THE EFFECTS OF LENGTH OF FALLOW AND CULTIVATION PERIODS ON THE FERTILITY AND PRODUCTIVITY OF LIXISOLS, IN DIZI CATCHMENT, ILLUBABOR REGION

A Thesis Presented to the School of Graduate Studies
Addis Ababa University

In Partial Fulfillment of the
Requirement for the Degree of
Masters in Geography

by

Getachew Gurmu
December, 1991

ADDIS ABABA UNIVERSITY

School of Graduate Studies

The Effects of Length of Fallow & Cultivation Periods on the Fertility and Productivity of Lixisols in the Dizi Catchment, Illubabor Region

by

Getachew Gurmu

College of Social Sciences

Approval by Board of Examiners

Belay Tegene
Advisor

KARL HERWEG
Examiner

Fikru Abebe
Examiner

Daniel Gamachu
Examiner

ACKNOWLEDGEMENTS

This piece of work got valuable help and support from several individuals. I am most indebted to Dr. Karl Herweg and Dr. Belay Tegene, both my thesis advisors, for their constructive criticism and comments on the draft. Particularly, Dr. Karl Herweg inspired my thinking on the topic and generously helped me in identifying the problem of the study. All along the work he was indeed with me and therefore my special thanks.

My sincere thanks also extend to Mr. Jürgen Hagman who gave me useful training in the field and laboratory on soil profile description and soil testing procedures. I express my gratitude also to Dr. Martin Grunder, the former Manager of the SCRP, for his useful comments and suggestions. My sincere thanks also goes to SCRP who offered me substantial grant of fund in carrying-out the research.

I have also enjoyed varied and extensive assistance and support of my friend Thomas Tolcha from the very conception of the idea of the study right up to completion. So my grateful thanks goes to Thomas Tolcha. Shemeket Lemma, who is also my sincere friend, assisted me in organizing materials. His encouragement also pushed me to go ahead up to the completion of the study.

My grateful thanks also go to the following:

- The farmers in and around the study area who cooperated with me during my field stay.
- Ato Tesfaye Zerai, Ato Asrat Tilahun, Ato Getachew Bekele and Ato Hailesellassie Berhanu, all members of SCRP at Dizi Station.
- Wro. Martha Bekele, Executive Secretary of SCRP who typed the study proposal and the final thesis.
- Ato Solomon Abate, Ato Kefeni Kejela, Ato Yohannes G/Michael, Ato Berhe W/Aregay, Ato Zelalem Desta, Dr. Hans Krüger, Ato Derese G/Wold, Ato Zewdu Lisanu, Ato Berhanu Admassu, W/t Yodith Tekle and other staff of the SCRP in Addis Ababa, for their encouragement and varied assistance.
- Ato Negussie Tesfaye, Ato Abraham Desta, W/t Yesewzer Yohannes, Wro. Amakelech Fenta, Ato Kebrom Tekle and Haile Sellassie Getachew who gave me various assistance and shared my pains during the execution of the study.
- Ato Azene Zenebe and Ato Solomon W/Mariam (System Design and Data Processing Department, Addis Ababa University) for their cooperation during data analysis.
- Daniel Abebayehu for drawing most of the figures.

TABLE OF CONTENTS PAGE

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this study was: (1) to assess the effect of fallow periods on the fertility of soils, (2) to evaluate the compounded effects of fallow periods and cropping years on the fertility and productivity of soils. Experiments were conducted on fallow-sites and on-farm plots (previously fallowed fields) to attain the above objectives. Data on soil and crop characteristics were collected using field and laboratory procedures. The collected data were analyzed using descriptive statistics and statistical methods such as correlation, analysis of variance and regression.

The results of the experiments on-fallow sites and on-farm plots indicate improvements in some of the physical and chemical properties of the soils with increase in fallow periods/years. The rates of regeneration were more pronounced in the earlier fallow periods and decline in time. However, the rates of restoration of organic matter and some other evaluated nutrients on the on-farm plots were higher than those on-fallow sites. For example, organic matter, total nitrogen, calcium rates of restoration in the on-farm plots were higher than the on-fallow sites by 8.5 percent, 4.3 percent, 1.6 me/100g respectively.

