongs to the Trap Series of Tertiary volcanics and is part of Ethiopia's central lava highlands and massifs. The major soil classifications are Cambisols, Phaeozems, and Lithosols (Anonymous 1988). Mean annual temperatures range between 15 and 20°C. Annual rainfall, which is heavy during the summer months (June–August), ranges between 800 and 1200 mm (Anonymous 1988).

The study area (Figure 1A,B) is located in Kalu, one of the most densely populated districts in Ethiopia, with no less than 250 persons/km$^2$ (Anonymous 1988). The population in Kalu increased by

FIGURE 1A Map of Ethiopia showing the approximate location of the study area in Kalu District.


212% from 1970 to 1984 compared with 57% for the whole Wello region (CSO 1974; CSA 1991). The population of Kombolcia, the district's capital town, more than doubled between 1984 (18,583) and 1994 (39,466) (CSA 1991; CSA 1995b).

Except for a small percentage of the population living in the urban area, the inhabitants are farmers engaged in crop production and livestock rearing. The region (including the study area) is generally classified as intensively cultivated. According to data compiled by FAO, UNEP, and UNESCO, the study area is in a high soil degradation risk zone, where runoff is estimated to cause soil loss of 50–100 tons/ha/y (Anonymous 1988). Over 65% of people in the study area are said to have suffered from the 1984 food shortage (Anonymous 1988).

## Sources of information

In conducting this study, our main sources of information were two black and white aerial photographs (scale 1:50,000) taken in 1958 and 1986. Land cover data for

FIGURE 1B Hillslope cultivation leading to land degradation in the study area. (Photo by M. Coendet, 1982)

