LAND USE DYNAMICS AND SOIL DEGRADATION OF THE DIFFERENT LAND USES IN WERKARYIA AREA, SOUTH WELLO, ETHIOPIA

Engdawork Assefa*

ABSTRACT *The paper examines the distribution of land use and land cover at different periods of time (1967,1986 and 1996) and identifies the rate of changes in Werkaryia area, Kutaber wereda, south Wello. Moreover, it assesses the physical, biological and chemical soil degradation under different land use/ land cover and slopes.*

Cultivated land and shrub land increased by 58% and 70%, respectively, in 1996 compared to 1965. During the same period of time, on the other hand, grass land, woodland and bush land declined by 12, 39 and 32 %s, respectively.

In the study area there are different types of soil degradation, which prohibited proper crop production. About 47% of soils are marked by very shallow soil depth. The crop cultivation is also affected by low organic matter, imbalances of nutrients and deficiency of Phosphorous. However, the extent and types of soil degradation vary in different land uses.

Key words and phrases: *land use patterns, chemical soil degradation, physical soil degradation, biological soil degradation.*

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* Lecturer, Arbaminch Water Technology Institute

INTRODUCTION

The significance of identifying land use/land cover patterns and soil degradation enables us to establish the status of ecology of the agro-ecological system and the impacts of man on the environment. It also enables us to suggest some points on the situation of the optimum use of the land.

In Ethiopia the present land use pattern is the result of three factors; namely, climate (mainly rainfall and temperature), terrain (slope and stoniness), and population size, distribution and cultural orientation and practices (UNDP/FAO, 1984). The land use patterns of Wello region is not an exception and as a result the largest share in the land use and land cover as a whole is cultivated land, which accounts for 90.26% (723, 999 sq. km, of which annual crops 69.4%, perennial crops 0.2% and fallow 20.5%). Pasture area is about 43,356 sq. km (5.4%), which consists of grassland and other land cover areas meant for grazing and browsing. All kinds of forests including community, state and natural forests account for 4.3% of the area. These land uses and land covers excluded the areas which are not fit for cropping and livestock rearing such as swamps, unutilizable land, water body etc. (EHRS, 1985).

Some important studies on vegetation and land use on a scale of 1:50,000 in Wello region include the survey of Borkena area by LUPRD/UNDP/FAO (1985), the Ambassel wereda by Bille and HayWood (1983) and, the Maybar area by Weigel (1986). The interdisciplinary study "*The African Environment Experience and Control*" project also has a paramount contribution to the study of the dynamism of Wello environment (IES, 1998).

The exploitative activities of people and their different land use systems, accentuated by population pressure, are the main causes of land degradation. The problem of erosion starts with the removal of natural vegetation by man for cropping, grazing, fuel, etc. Deforestation is very high in Wello region, which has resulted in the decline of natural vegetation from 16% to 4% between 1954 and

1975 (Sebsibe, 1998:189). The high rate of deforestation accentuates erosion by affecting the infiltration and run off. As Hurni (1988) estimates, the cropland, which is less than 15 % of the total area of the country, accounts for 45 % of the total soil loss while the soil loss in forest areas is negligible. Thus, rate of erosion is high in areas where there is low vegetation cover.

Soil erosion is the main cause of deterioration of soil productivity in the Ethiopian highlands. About 50% of the total area of the country is under the threat of soil degradation and the impact of this is causing decline in food production by one to two % per annum (NCS, 1990). The most severe degradation, however, is observed in the northern highlands (Constable, 1984). The Wello highlands (>1500m a.s.l.) is one of the most seriously affected area in the northern part, and as a result about seventy- two % (5,817,600 ha) of the highlands is covered by very shallow soils which are less than 25 cm depth, (Hurni, 1988: 125). These shallow soils are characterized by very low moisture holding and infiltration capacities, and hence undermine the ability of crops to withstand drought, exacerbating the decline in crop yield. It is to be noted that these shallow soils are closely correlated with more frequent occurrence of drought and famine in the area (Webb and von Braun, 1989).

The investigation of the extent, causes and consequences of soil degradation is vital to recognise the repercussion of environment by the growing population, and the threats to the productive capacity of agriculture and thereby the livelihood of population. Accordingly, it is important in providing information to work out production system and conservation measures. Likewise, soil degradation, land use survey, which comprises investigation, classification, and mapping the pattern of land use and land cover also portrays the status of resource utilisation and land management. In such a way, it provides basis for conservation planners to plan for the sustainable use of land.

This paper has the following objectives:

- to describe and classify the nature and intensity of the present and past use of land by man and then to identify the trends and dynamics of land use and land cover,
- to investigate the extent and distribution of physical, biological and chemical soil degradation and to examine the influence of land uses and topography on soil degradation.