The findings in the on-farm plots, reveal the combined effects of fallow periods and cropping years on the fertility and productivity of the soils. For example, the amount of increase in organic matter was predicted at 16 percent when the fallow period increased from the first to the second year, whereas it increased by only 0.5 percent between 19 and 20 years of fallow. On the contrary, organic matter decreased by 12 percent between the first and second years of cropping and the rate of its degradation declined to 2.5 percent between 10 and 11 years.

The increase in maize yield on the average was estimated to be 28 percent with every doubling in fallow period (e.g. 1, 2, 4, 8, 16 ... years). On annual basis this increase was declining in time. For instance, the estimated maize yield increase was as high as 28 percent between the first and second year of fallow, but this increase dropped to 4.8 percent between 10 and 11 years of fallow. On the other hand, maize yield decreased with cultivation years. For instance, the decline in maize yield varied between 20 percent between the first and second year of cropping and 3.7 percent when the cropping year was 10 to 11 years.

From the above, it is realized that the recurrence of cropping-fallow cycles (particularly if each cycle lasts short duration) result in soils with low fertility and productivity status. This emphasizes the very high risk of soil degradation with increasing population density and attendant intensity of cultivation. The thesis at hand suggests some possible measures which must be taken to ameliorate this problems.

1. INTRODUCTION

1.1 A Brief Outline of Soil Degradation in Ethiopia

Agriculture plays the most important economic role in Ethiopia. It employs 80 percent of the total population, Contributes 45 percent of the Gross Domestic Product (GDP), and 85 percent of foreign earning comes from the export of agriculture products (World Bank, 1987). Thus any development of the economy depends to a large extent on the development of the agricultural sector. Yet, one of the outstanding features of the Ethiopian agricultural sector is the low productivity. For instance, the average grain yield of Ethiopia was 13 quintals per hectare per year (Adugna, 1984) and those of Mouritius and France were 38 and 60 quintals per hectare per year respectively (FAO, 1988). Thus even by African standard, the agricultural productivity in Ethiopia is very low. This is partly because of soil degradation which itself results from various interacting factors such as topography (slope steepness, slope length), climate, soil type, landuse and socio-economic conditions (Constable, 1984 and Aggrey-Mensha, 1984).

Soil degradation is more pronounced on the Ethiopian highlands (>1500 m a.s.l.). The available evidence suggests that out of the estimated 60 million hectares of agriculturally productive land, 27 million hectares are significantly eroded 14 million hectares are sriously eroded and 2 million hectares are now at a point of no return

(Constable, 1984, Aregay Waktola, 1988). This would hardly be surprising in view of the fact that the highlands of Ethiopia that constitute only 43 percent of the total area host 88 percent of the population and about two third of the livestock; the highlands also contribute 60 percent of the Gross National Product (Constable, 1984). On the top of such a high population pressure on the resource base, lack of appropriate soil conservation measures and improved agricultural practises have been added factors of accelerated land degradation and decline in soil productivity.

The northern highlands of Ethiopia were the first to experience serious soil degradation and accompanied problems because of the long history of farming system and settlement. The persistence of soil erosion and degradation and their cumulative effects in these areas were among the major cause for the fall of the civilizations flourished in these same areas. For example, soil degradation accounted for the decline and downfall of Axumite Civilization around 100 A.D. (Butzer, 1981), of

Lalibela in the 14th and that of Gonder in the 17th century, (Hurni, 1987). Though, the problem of soil degradation may not be as severe as that in the northern highlands of Ethiopia, it has been spreading to the rest of the country at an accelerated rates as one can learn from the extent of area affected.

1.2 The Problem of the Study

In recent years, soil degradation has been fully recognized as one of the major causes of degradation of the natural environment, recurrence of drought, famine and malnutrition in Ethiopia (Wright, 1984). It seems highly probable that the 1973/1974 and 1984/1985 drought and famine have enhanced this recognition of soil degradation problem and initiation of efforts to combat it by the Ethiopian government. Among the efforts so far made, the following two can be mentioned as the most significant:

1. Implementation of various conservation measures to prevent any further degradation.
2. Rehabilitation of the seriously degraded areas.