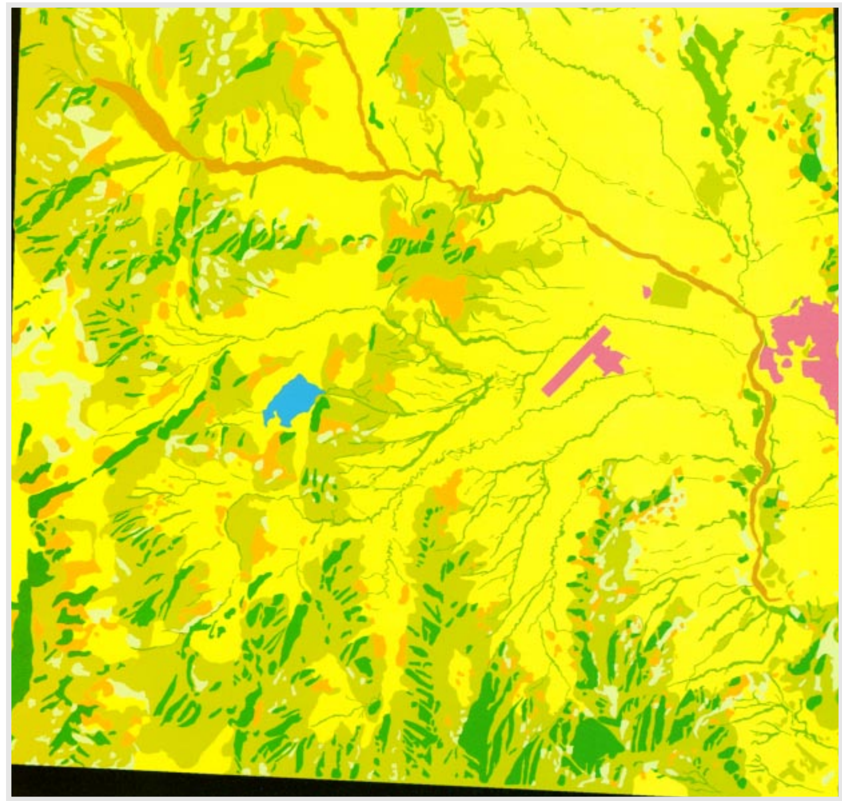

**FIGURE 2** Land use cover in the study area in 1958.

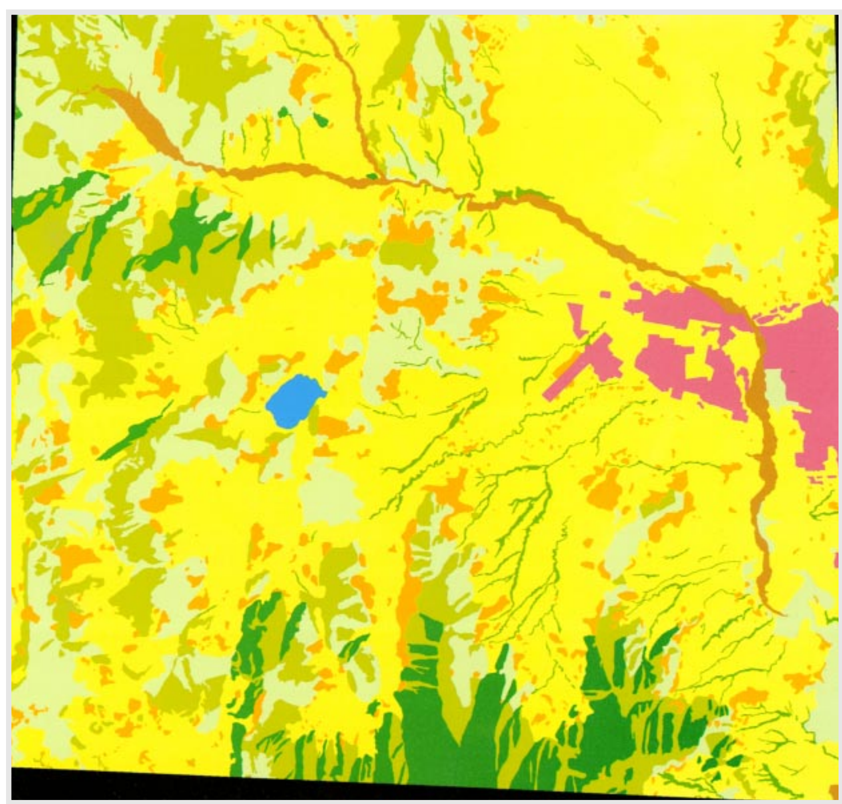

**FIGURE 3** Land use cover in the study area in 1986.

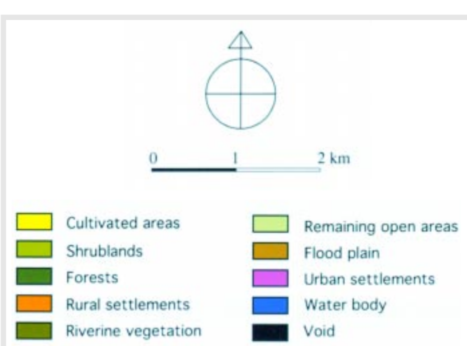

**TABLE 1** The nine land cover categories for which changes were detected for the period between 1958 and 1986 (listed in the order of magnitude of coverage in 1958).

| Land cover | General description |
|---|---|
| **Cultivated areas** | Areas allotted to rainfed crop production, mostly of cereals in subsistence farming |
| **Shrublands** | Land covered by small trees, bushes, and shrubs, in some cases mixed with grasses; less dense than forests |
| **Forests** | Areas covered by trees forming closed or nearly closed canopies; predominant species are *Juniperus procera* and *Olea europaea* ssp *cuspidata* |
| **Rural settlements** | Areas composed of small villages and/or scattered hamlets; mostly located on the slopes or at the foot of the highlands |
| **Riverine vegetation** | Vegetation along the main river valleys draining to the floodplain of River Borkenna; the middle part of the river valleys is generally covered by dense shrub vegetation |
| **Remaining open areas** | Areas that include a group of features (such as barren eroded lands mostly on top of mountains, open areas near homesteads, grazing areas) that are difficult to distinguish on the aerial photos because of their similar tones |
| **Floodplain** | Area covered by the lower course of River Borkenna, carrying a large volume of water during the rainy season but covered most of the year by sand and different sizes of gravel and stones |
| **Urban settlements** | Land occupied by small and large buildings, roads, factories, and an air strip |
| **Water body** | Area covered by a small dammed lake fed by rainfall and small streams |

1958 is based on aerial photo M BNRB M73 no. 10840 and data for 1986 on aerial photo S 13 03 no. 0111. Both photos were acquired from the Ethiopian Mapping Authority (EMA). Ground checking was done to compare information (on categories such as remaining open areas, shrublands, etc.) on the aerial photos with existing features of land cover on the ground. The topographical map (EMA 1993) provided sound information on elevation, settlements, and drainage in the study area. Various atlases, statistical reports, and other relevant documents on the study area and the district were of great help. Prior knowledge of the region and discussions with the local population also contributed to the study.

## Methodology

The study depended on the use of computer-assisted interpretation of digitized aerial photos. The two aerial photographs used for this study were scanned at the Swedish Land Survey office with a resolution of 1100 and 1200 dots per inch and were saved in TIFF format. Before interpretation, the original image files were enhanced through sharpening with Adobe Photoshop 1996 software, saved in TIFF format and imported into Thinkspace's Map•Factory. It was also possible to enlarge the original scale of the scanned aerial photos from 1:50,000 to about 1:3000. This facilitated the interpretation of specific features in the aerial photographs.