DESCRIPTION OF THE STUDY AREA

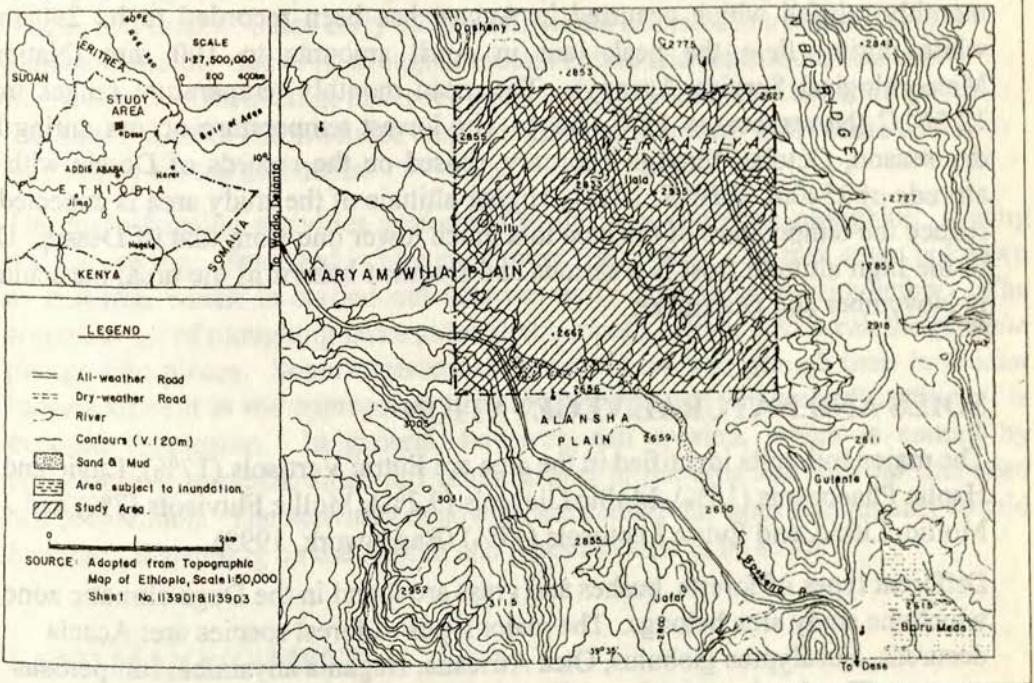
LOCATION, PHYSIOGRAPHY AND GEOLOGY

The study site, "Werkaryia", is situated in Kutaber Wereda, South Wello (Fig.1). It is located about 15 km north north west (NNW) of Dessie, along the road from Dessie to Wadla Delanta. Astronomically, the study site roughly lies at 11^0 12' 45"-11^0 15' 30" N and 39^0 34`30"-39^0 36'30" E and covers an area of 1170 ha. It has an altitude ranging from 2650-3005 m a.s.l. and falls within the Dega agroclimate zone.

The study area is characterised by slopes ranging from flat to steep, which account 7% and 24% of the total area, respectively. A good proportion of the area (64%) has a general slope of 5-30%.

Of the different groups of Lava, Termaber basalt covers the region around Dessie. The dominant rock of this group is the alkaline basalt, which falls within the age range of 26-22 million years (Mohr, 1983:381). Along the road from Haiq to Kombolcha through Dessie violet and coarse-grained pyroclasts are well exposed together with fine light grey tuffs. In addition to these tuffs, basalt mainly of lava flows occurs. The dominant rock type of Werkaryia is trachyte.

Fig.1 LOCATION MAP OF THE STUDY AREA



CLIMATE

The area is characterized by sub-humid climate. The mean annual rainfall based on records from Borumeda (located about 5 km south of Werkaryia and has an altitude of 2720 m) is approximately 1185 mm. The area is marked by two rainy seasons (bimodal pattern). The main rainy season is between July and September *(Kiremt)* and a small rainy season from March to May *(Belg)*. The highest monthly rainfall which occurred in August has been recorded to be 290 mm, while during *Belg* the peak rain in April amounts to 100 mm (National Meteorological Service Agency). The mean monthly temperature ranges from 12.50^0 C (November) to 17^0C (July). The lowest temperature occurs during the dry season, October through February, (based on the records of Dessie with an altitude of 2540m. (EHRS, 1985). Higher altitude of the study area is expected to reduce the temperature of the area to a much lower one from that of Dessie. Due to the high altitude frost is a serious and frequent hazard in the area, particularly in November and December.

SOILS AND NATURAL VEGETATION

The major soil units identified in the area are Eutric Vertisols (17%), Luvic and Haplic Phaeozems (18%), Mollic Gleysols (9.2%), Mollic Fluvisols (7%) and Mollic, Lithic, and Eutric Leptosols (47%) (Engdawork, 1999).

Different types of forests, bushes and grass are found in the Dega climatic zone to which the study area belongs. The major types of forest species are: Acacia decurens, Eucalyptus globulus, Olea Africana, Hagania abysinica, Junipereous procera. The dominant bush species include Solaniain indium, Adhatoda schimperana, Galiana apaginoides etc. (Survey of Agricultural Office of Kutaber Wereda, 1994/95).

FARM SIZE AND CROPPING PRACTICES

In the area the average household land size is 0.96 ha. The average number of farm plots of farmers was 3 with each plot having an average size of 0.296 in 1996. The estimated average distance from home is 3 km (Survey of Agricultural Office of Kutaber Wereda, 1996).

The major types of crops that grow in the area, in order of importance are: barley, wheat, and maize. Since early 1970s, cultivation of maize has increasingly expanded mainly due to its drought resistant nature and less labour and cost involvement. The average product of a household is estimated to be 3.8 to 7.6 quintals. Most of the produced crop is consumed at home. Only some of it is sold to pay for tax and debts.