The latter involved transfer of people from one part of the country to the other, the sending areas being the highly degraded northern highlands and some central parts of the country, while the receiving areas were the western and south western parts of Ethiopia supposed to posses high agricultural potential (RRC, 1985). This obviously means an increase of population pressure in the receiving areas than that warranted by the natural population growth. For example, during the 1984/86 resettlement programme the Sore "Awraja" of Illubabor region (where the study area is located) alone received a total of 31331 persons; this increased the size of the total population from 217327 to 248658 persons i.e. an increase of population size and density each by 12.6 percent (Kloos and Aynalem, 1988).

Among the reasons for the high agricultural potential of the south western Ethiopian highlands are well distributed and high annual rainfall, large volume of river water, considerable forest reserve, long growing seasons, deep soils and large cultivable land per household (Daniel, 1988). However the potentiality of this region for arable crop production is not as high as these resources suggest. This is mainly because of the inherent low level of soil fertility (see Section 2.4.1). Moreover rainfall erosivity and soil erodibility are higher than the northern highlands of Ethiopia (Hurni, 1985). This obviously means in the case of poor vegetation cover, which often happens when the land is used frequently for crop cultivation, the soils of the south western highlands are susceptible to accelerated erosion and degradation. These problems might have been the main cause for the development of the traditional shifting cultivation system, a system that has passed on from generation to generation and apparently suited to the region in view of natural and socio-economic constraints of the region.

In parts of the south western highlands, the present farming practices are modified form of the shifting cultivation system of the remote past (Westphal, 1973 and Wood, 1977). For example, in addition to their other economic activities (e.g. hunting) the Majang (Mesengo) people still practice a farming system which has many similar aspects to that of typical shifting cultivation. In areas inhabited by the Majang people the fallow - cropping ratio, according to Stauder (1971), varies between 3:1 and 15:1. These people had inhabited most of the region now referred to as the Illubabor highlands before they were pushed away to their present domain (southern most fringe of the south western highlands of Ethiopia) by the immigrant people such as Shakatcho (Mochas) and later on the Oromos (Yasin, 1990). From this, it may be deduced that the ancestors of the Majang people were once a typical shifting cultivators. Since the displacement of the Majang people, the present Illubabor highlands have been experiencing immigration of various tribes (Yasin, 1990). Understandably, the increased population pressure has been accountable for the transformation of shifting cultivation into its variants (see Section 1.5.2 and 2.7.2.2).

In recent years more intensive cultivation (reduced follow period), a system now becoming important, following the natural population growth and spontaneous resettlement has caused serious soil erosion and degradation (Wood, 1982). Wood (1982) writes spontaneous resettlement in the recent past has caused ecological damage through exploitative landuse practices and cultivation of unsuitable/marginal areas.

On the other hand, the south western highlands as a whole are likely to have a high potential for the development of perennial cash crops such as coffee and tea. This is because of conducive climatic condition, and also because perennial crops are deep rooted and hence are able to siphon nutrients from the sub-soils. Moreover, once tree crops are well established soil erosion and degradation will be tolerable. Nevertheless, considering the present subsistence production level of the local farmers and lack of surplus food crops from other parts of the country, it seems unlikely that the farmers will accept total involvement in the perennial cash crop production (Daniel, 1988). Therefore, with increasing population pressure and land use intensity, soil erosion and land degradation are imminent.

In view of these circumstances, it appears highly useful to evaluate the overall potential of the south western highlands of Ethiopia in general and the study area in particular for food crop production. To attain this goal, studies aimed at determining the extent and rate of damage of soils through intensity of cultivation on one hand and the rate of soil fertility regeneration through fallowing on the other are understandably helpful. To the knowledge of the writer, no critical study has so far been carried out to determine the effect of intensity of cultivation (length of cultivation) on the fertility and productivity of soils in the south western highlands of Ethiopia. Secondly, even if it is known that fallowing restores soil fertility, no adequate study focussed at determining the rate and trend of nutrient regeneration by fallowing and its effects on physical and chemical properties of the soils of the study area have been done.

1.3 The Objectives

In view of the problem outlined in the previous section, the main objectives of the study were:

a) to assess, through field experiment, the effect of length of fallow periods on the fertility of Haplic and Albic Lixisol. The intent in this case is to evaluate the magnitude and rate of soil fertility restoration by fallowing,

b) to evaluate also through field experiment, the effect of length of fallow periods (years) and intensity of cultivation (cropping years) on the fertility and productivity of Haplic and Albic Lixisol.