To investigate the changes that occurred between 1958 and 1986, nine land cover categories (hereafter categories) were distinguished: cultivated areas, shrublands, forests, rural settlements, riverine vegetation, remaining open areas, floodplain, urban settlements, and a water body (Table 1). These nine categories, identified from the scanned aerial photos, were screen digitized manually as polygon coverage in raster format. A color was selected for each of the nine categories (Figures 2 and 3). Each image was georeferenced according to the Universal Transverse Mercator (UTM) system by selecting five reference points with known coordinates that were later digitized from a 1:50,000 topographic map. To successfully transform coordinates, four control points had to be selected somewhere near the corners and one near the center of each image.

The control points were marked on the digitized aerial photos and registered in UTM coordinates using the ESRI Grid Module of the ArcInfo GIS program. The images were then rubber-sheeted in ArcInfo using the Grid Warp function to transform the coordinates into UTM. The overlapping areas from the two images (1958 and 1986) were clipped from the georeferenced images.

Computation of area in the nine categories was made by exporting the two images from ArcInfo to Map•Factory. By overlaying the two images, the area (%) converted from each of the categories to any of the other categories was calculated.

**TABLE 2** Comparison of areas and rates of change of the nine land cover categories between 1958 and 1986.

| Land cover categories | 1958 land cover ($km^2$) | % of land cover 1958 | 1986 land cover ($km^2$) | % of land cover 1986 | Difference in land cover 1958–1986 ($km^2$) | Change in land cover 1958–1986 (%) | Rate of change in cover ($km^2$/y) |
|---|---|---|---|---|---|---|---|
| Cultivated areas | 54.7 | 49.6 | 56.0 | 50.8 | +1.3 | +2.4 | +0.046 |
| Shrublands | 30.4 | 27.6 | 14.9 | 13.5 | –15.5 | –51.0 | –0.554 |
| Forests | 8.6 | 7.8 | 5.9 | 5.4 | –2.7 | –31.4 | –0.096 |
| Rural settlements | 4.6 | 4.2 | 7.2 | 6.5 | +2.6 | +56.5 | +0.093 |
| Riverine vegetation | 4.5 | 4.1 | 1.8 | 1.6 | –2.7 | –60.0 | –0.096 |
| Remaining open areas | 4.3 | 3.9 | 18.6 | 16.9 | +14.3 | +332.6 | +0.511 |
| Floodplain | 1.6 | 1.4 | 1.9 | 1.7 | +0.3 | +18.8 | +0.011 |
| Urban settlements | 1.2 | 1.1 | 3.5 | 3.2 | +2.3 | +191.7 | +0.082 |
| Water body | 0.3 | 0.3 | 0.4 | 0.4 | +0.1 | +33.3 | +0.003 |

**TABLE 3** Overview of land cover changes (%) in the nine categories, including land cover gained and lost from each category for the period between 1958 and 1986.

| Land cover categories | % of land cover in 1958 and unchanged in 1986 | % of land cover in 1958 lost to other categories by 1986 | % of land cover in 1958 gained from other categories by 1986 | Difference in % of land cover lost or gained (1958–1986) |
|---|---|---|---|---|
| Cultivated areas | 76.8 | 23.2 | 25.3 | +2.1 |
| Shrublands | 30.6 | 69.4 | 18.9 | –50.6 |
| Forests | 28.3 | 71.7 | 41.1 | –30.6 |
| Rural settlements | 34.9 | 65.1 | 120.0 | +54.9 |
| Riverine vegetation | 10.9 | 89.1 | 28.4 | –60.7 |
| Remaining open areas | 38.7 | 61.3 | 393.8 | +332.5 |
| Floodplain | 59.7 | 40.3 | 58.3 | +18.0 |
| Urban settlements | 89.2 | 10.8 | 204.9 | +194.1 |
| Water body | 100.0 | 0.0 | 33.3 | +33.3 |

## Results and discussion

### Land cover changes in the nine categories

*Cultivated areas:* During the period between the two photographs (1958–1986), a major portion of the study area was under cultivation (Table 2, Figure 4). However, contrary to general expectations, there was not much change in the cultivated areas (with only an increase of 0.05 $km^2/y$), especially compared with changes in shrublands (with a decrease of 0.6 $km^2/y$) and remaining open areas (with an increase of 0.5 $km^2/y$). About three quarters (77%) of the cultivated areas in 1958 remained in the same category until 1986, while 23% changed categories (Table 3). Transformation was largely into remaining open areas, rural settlements, and urban settlements (Table 4). However, the loss of cultivated areas to these three categories was compensated by a gain from other categories (Table 3). Two reasons partially explain the small increase in cultivated areas, the reasons being either the areas left uncultivated were not suitable for cultivation or they were under the protection of the Ministry of Agriculture.