The main farming activities performed in the area comprise ploughing, sowing and harvesting. Farmland is ploughed more than once. The first stage is known as *gimisha*, which is carried out between early September to November. The second stage of ploughing takes place after a month, which is to break the *gimisha* plough into pieces. Some experienced farmers, however, plough their land after harvest since it is the appropriate time to easily plough the soil. But the soil is exposed to erosion. In general, however, soil erosion, which is caused by ploughing, is minimal, since teff is not grown in the area and thus no fine seed bed preparation. The activities of sowing are carried out from late January to mid February, depending on the rainfall and types of crops to be sown.

LAND MANAGEMENT

The farmers themselves have been aware of the problems of soil degradation and have attempted different practices to tackle the problems at certain levels. The attempts are: terraces, ploughing along contours, and building trenches, bunds, ridges, etc. Moreover, to maintain soil fertility, they have employed crop rotation, manuring and compost.

Earlier, when the yield in their holdings decreased, they left some parts of their holdings for fallowing for 1-3 years in order to restore the land's nutrients. But at present, due to population pressure and the subsequent scarcity of land, the practice of fallowing is abandoned, unless the land ceases to give yields. Moreover, people used to leave crop residues or stalks on their farm to maintain soil fertility. At present, however, peasants use stalks and crop residues for cattle feeding and for fuel. Peasants plough along contour lines and leave thin strips of grass locally called "*wober*" unploughed between plots especially on the upper slopes to control soil erosion. Terracing was also practiced long before it was widely encouraged during the Derg period. During the years from 1984 to 1989, peasants of Kutaber Wereda through "food for work" program constructed terraces on about 25-75 ha, out of which they maintained terraces on 63 ha (Survey of Agricultural Office of Kutaber Wereda, 1994/95).

However, the peasants in Kutaber wereda, in general, and in the study area, in particular, remove terraces from their fields because terraces harbor rodents which are difficult to get rid off, consume land and are difficult for ploughing. Consequently, the people have developed negative attitude towards terracing, though at present, despite their negative attitude, they are constructing terraces through government encouragement. They are making some adjustments to the past practices, which include constructing at the boundary of two farm fields of different holders, and, the terraces are also separated by wide spacing.

Farmers practice manuring to maintain soil fertility. Animal dung, especially of horses, donkeys, sheep and goats, locally called *"fig"*, is scattered over small plots around the homestead called "*Kosi*" (dung land). They accumulate the dung in the field at different spots, and then during the ploughing period, they mix it with the soil. They also use ash as water absorbent in areas where drainage is a problem. Cattle dung, however, is mainly used for fuel.

Rotation of cereals and legumes is also one of the main forms of maintaining the fertility of the soil. The rotation depends on the condition of the soil such as if the

yield declines in the area, and depending on the family needs and the weather condition.

Despite the different traditional management of land which attempted to halt degradation problems and maintain the soil fertility since earlier periods, the present rate of degradation is high due to low scale achievements and the problems associated with indigenous soil management practices (Belay, 1998).

MATERIALS AND METHODS

The data generated for land use and land cover analysis was the areal distribution and percentages of different land cover types of 1967, 1986, and 1996. This information was acquired through stereoscopic aerial photo interpretation. Field survey was also carried out to collect data on the current land use/land cover. The land uses and land cover were grouped into forest, woodland, bush land, shrub land, grassland and cultivated land, based on the physiognomic vegetation classification systems of the LUPRD/UNDP/FAO (1985) (App. 1).

Comparative study of three types of degradation with respect to different land uses and slopes were carried out. The Phaeozems, which were found under different land uses and slopes, were selected. These Phaeozems were mantled by forests (transect II- Profile 3), grassland (transect IV- profile 1 and transect V- profile 3) and were also used for cultivation (transect I- profile 3 and transect III- profile 3) (Fig 2). The respective average slopes of cultivation, grassland, and forest are 22, 33, and 37 %s. The surface and subsurface morphological, physical and chemical properties of cultivated land, forestland, and grassland were described in the field and analysed in laboratory.