1.4 Significance of the Study

From the discussion so far presented, the following points become clear:

1. In the south western highlands of Ethiopia in general, and the study area in particular, traditional fallowing system of farming has been practiced for a long time.

2. Nevertheless, this form of traditional land use pattern which was effective in maintaining soil fertility and productivity on a sustainable levels has been threatened and tends to be replaced by permanent arable crop production. This change in land use pattern has been induced mainly by the decreasing man-land ratio (high population density). This condition, in turn, has induced accelerated soil erosion and degradation and thereby diminishing soil fertility and productivity.

This study attempts to show the true/actual agricultural potential and environmental limitations with respect to arable crop production. Choosing policies for agricultural development requires the use of information about the existing farming systems. The realization of drawbacks and merits of the traditional farming situation is pre-requisite for the choice of appropriate agricultural developmental strategies. The study in hand would offer a useful ground for development planners and policy makers in proposing large scale developmental projects (e.g. resettlement scheme). The results of this study may also stimulate further studies on this problem and to seek appropriate conservation measures that are not only effective, but also socially and economically acceptable.

1.5 Literature Review

1.5.1 Environmental Constraints and Nutrient Recycling in the Humid Tropics

Humid climates have over seven months of wet period (usually over 1400 mm per annum) (Ruthenberg, 1980). According to Greenland (1977), humid tropics lie between 10°N and 10°S latitudes; and rainfall amount exceeds evaporation for at least seven and a half month. The former exceeds 1000 mm per year while the latter varies between 100-150 mm a year. In view of this definition the study area can be categorized into humid tropics (see Section 2.2). The humid tropical areas have also warm temperatures (>20°c) throughout the year. Thus the humid tropical areas are wet and warm for most part of the year.

Climate has an important influence on the characteristics of soils, the type of natural vegetation, organic matter content, the crop grown as well as the type of farming that can be practised (Webster, 1980). Among climatic elements, temperature and rainfall are important. The warm and wet climatic conditions of the humid tropics are favorable for the growth of luxuriant forests, even if the soils are inherently poor in their chemical make up. Hunter (1978) wrote, "vegetation growth of these areas had deceived several European explorers especially during the colonial periods to Africa." This implies that humid tropical environments have been considered to be naturally endowed with high soil fertility as it is reflected by their vegetation cover. But the reverse is true.

Soils of the humid tropics apart from volcanic and alluvial areas contain less humus and lower bases than the middle latitude soils (Odum, 1971 and Buring, 1970). The low level of soil fertility status of these areas is mainly attributed to the geological nature of parent materials, climatic conditions and nature of soil forming processes (Ruthenberg 1980). In most of the humid areas, soils are mainly derived from old igneous and metamorphic rocks such as granite and gneisses. These soils are deeply weathered - that is, the break down of rocks and the formation of regolith materials are more rapid than their temperate counterpart (Bridge, 1979). This deep weathering process limits the replenishment of mineral nutrients from the bedrocks lying below the thick soil profiles (Hunter, 1978). Soil of the humid tropics are also prone to erosion and leaching. Leaching of bases is quite intensive due to sudden and heavy rainfall characteristics. Hence, significant amount of plant nutrients can be carried below the root zone of annual crops (Webster, 1980). Although data on the extent of leaching is rare, Sanchez (1976) reported that a loss of 0.6 kg of nitrate, 3 kg of magnesium and 5 kg of sulfate per year from every hectare of the Amazon basin. On the other hand evidence from Nigeria indicates that soil erosion is almost negligible in the forest zone (Lal, 1977). But, results of erosion productivity test in Nigeria showed that yield declined by about 50 percent upon the removal of the first few inches of top soil (Lal, 1975 quoted in Sanchez 1976). The above environmental limitations reveal that humid tropical areas have a fragile ecosystem and are susceptible to degradation following the removal of forests or bush land for the cultivation of arable crops.

On the other hand, areas in humid tropics do have specific mechanisms of ecological adjustment and that is the recycling of nutrients via soil plant system. The growth of luxuriant forest vegetation on the relatively poor soils is largely maintained because in the forest there is a nicely balanced closed cycle of nutrients between vegetation and soil (Webester, 1980). Likewise, farming systems based on perennial crop production are ecologically more compatible in the rain forest than arable crop production (Lal, 1985). Trees and bushes present less difficulties since once established they themselves protect the soil from battering impacts of rainfall and enhence circulation of nutrients in the same way as do forests (Webster, 1980).