*Remaining open areas:* Considerable change was observed among the remaining open areas, with an increase of 14.3 $km^2$, or 333%, from 1958 to 1986 (Table 2). About 39% of the remaining open areas in 1958 were in the same category in 1986, while 61% were changed into cultivated areas, shrublands, and other categories (Tables 3, 4). Conversely, the total rate of change of other categories into remaining open areas was so high (394%) that it outbalanced this loss by far (Table 3).

**FIGURE 4** Land cover changes ($km^2$) in the nine categories between 1958 and 1986.

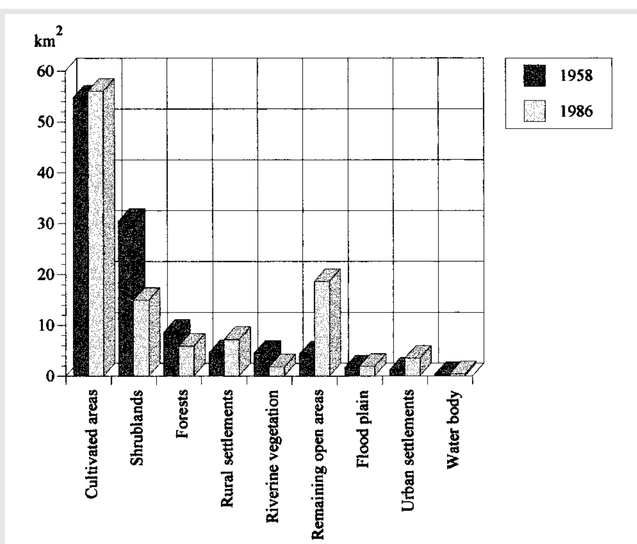


**TABLE 4** Percent of land cover that was converted from each of the eight categories into the rest (1958–1986); no part of the water body was changed into any other category.

| Changed from | Changed to | % |
|---|---|---|
| Cultivated areas | Remaining open areas | 7.4 |
| | Rural settlements | 5.3 |
| | Urban settlements | 4.1 |
| | Shrublands | 2.4 |
| | Others | 4.0 |
| Shrublands | Remaining open areas | 31.7 |
| | Cultivated areas | 21.6 |
| | Forests | 9.5 |
| | Rural settlements | 5.6 |
| | Others | 1.0 |
| Forests | Shrublands | 34.0 |
| | Remaining open areas | 18.5 |
| | Cultivated areas | 14.4 |
| | Others | 4.8 |
| Rural settlements | Cultivated areas | 33.2 |
| | Remaining open areas | 20.2 |
| | Shrublands | 9.5 |
| | Others | 2.2 |
| Riverine vegetation | Cultivated areas | 67.0 |
| | Remaining open areas | 12.2 |
| | Rural settlements | 4.1 |
| | Floodplain | 2.5 |
| | Others | 3.3 |
| Remaining open areas | Cultivated areas | 24.9 |
| | Shrublands | 20.0 |
| | Rural settlements | 8.6 |
| | Forests | 6.5 |
| | Others | 1.3 |
| Floodplain | Cultivated areas | 28.0 |
| | Remaining open areas | 6.5 |
| | Others | 5.8 |
| Urban settlements | Cultivated areas | 4.9 |
| | Remaining open areas | 3.9 |
| | Others | 2.0 |

*Shrublands:* Unlike the remaining open areas, the shrublands shrank massively in size, ie, only 31% remained in that category (Table 3), while 69% were converted into other categories, especially into remaining open areas, cultivated areas, and forests (Table 4). Cultivation and harvesting of fuelwood must have contributed to the deterioration of shrublands. The area changed from other categories into shrublands was small, compared to the loss of shrublands to other categories (Table 3).

*Forests:* The forest cover in the southern part of the study area, a remnant of the once dense natural forest on Mt. Yegof dominated by *Juniperus procera*, diminished by 2.7 km$^2$ (or 31%) between 1958 and 1986 (Table 2). Only 28% of forests remained in the same category (Table 3); 34% were lost to shrublands, 19% to remaining open areas, 14% to cultivated areas, and 5% to other categories (Table 4). Conversion from other categories, especially from shrublands to forests, took place as a result of the Ethio-German Reforestation Program starting in 1975. But this conversion was low so that, on balance, a net decrease of about 30% of forests was observed (Table 3).

Forests are under the protection of the Ministry of Agriculture and, as such, there is no massive deforestation. Until the early part of the century (ca 1915), when a large portion of natural forest was burned, no permanent human settlements existed in these areas (FWCD 1989). By now, however, parts of the natural forest in the study area have been replaced by settlements (Figures 2 and 3).