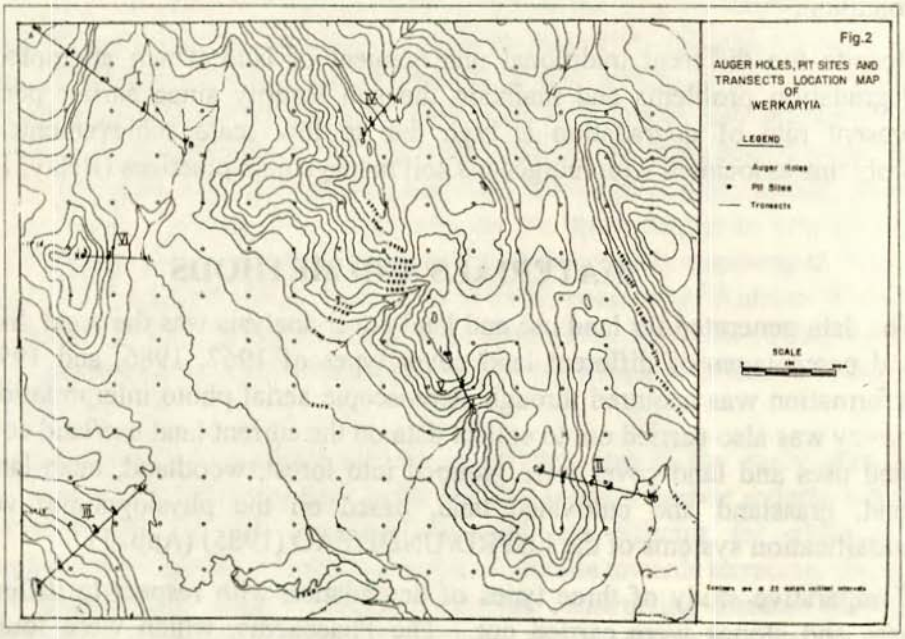


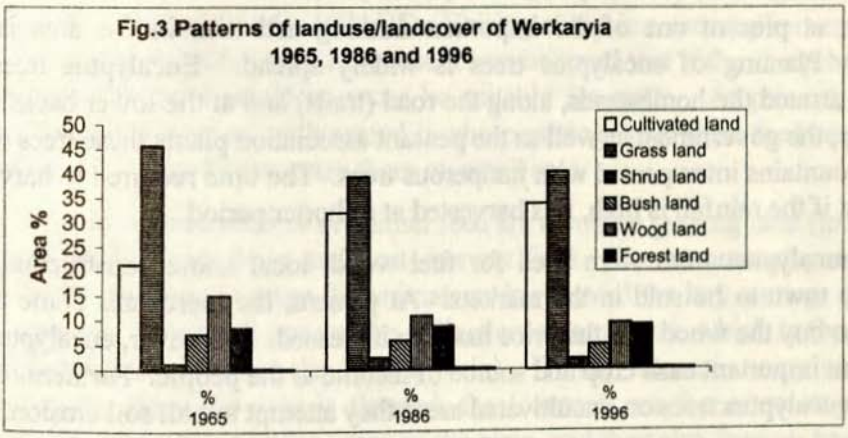
Fig.2
AUGER HOLES, PIT SITES AND TRANSECTS LOCATION MAP OF WERKARYIA
LEGEND
Auger Holes
Pit Sites
Transects
SCALE

RESULTS AND DISCUSSION

PATTERNS OF LAND USE LAND COVER

In the study area, the major land use and land cover units distinguished are cultivated land, forestland, woodland, bush land, shrub land and grassland. There are also some pockets under rock outcrops and swamp (App. 2-5).

The area of forest coverage increased by 1.5% in 20 years. The trend of increase in the coverage of forest area is consistent with what was observed on the Mafud escarpment, which is located near Debersina town (Woien, 1995:6).



Source: - Aerial photo interpretation and field survey

The coverage of forest area in 1965 was 103.3 ha and in 1986 was 104.89ha (Fig 3). However, this doesn't mean that deforestation and vegetation change has not taken place in Werkaryia area. Had deforestation not taken place, the original forest species would have covered the whole area of forests (Sebsibe, 1998). Therefore, deforestation and species loss of the area are evidenced by the change in composition of forests, which are dominated by the newly introduced trees such as Eucalyptus and Juniperous trees.

The important point to be considered in the dynamics of land use/land cover is the time of breaks in trends in land use/land cover and whether the change in time is permanent or temporary (Solomon, 1994:52). In Werkaryia area, thus, temporal change of the forest cover had taken place. The present size (area) of state and community forest, therefore, is due to reforestation program launched by the Derg in 1981.

On the other hand, the woodland area of 1965, which had been about 15.08% of the total area declined to 10.88% in 1986. Similar trends were also reported in Mafud escarpment (Woien, 1995:7). This is attributed to the land proclamation of 1975, which reduced the incentives in investment in trees, and ownership of land.

However, at present one of the important farming activities in the area is tree farming. Planting of eucalyptus trees is widely spread. Eucalyptus trees are common around the homesteads, along the road (trails) and at the lower backslopes. Moreover, the government as well as the peasant association plants these trees on the barren mountains interspersed with juniperous trees. The time required to harvest is 4-5 years; if the rainfall is high, it is harvested at a shorter period.

Earlier, eucalyptus trees were used for fuel wood, local home construction, and carried to town to be sold in the markets. At present, the merchants come to the villages to buy the wood and the price has also increased. Moreover, eucalyptus has become an important cash crop and source of income to the people. Furthermore, by planting eucalyptus trees on uncultivated areas they attempt to halt soil erosion.

However, farmers that engage in tree farms face some problems. The first problem of growing eucalyptus trees is that its root grows far deep and drains all water and nutrients to a depth. It also affects a greater radius and hence neighboring crops are very much affected by the eucalyptus trees. It also harbors birds, which damage crops. Furthermore, the raindrops over the leaves of the tree affect the nearby cultivated crops. Regardless of the above problems, people continue to grow trees since they have become important sources of income.

The grassland area in 1965 had been 547.8 ha whereas in 1986 it was 471.7 ha. This suggests a contraction by 76.1 ha or 13.9%. The average rate of change of the grassland is 3.6 ha or 0.63% per year.

Livestock raising, which is mainly dependent on grassland, is one of the integral activities of mixed farming. It provides the farmer with draught power, as a means of transportation, and source of earning cash. The products of livestock such as meat, milk and its products are used for home consumption and the skins and hides are also used as source of money earnings.

The total number of livestock in the study area is 27072. The most important livestock in the area is cattle (55.6%) and Sheep (36%) (Survey of Agricultural Office of Kutaber Wereda, 1994/95). Raising sheep is a recent phenomenon, for in the past sheep were not raised because it was believed that if the sheep browsed over the plain, the grass could no more be suitable for cattle. At present, there is an important development with regard to sheep raising since their feed requirement is small and it is possible to graze them on small area.

The most important sources of animal feed are common grazing land (locally known as *beni* land), straw, hays and post- harvest field. The communal grazing land is used either to directly graze the animals or is reserved for hay cutting. The pattern and intensity of rainfall govern the utilization of beni land, which is found far from their homestead (such as the Alasha plain). During the main rainy season (June-September), since the area is flooded, the livestock are forced to stay out in the peripheral areas that is in the edges of the plain, and they also feed on hay, straw and the cut and carried grass around homesteads. This time is a period of recovery for the grass and some palatable species. Moreover, at the beginning of the harvest the livestock move to the harvested field. Although there are some on and off grazing over the plain, the people mainly use the plain for grazing during the winter season. Besides grazing over the plain, the working oxen and the milk cows feed the stored hay and straws at home.

At present, the number of livestock per household is very much reduced to an average of 3-4 cattle per household (Survey of Agricultural Office of Kutaber Wereda, 1994/95). The main reasons for the decline of livestock are shortage of feed resources, which are caused by the conversion of much of the nearby *'beni'* land around the village, which have been important grazing fields in the past, into farms. Moreover, the closure of large area of land for reforestation is another factor for the shortage of grassland. The other main factor that reduced the cattle feed is the low rainfall; particularly, the situation is worse during a dry season. Animal disease is also responsible for the decline in the number of livestock.

Compared to 1965, the area of cultivation in 1986 increased by 58% showing expansion rate of 1.9% per year. The people of Werkaryia mainly depend on agriculture in order to meet their basic needs and subsequently the peasants cultivate every available parcel of land. The major areas of cultivation, situated at the foot of ridges and hills and in the plain, in which Vertisols and Haplic Phaeozems and Luvic Phaeozems are dominant soils, are characterized by high chemical fertilities. On the other hand, one of the salient features of the study area is that more and more mountain lands such as mountain slopes, summits and ridge tops are brought under cultivation mainly due to the growing pressure of population. Moreover, more land is also brought under cultivation in times of political and social crises and when yield per unit area of land declines (Bahru, 1998:115 and Dessalegn, 1998:49). Cultivation of these parts is resulting in serious degradation hazards.

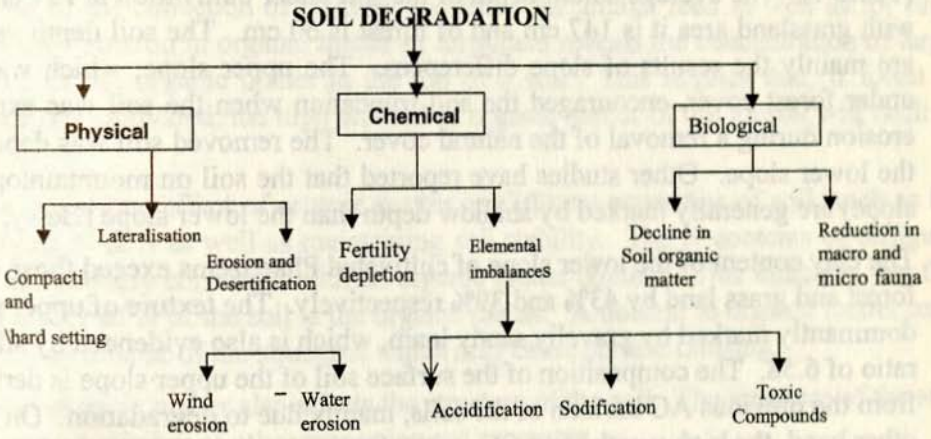
The shrub land and bush land areal coverage has been marked by irregular changes. The bush land and shrub land area coverage in 1967 had been 88.55 and 15.25 ha respectively, while in 1986 the bush land declined to 71.7 ha, and the shrub land increased to 30.32 ha.

SOIL DEGRADATIONS OF THE DIFFERENT LAND USES

Man as an ecological factor and a manipulator of the environment alters the course of the normal soil processes and modifies soil properties. The perturbation on soil characteristics is reflected in the land use and land cover of the area and in the land management.

There are three principal types of degradation: physical, chemical and biological. (Fig.4)

Fig 4. Types and processes of soil degradation



(Source: Lal, R. and Stewart, B.A: 1990)

PHYSICAL DEGRADATION

Physical degradation refers to the deterioration of the physical properties of a soil (Table 1). The average solum depth of the soil under cultivation is 157 cm, while with grassland area it is 147 cm and of forest is 60 cm. The soil depth variations are mainly the results of slope differences. The upper slope, which was found under forest cover, encouraged the soil truncation when the soil was exposed to erosion during a removal of the natural cover. The removed soil was deposited at the lower slope. Other studies have reported that the soil on mountaintop (upper slope) are generally marked by shallow depth than the lower slope (Belay, 1997).

The clay content of the lower slope of cultivated Phaeozems exceed those of the forest and grass land by 43% and 39% respectively. The texture of upper slope is dominantly marked by gravelly sandy loam, which is also evidenced by silt/ clay ratio of 6.58. The composition of the surface soil of the upper slope is derived from the previous AC horizon of the soils, mainly due to degradation. On the other hand, the high weathering rate on the lower slope resulted in raising the clay content. From the texture of a soil, it is possible to suggest about the water storage capacity of a soil, which is computed as $W = 1.5s + 3c$ where W = water storage, s = sand and c= clay content (Lal, 1987:252). This formula indicates that the lower slope is marked by relatively high water storage capacity while the upper slope is marked by high run off velocity. In general, the forestland that has been re-afforested recently has suffered from serious erosion. The impacts of the antecedent erosion have left its marked effects on the soil.