*Urban settlements:* The area covered by urban settlements increased by 2.3 km$^2$ (192%) in 28 years (Table 2). Eighty-nine percent of the area under urban settlements in 1958 remained unchanged (Table 3). Although 11% of urban areas changed into other categories, a much higher percentage of other categories (about 205%) was converted into urban settlements (Table 3).

*Rural settlements:* Area covered by rural settlements increased by 2.6 km$^2$ (57%) between 1958 and 1986 (Table 2). About 35% of rural settlements in 1958 remained in the same category (Table 3) while 65% changed to cultivated areas, remaining open areas, shrublands, and other categories (Table 4). On the other hand, conversion of other categories into rural settlements was in excess of 50% (Table 3). The increase in rural settlements occurred mostly on hillslopes that are not suitable for cultivation.

*Riverine vegetation:* By 1986, riverine vegetation had decreased by 2.7 km$^2$ (60%) in comparison with coverage in 1958 (Table 2). A large part of riverine vegetation (79%) in 1958 was transformed into cultivated areas and remaining open areas and 10% into other land cover categories (Table 4), implying much clearing of vegetation. Only 11% of the original area remained riverine vegetation. Conversion of other categories into riverine vegetation only totaled about 28% compared with 89% that was lost to other categories (Table 3).

*Floodplain:* The floodplain, which is affected by increasing runoff from tributaries, increased by 0.3 km$^2$ (19%) between 1958 and 1986 (Table 2). Twenty-eight percent was transformed into cultivated areas and about 12% was lost to other categories (Table 4). On the other hand, the floodplain gained about 58% coverage from other categories, leading to an overall increase of area in this category (Table 3).

*Water body:* The only water body in the study area was a small dammed lake that is fed by rainfall and small streams. By 1986, its surface had increased by 0.1 km$^2$ (Table 2), not only by retaining its 1958 surface but also by gaining coverage from cultivated areas (Table 3).

*Classification of the nine categories:* The nine categories can be divided into two types:

1. those with dense natural or seminatural vegetation cover (forests, shrublands, riverine vegetation) and
2. those with little or no plant cover (remaining open areas, rural and urban settlements, cultivated areas, floodplain, and water body).

A deterioration of 20.9 km$^2$ (19%) from the former group to the latter was observed. As mentioned earlier, the most substantial changes in land cover refer to decreases in shrublands and increases in remaining open areas (Figure 4). Thus, clearing of vegetation cover to gain additional cultivation areas was minimal; almost all clearing was done to collect wood for fuel, construction of houses, etc. In the long run, such clearing leads to reduced plant cover and subsequently to an increase in runoff from the slopes. This clearly affects agricultural areas at lower elevations.

Physical attributes (topography, altitude, slope, etc.) generally play an important role in land cover changes. This has been underlined, eg, by Thomlinson et al (1996), who explain that inaccessibility (due to high elevation, steep slopes, long distance from roads, etc.) is one factor that contributes to forest regeneration in areas unsuitable for agricultural and urban development in a postagricultural Puerto Rican landscape. In our study area, inaccessibility, coupled with protection by guards from the Ministry of Agriculture, also played a role in natural regeneration of forest patches through secondary succession (Kebrom et al 1997). Most of the remnants of secondary forests are found at high elevations and on steep slopes and are relatively well guarded.

Land cover changes can be multi- or unidirectional. In studies made in different parts of Nepal, Schreier et al (1994) and Schweik et al (1997) observed that conversions were both from forests to cultivation plots and from agricultural areas to shrublands or dense forests. In some parts of our study area, where the Ethiopian Red Cross Society (ERCS) imposed hillside closures, vegetation cover showed signs of restoration. But due to low local participation, the hillside closures were destroyed in 1991 and restoration was short lived. Since our study was based on aerial photographs from only two moments in time, it is not possible to conclude whether land cover changes were multi- or unidirectional. However, cumulative results of comparative analysis of the two maps show that many forests and shrublands in 1958 were converted by 1986 into remaining open areas, settlements, cultivated areas, etc.

#### Possible consequences of land cover changes

Further computer-assisted photographic analyses of land cover changes from 1986 up to the present could not be undertaken for this paper because recent aerial photographs were not available and satellite images were not affordable. However, personal on-site observations showed that, especially during the transition period of 1991, when the government changed, most of the shrublands under hillside closures disappeared. It is therefore to be expected that, since 1986, shrublands and forests have undergone a greater decrease than for the period between 1958 and 1986 (see Table 2) with a matching higher increase in remaining open areas and settlements.