BIOLOGICAL DEGRADATION

Biological degradation is expressed by the deterioration of the humus content of soil (Table 1). The forest cover of the area is characterized by high organic matter (3.18%), while in cultivated land it is 2.1%. The high organic matter in the forest is due to ample supply of organic residues. As the C/N values also indicate, the degree of humfication of soils under forest cover is low. This is mainly because of the retarded microbial activities under the forest cover. On the other hand, factors that

are responsible for low organic matter in cultivated land are the high rate of mineralization due to conducive temperature and moisture condition of an exposed cultivated soil. Moreover, the organic matter supply is low in cultivated land because of the collection of residues and straw for animal feed as well as for fuel. The wide variation in organic matter in forestland reveals the concentration of large amount of the organic matter at the top of a soil. This implies that, if forest is cleared and cultivated, the high amount of organic matter of the topsoil will decline sharply.

There is a strong effect of organic matter on different properties of soil, such as by supplying N & S as well as maintaining soil stability. The N contents of different soils are strongly correlated with an organic matter content. This indicates that the main source of N of the soil is the organic matter. A decline in organic matter may result in a collapse of the structure, which may cause surface crusting.

The low organic matter also affects the structure of the soil. The structure of the soil influences a number of other properties and processes.

The physical processes influenced by soil structure are infiltration, water redistribution and storage, drainage, soil erosion by wind and water, movement of water, exchange of gasses with the atmosphere and flow of heat. Chemical processes include those involved in the C & N cycles within the soil, and oxidation, & reduction. Biological processes include seed germination and seedling emergence, root growth and the function & the activity of soil flora and fauna. (Smith et al., 1990:167).

In general, therefore, biological degradation further affects a physical as well as chemical degradation.

CHEMICAL DEGRADATION

Chemical degradation refers to the deterioration of chemical properties of a soil (Table 1). The chemical deterioration of a soil is related to erosion and deposition. The nutrient retention capacity of a soil (CEC) is higher in cultivated land. This is attributed to the high percentage of clay and the high content of montomorillionite clay, which is partly related to the depositional effect. On the other hand, CEC at the upper slope of forest cover is low, mainly due to the loss of soil colloids.

The base saturation on the soil of forestland is higher. This is ascribed to the replacement of the lost minerals by the high amount (content) of weatherable minerals of the soils of the forest areas. While the low percentagebase saturation in cultivated land is due to loss of nutrients by continuous cultivation, the replacement of nutrients in the soil is also low.

Besides fertility depletion, nutrient imbalance is one of the components of chemical degradation (Lal and Stewart, 1990). The imbalances are in general common features particularly to forestland and grassland. This is indicated by the value of EPP and Ca:Mg ratio, which are in general below 2% and 3% respectively.

Table 1 Mean Values of the Properties of Phaeozems under Different Land Use/Land Cover

	Sand	Silt	Clay	Silt: Clay	pH	Org. carbon	Org. Matter	Total N	C/N	Avail.P	CEC /soil	CEC/ Clay	Na	K	Ca	Mg	Bs	EPP	Ca/ Mg
Cultivated land																			
Ave. Top soil	19	34	47	0.72	6.7	1.42	2.44	0.16	8.5	53.5	48.8	92.4	0.6	2.11	26.7	9.45	79	4.37	4.1
Ave. Sub soil	24.3	28	47.7	0.6	6.87	1.15	1.99	0.14	8.3	26.97	53.8	91.2	0.73	0.79	31.1	12.88	84	1.36	2.8
Mean solum	23	29.5	47.5	0.63	6.8	1.21	2.10	0.14	8.37	33.6	52.6	91.5	0.69	1.13	30.0	11.97	82.7	2.22	3.2
Grass land																			
Ave. Top soil	41.5	37.5	21	1.78	6.6	1.41	2.42	0.16	9	11.91	50.5	218.5	0.51	0.42	30.40	16.7	96	0.85	1.9
Ave. Sub soil	35.8	31.2	39.7	1.01	6.9	0.89	1.69	0.11	9.4	3.8	50.8	154.4	0.43	0.38	30.40	14.6	90	0.75	1.9
Mean solum	37.4	33	29.6	1.23	6.8	1.10	1.9	0.12	9.3	6.1	50.7	172.7	0.45	0.39	30.40	15.2	91.7	0.78	1.9
Forest land																			
Ave. Top soil	35	38	27	1.41	6.48	2.334	4.6	0.180	13	5.18	45	137	0.24	0.73	38.9	12.58	117	1.62	3.1
Ave. Sub soil	35	38	27	1.41	6.69	1.357	2.3	0.17	8.0	7.06	49	164	0.24	0.30	40.9	15.33	116	0.61	2.7
Mean solum	35	38	27	1.41	6.58	1.845	3.2	0.175	10.5	6.12	47	150.5	0.24	0.515	39.9	13.96	116.5	1.12	2.88

CONCLUSIONS

In 1965, the dominant land use/land cover was grassland, covering about 45.7% of the total area followed by cultivated land (21.39%). The proportions of the others, that is, the woodland, forestland, bush land and shrub land were respectively 15.08, 8.6, 7.39, and 1.27 %. In 1996, the grassland has declined by 12% whereas the cultivation land has increased by 58%. A major decline has also been recorded in woodland and bush land. On the other hand, forest and shrub land has increased by 3% and 70% respectively in 1996 as compared to 1965.