Inappropriate management of highland Nepali forests has been shown to result in local flooding (Schreier et al 1994). While it is impossible to determine whether the same mechanism applies to a small area such as the one studied here, we believe that runoff is likely to have contributed to the shallow soil depth of about 10 cm (Henrickson et al 1983) measured in the early 1980s in most highlands of southern Wello. If the deterioration of shrublands continues in the same way as occurred between 1958 and 1986, the increase in runoff may not only erode the soils from the highlands but also cause flooding in the adjacent lowlands. Inundation of the food-producing Kyele lowlands by annual floods from the Mbeya highlands (Mashalla 1990) and sedimentation in the surface-water reservoirs in the Dodoma region, Tanzania (Christiansson 1981), must be avoided.

The general loss of vegetation cover and its possible implication in ecological disturbances in the study area in particular, and in the country in general, have already led to problems and may also lead to further destructive scenarios in the future. Partly because the 1973 famine in Wello was associated with activities such as deforestation and clearing of areas for cultivation (Yeraswork 1995), land rehabilitation programs were established under which hillsides were closed and kept free from human and animal intervention. This led to an increase in protective vegetation cover but at the expense of negative feelings among the local population.

The other scenarios are not particular to the study area but rather are reflections of the current situation in the whole country. Destruction of vegetation cover to gain fuelwood and areas for cultivation is taking place in most parts of Ethiopia. In an investigation similar to ours, Gete (1997) compared aerial photos made in 1957 and 1982 to analyze land use/land cover changes in the Dembecha area, Gojam, Ethiopia, and reported that the loss of forest cover was dramatic, with a matching increase in cultivated land. If negative consequences are not controlled, it will not be long before a third scenario of loss of vegetation cover and ground may take place because most areas currently cultivated will be affected by increasing runoff.

#### Implications of population growth

There are different views of the relationship between population growth and land degradation. Even where population increase is rapid, agricultural lands have sometimes remained stable and suffered less land degradation. Off-farm employment, increasing net imports of food, strict land tenure systems (Virgo and Subba 1994), intensification of agriculture (Tiffen et al 1994), and development of activities such as hunting, fishing, and tapping palm wine (Fairhead and Leach 1996) are some of the means by which farmers supplement their income from crop production. In Machakos District (Kenya), eg, massive outmigration of men employed in wage labor and off-farm enterprises contributes to about 40% of the population's income (Ondiege 1992; Rocheleau 1995). Having alternative means of income reduces the overall dependence on agriculture, which, in turn, diminishes pressure on land and thus reduces the impact of population growth on the land.

But worldwide, in most developing regions with traditional agricultural methods, there is little or no possibility of earning income from wage labor or off-farm employment and there are no alternatives to wood for fuel. Thus, population pressure has a negative effect on land because more shrubs and trees are cut for fuel and cultivation of marginal areas. Among others, Ives and Messerli (1981), Pimentel et al (1986), Abernathy (1993), Hurni (1993), and Mortimore (1993) have shown that population growth is a major driving force in land cover changes and that it contributes to resource degradation.

For the area under study, data on rural population density were not available. But the overall increase in population that was mentioned earlier and the fact that the region has the country's smallest landholding ratio with 0.57 ha/household, ie, only about 60% of the country's average of 0.93 ha/household (CSA 1995a), indicate the seriousness of population pressure. There is little or no off-farm employment with which people may supplement their income from agriculture. Nor can farmers invest in inputs (eg, fertilizers, selected seeds, etc.) to increase the productivity of the small holdings they cultivate. Thus, unlike the examples mentioned above, the population in our study area depends almost entirely on the land they cultivate.

Fuelwood is another problem associated with population growth. The size of Kombolcia, the district's capital town, increased by nearly 200% in 28 years (Table 3) and its population more than doubled in a decade (CSA 1991, 1995b). This spatial and demographic growth has definitely had an impact on agricultural land and availability of fuelwood in surrounding areas. The demand for fuel increased even more because the study area is located between two urban areas (Dessie and Kombolcia), which are only 23 km apart.

The fuelwood problem has an indirect effect on soil fertility and crop production because, as in many other parts of the country, it is customary in the study area to burn animal dung when wood is scarce. Recent reports show that, throughout the country, the burning of dung for fuel rather than using it to regain soil fertility results in a reduction of grain production by about 550,000 tons annually (EPA 1997).

In their studies of the Sahel, Broekhuyse and Allen (1988) found that crop yields from intensive farming declined by a third to a half compared with a period during which there was enough fallowing. In our study area, population increase has led to a shortage of land and farmers no longer practice fallowing. Even when farmers do not possess a pair of oxen and cannot cultivate the land as intensively as others, arrangements are made with those who own oxen to plow their plots and share the production.

### Village elders and policy makers

Although physical attributes (such as altitude, slope, etc.) have been shown to contribute to natural protection of the vegetation cover, it is the united effort of village elders and various governmental and nongovernmental organizations that can make a real difference. Especially in rural parts of the country, one should not underestimate the role that can be played by village elders. About 30 km north of the study area, eg, elders successfully convinced the local population to participate in a significant land rehabilitation program (personal observation).

Steps taken to rehabilitate degraded slopes in the study area were not successful because, in most cases, farmers were neither consulted nor included in planning land rehabilitation. Lack of local participation was a strong reason why people felt alienated and indifferent. This, in turn, must have contributed to the failure of most rehabilitation programs (Yeraswork 1995; Kebrom 1999). The attitude of subsistence farmers toward land rehabilitation may not always be right nor are policy makers always wrong (Ives and Messerli 1989), but it is our belief that attempts to reduce land degradation problems are futile exercises if the local population is not involved. In addition, plans designed by policy makers should be compatible with people's basic needs and at least satisfy them. Trying to alleviate the problem by reallocating present agricultural land to reforestation without doing much to help farmers increase crop production from the land they currently cultivate may create a new problem by solving the first. Implementation of forced reforestation may lead to a scenario of gaining forests but losing ground, such as was observed in the Middle Mountains of Nepal (Schreier et al 1994).

## Conclusions

The general trend observed by the present study is a decrease in shrublands and forests and a matching increase in remaining open areas and settlements. The implication is that the present tendency may lead to more land degradation. Thus, this trend needs to be corrected. Land cover mapping and documentation may not provide the ultimate explanation for all problems related to land cover changes and cannot be an end in itself. Nevertheless, it serves as a stepping stone for understanding trends and possible causes of land cover changes.

The ecological problems associated with the land cover changes we discussed are linked with the basic livelihood of the local population as well as, to a certain extent, with population growth. Ambiguous and uncertain land ownership systems (Yeraswork 1995) and a lack of coherent national forest policies or guidelines on utilization of trees in the forests (Alemneh 1990) have exacerbated the problems. Moreover, the lack of coordination among nongovernmental organizations (NGOs) and between NGOs and the local population is a problem that should not be underestimated.

A governmental agency (ministry), a village association, or an NGO cannot solve the problem of unrestrained clearing of vegetation and its possible degrading impact on hillslopes. If long-term solutions are to be found, the role of local participation, the influence of village elders, the involvement of researchers from both natural and social sciences, the commitment of policy makers, and coordination of activities among the relevant NGOs should be given due consideration.