The extent and types of degradation of soils are dependent on land uses and landscapes. The main types of land uses on the shallow soils (Leptosols) mantling the steeper slopes are forest and woodland. The landscape has suffered from serious erosion that has left its marked effects on soils while, on the gentler slopes where soils are deep and Vertisols and Phaeozems are dominant, crop cultivation is practiced; and the soils are mainly affected by biological degradation.

As the study indicates various forms of soil degradation in the area is attributed to the land use / land cover changes. There is decline in organic matter and soil nutrients on cultivated land in comparison with forestland and grassland. This is attributed to the improper land management of the area, which is manifested in the severity of degradation and high intensity of cultivation. The root cause of over-cultivation is the high population pressure. As the population increases land is fragmented, frequencies of fallowing is reduced, and marginal lands are cultivated

Thus, in order to raise the productivity of soils, understanding the degradation type and extent is very crucial. Measures to improve and maintain soils should also be in accordance with degradation types and magnitude.

The farmers themselves have attempted to use different practices to maintain soil erosion (through terrace, ploughing along contours and building trenches) and to improve soil fertility through crop rotation, manuring and compost. However, these indigenous soil conservation practices are with limitations and thus thorough investigation is required.

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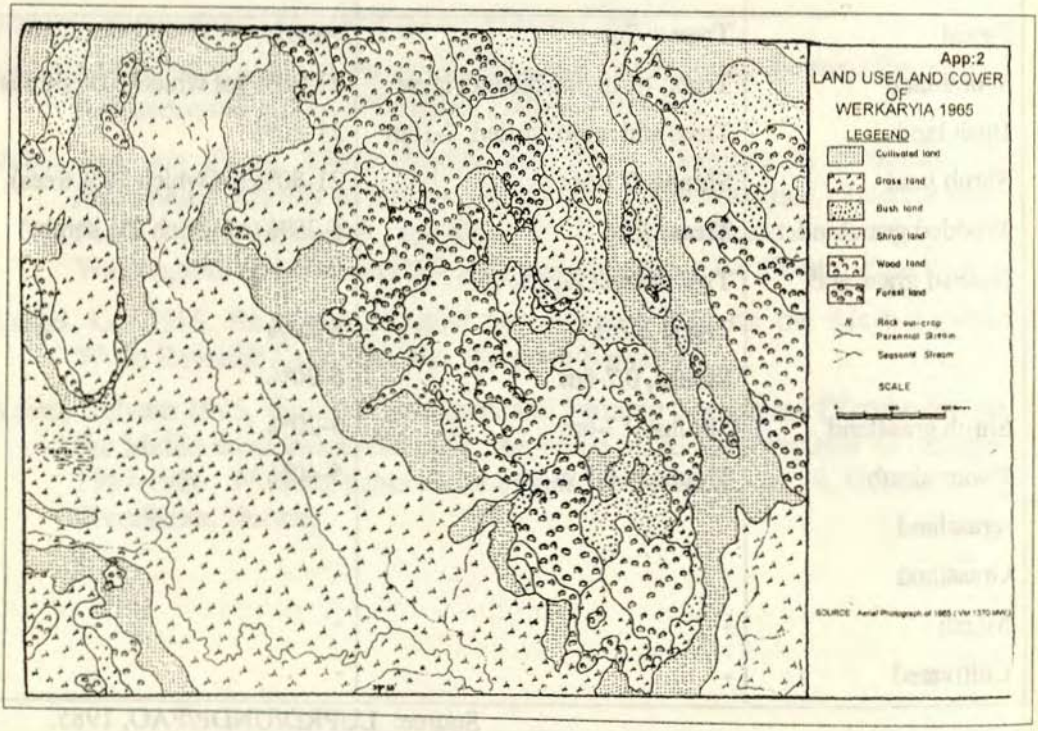
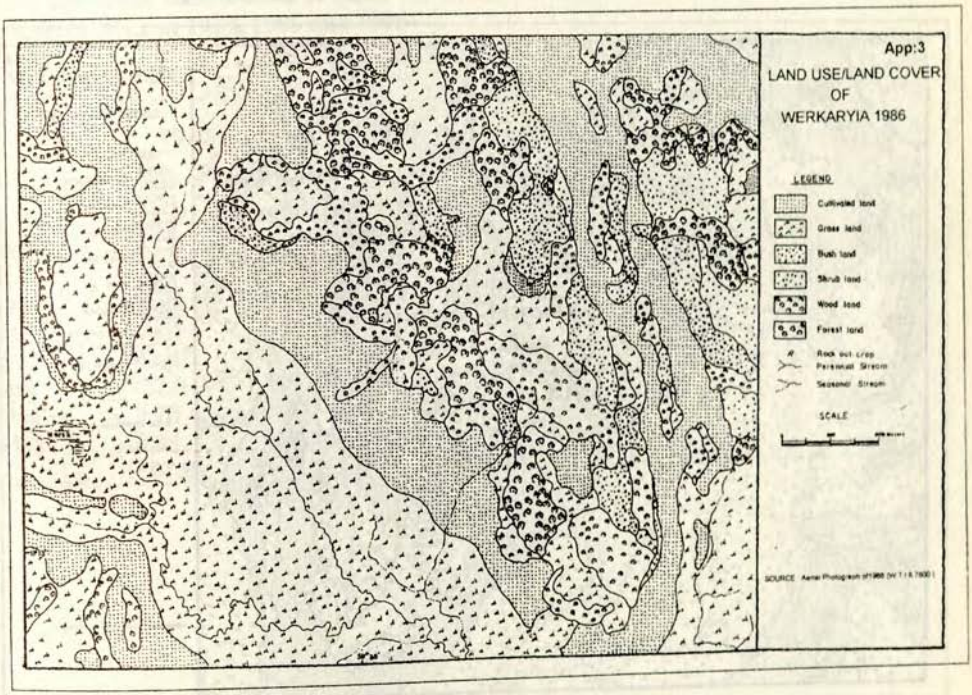
Appendix 1