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## REFERENCES


***Abernathy V.*** 1993. *Population Politics: The Choices That Shape Our Future*. New York: Plenum Press/Insight Books.
***Alemneh D.*** 1990. *Environment, Famine and Politics in Ethiopia: A View From the Village*. London: Lynne Rienner.
***Anonymous.*** 1988. *National Atlas of Ethiopia*. Addis Ababa: Ethiopian Mapping Authority.
***Broekhuyse JT, Allen AM.*** 1988. Farming systems research. *Human Organisation* 47:330–342.
*[**CSA**]* ***Central Statistical Authority.*** 1991. *Population and Housing Census 1984: Analytical Report on Wello Region.* Addus Ababa: CSA.
*[**CSA**]* ***Central Statistical Authority.*** 1995a. *Report on Land Utilisation. Agricultural Sample Survey 1991/92,* Statistical bulletin 134. Addis Ababa: CSA.
*[**CSA**]* ***Central Statistical Authority.*** 1995b. *Report on Population Size and Characteristics for Amhara Region,* Volume 1, Part 1. Addis Ababa: CSA.
*[**CSO, currently CSA**]* ***Central Statistical Office.*** 1974. *Results of National Sample Survey 1970 (Second Round): Estimates of Population in Wello,* Volume 2. Addis Ababa: CSO.
***Christiansson C.*** 1981. *Soil Erosion and Sedimentation in Semi-Arid Tanzania: Studies of Environmental Change and Ecological Imbalance.* Report Series N. A119. Department of Physical Geography, University of Stockholm.
***Civco DL, Kennard WC, Lefor MW.*** 1986. Changes in Connecticut saltmarsh vegetation as revealed by historical aerial photographs and computer-assisted cartographics. *Environmental Management* 10:229–239.
***Davis FW, Stine PA, Stoms DM.*** 1994. Distribution and conservation status of coastal sage scrub in southwestern California. *Journal of Vegetation Science* 5:743–756.
*[**EMA**]* ***Ethiopian Mapping Authority.*** 1993. Map, series ETH. 4, sheet 1139 D3, 1st edition. Addis Ababa: EMA.
*[**EPA**]* ***Environmental Protection Authority.*** 1997. *Environmental Policy of the Federal Democratic Republic of Ethiopia.* Addus Ababa: EPA.
***Fairhead J, Leach M.*** 1996. *Misreading the African Landscape: Society and Ecology in a Forest–Savanna Mosaic*. Cambridge: Cambridge University Press.
*[**FWCD**]* ***Forestry and Wildlife Conservation Development.*** 1989. *The Last Forests of Ethiopia.* Addis Ababa: FWCD.
***Gete Z.*** 1997. *Land Use/Land Cover Maps (of 1957 and 1982) of Dembecha Area, Gojam, Ethiopia.* Berne: Centre for Development and Environment, University of Berne.
***Henrickson B, Sultan T, Ross S, Wijntje-Bruggeman HY, Fitssum F.*** 1983. *Provisional Soil Depth Map of Ethiopia.* Addis Ababa: Ministry of Agriculture.
***Hurni H.*** 1993. Land degradation, famine, and land resource scenarios in Ethiopia. *In:* Pimentel D, editor. *World Soil Erosion and Conservation.* Cambridge.
***Ives JD, Messerli B.*** 1981. Mountain hazards mapping in Nepal: introduction to an applied mountain research project. *Mountain Research and Development* 1:223–230.
***Ives JD, Messerli B.*** 1989. *The Himalayan Dilemma: Reconciling Development and Conservation.* London: Routledge.
***Jean M, Bouchard A.*** 1991. Temporal changes in wetland landscapes of a section of the St. Lawrence River, Canada. *Environmental Management* 15:241–250.
***Kebrom T.*** 1999. Land degradation problems and their implications for food shortage in South Wello, Ethiopia. *Environmental Management* 23:419–427.
***Kebrom T, Backéus I, Skoglund J, Zerihun W.*** 1997. Vegetation on hillslopes in southern Wello, Ethiopia: degradation and regeneration. *Nordic Journal of Botany* 17:483–493.
***Larson JS, Mueller AJ, MacConnell WP.*** 1980. A model of natural and man-induced changes in open fresh water wetlands on the Massachusetts coastal plain. *Journal of Applied Ecology* 17:667–673.
***Mashalla SK.*** 1990. The human impact on the natural environment of the Mbeya highlands, Tanzania. *In:* Messerli B and Hurni H, editors. *African Mountains and Highlands: Problems and Perspectives*. Marceline, MO: Walsworth.
***Mortimore M.*** 1993. Population growth and land degradation. *GeoJournal* 31:15–21.
***Mwalyosi RBB.*** 1992. Land-use changes and resource degradation in south-west Masailand, Tanzania. *Environmental Conservation* 19:145–152.
***Ondiege PO.*** 1992. Local coping strategies in Machakos District, Kenya. *In:* Taylor DRF and Mackenzie F, editors. *Development From Within: Survival in Rural Africa.* London: Routledge.
***Pandee P, Chapman EC.*** 1983. Recent changes in land use and land cover at Huai Thung Choa. *Mountain Research and Development* 3:346–352.
***Pimentel D, Dazhong W, Eigenbrode S, Lang H, Emerson D, Karasik M.*** 1986. Deforestation: interdependency of fuelwood and agriculture. *Oikos* 46:404–412.
***Rocheleau DE.*** 1995. More on Machakos. *Environment* 37:3–5.
***Schreier H, Brown S, Schmidt M, Shah P, Shrestha B, Nakarmi G, Subba K, Wymann S.*** 1994. Gaining forests but losing ground: a GIS evaluation in a Himalayan watershed. *Environmental Management* 18:139–150.
***Schweik CM, Adhikari K, Pandit KN.*** 1997. Land-cover change and forest institutions: a comparison of two sub-basins in the Southern Siwalik Hills of Nepal. *Mountain Research and Development* 17:99–116.
***Thomlinson JR, Serrano MI, López TM, Aide TM, Zimmerman JK.*** 1996. Land-use dynamics in a post-agricultural Puerto Rican landscape (1936–1988). *Biotropica* 28:525–536.
***Tiffen M, Mortimore M, Gichuki F.*** 1994. *More People, Less Erosion: Environmental Recovery in Kenya*. New York: Wiley.
***van Dorp D, Boot R, van der Maarel E.*** 1985. Vegetation succession on the dunes near Oostvoorne, the Netherlands, since 1934, interpreted from air photographs and vegetation maps. *Vegetatio* 47:123–136.
***Virgo KJ, Subba KJ.*** 1994. Land-use change between 1978 and 1990 in Dhankuta District, Koshi Hills, Eastern Nepal. *Mountain Research and Development* 14:159–170.
***Yeraswork A.*** 1995. *Twenty Years to Nowhere. Property Rights, Land Management and Conservation in Ethiopia* [PhD dissertation]. Uppsala, Sweden: Uppsala University.