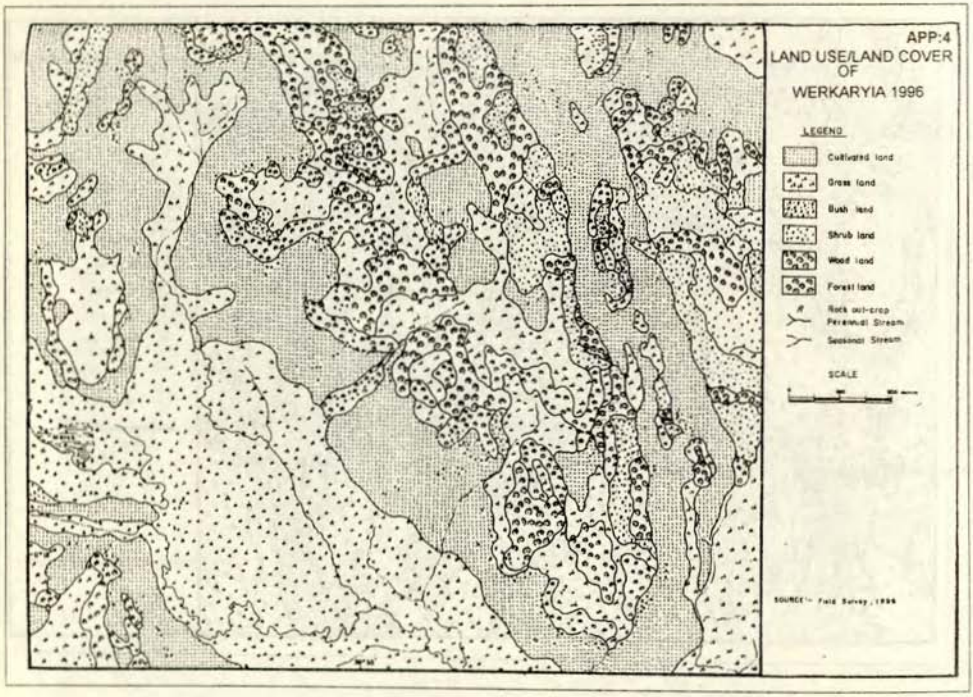
Physiognomic Vegetation Classification

Name	**Height of Woody Species**	**Coverage by Woody Species**
Forest	Trees > 7m	>80%
Wood land	Trees, > 7m one distinct layer	21-80% (of which 10% shrubs)
Bush land	Trees and multi storied, 2-10m -	21-80%
Shrub land	Shrubs, 0.7-6m	21-80% (of which 10% trees)
Wooded grassland	Trees, >7m	5-20% (of which 2% shrubs)
Bushed grassland	Two distinct layers:	
	Trees, 2-7m,	5-20%
	Shrubs, 0.7-6m	5-20%
Shrub grassland	Shrubs, 0.7-6m	5-20%
Dwarf shrub grassland	Shrubs, < 0.7 m	5-40%
Grassland	-	-
Marsh	-	-
Cultivated	-	-

Source: LUPRD/UNDP/FAO, 1985.


App:2
LAND USE/LAND COVER
OF
WERKARYIA 1965
LEGEEND
Cultivated land
Grass land
Bush land
Shrub land
Wood land
Forest land
Rock out-crop
Perennial Stream
Seasonal Stream
SCALE


App:3
LAND USE/LAND COVER
OF
WERKARYIA 1986
LEGEND
Cultivated land
Grass land
Bush land
Shrub land
Wood land
Forest land
Rock out crop
Perennial Stream
Seasonal Stream
SCALE


APP:4
LAND USE/LAND COVER
OF
WERKARYIA 1996
LEGEND
Cultivated land
Grass land
Bush land
Shrub land
Wood land
Forest land
Rock out-crop
Perennial Stream
Seasonal Stream
SCALE

Appendix 5: Patterns of Distribution of Land Use and Land Cover of Werkariya Area in 1965, 1986 and 1996

Land use/Land cover	1965		1986		1996		Change between 1965-96	
	ha	%	ha	%	ha	%	ha	%
Cultivated land	256.27	21.39	382.7	31.94	404.79	33.79	148.52	8
Grass land	547.8	45.73	471.7	39.38	483.2	40.34	-64.3	-12
Shrub land	15.25	1.27	30.52	2.55	25.92	2.16	10.67	70
Bush land	88.55	7.39	71.7	5.99	60.22	5.03	-28.33	-32
Wood land	180.67	15.08	130.34	10.88	110.98	9.26	-69.69	-39
Forest land	103.3	8.6	104.89	8.76	106.77	8.9	30.47	3
Marsh area	3.23	0.27	3.23	0.27	3.23	0.27	0	0
Rock outcrop	2.84	0.24	2.84	0.24	2.84	0.24	0	0
Total	1197.9	100	1197.9	100	1197.9	100		