In humid tropics, in general a large proportion of available nutrients are in biomass and are recycled within plant-soil system (Odum, 1971, Sanchez, 1976, Hunter, 1978 and Upton, 1987). Forest vegetation is not only a medium of nutrient recycling but also stores most of the available nutrients in itself (Young 1976 and Hunter, 1978). This is to say that the dense forest trees of the humid tropics are capable to siphon nutrients from the subsoils and store them in their biomass. In turn, surface soils are constantly supplied with adequate nutrients through leaves and litter fall. Nevertheless, when forests are cleared and the land is put under cultivation of arable crops, this cycle will be disrupted. In other words, the process of nutrient recycling from plants to soils and back to plants is interrupted; consequently, rapid decline in soil fertility and productivity results. Soil erosion is also accelerated because of the reduced ground cover. At this point, it is worth mentioning that the extent of interruption of the naturally stabilized ecosystem speeded up even more with reduction of fallow periods and increasing cultivation years.

1.5.2 Landuse Dynamism: From Shifting Cultivation Towards Permanent Cultivation

It is evident that in the humid tropics cultivation of arable crops involves removal of either forest or bush fallow. This change in landuse not only reduces or interrupts the ability of land to recycle nutrients, but also accelerates soil erosion and degradation which in turn results in rapid decline of soil productivity. Consequently, after a few years of repeated cropping, the field will be lain fallow to allow natural recuperation of soil fertility. New areas are then cleared to replace those abandoned. The field lain fallow can also be used after long fallow periods. This system of farming is what generally referred to as shifting cultivation. This system is basically a system of nutrient accumulation, conservation and recycling (Brady 1985). In the humid tropical parts of Africa, there is a historical evidence that some five thousand years ago farming operations were carried by small scale farmers practicing shifting cultivation, and these people maintained the soils without pronounced soil degradation till the middle of this century (Agboola, 1989). The ever increasing demand for food and cash crops have induced the transition from extensive type of shifting cultivation to semi permanent and even to permanent cultivation practices (Lal, 1977). Indeed, as population increases and land becomes scarce, shifting cultivation tends to be modified or replaced by other more intensive methods of cultivation (Olubajo, 1984).

Several authors argue that up until now, no alternative to shifting cultivation practice has proven environmentally, biologically and economically more rewarding in the humid tropics (Young, 1976, Ruthenberg, 1980, Webster, 1980, Brady, 1985 and Upton, 1987). Stocking (1984) also noted that shifting cultivation appears primitive or archaic, but on closer investigation of environmental and socio-economic conditions, it is a system of farming better suited to humid tropics. However, the problem of soil erosion and degradation will arise and result in the decline of soil fertility, when new farming systems are introduced or new people moved into these areas or when an old system breaks down by over population (Sanchez, 1976). In this respect, Okigbo (1984) referring to west Africa suggested that when a fallow to cropping ratio is more than 10:1, shifting cultivation is ecologically stable, but when population pressure increases, food production has to be intensified at the expense of shortening fallow periods. This means, as Allan (1965) and Lagemann (1967) pointed out, total production is increased through increased proportion of cultivated area or reduced proportion of fallow land, but the result is a continuous and serious soil and land degradation and reduced yield per unit area. Several writers reported that the replacement of shifting cultivation by its variants and the subsequent impacts in the humid tropics. For instance, the vast highland areas of Latin America, particularly in Equador, Colombia and Andes which are characterized by the rugged land forms, high rainfall erosivity and soil erodibility, have been destroyed or seriously degraded (Lal, 1977). Morgan (1955) in eastern Nigeria also observed the transformation of long fallow cropping practice into semi permanent and ultimately to permanent cropping landuse pattern and the subsequent negative impacts.

In humid part of Madagascar, the population density was reported to be 83 persons per square km (Oxby, 1985). This figure is about twice the threshold density (40 persons/km^2) under shifting cultivation noted by Kpukole (1984). Through realization of the landuse dynamism attributed to increase of population and density Oxby (1985) preferred to call it as "accelerated shifting cultivation."

Baum (1968) in Tanzania attempted to gauge the intensity of cultivation (degree of landuse dynamism) through quantitative indices that were based on the relationships between fallow periods and cultivation years. He collected information of 26 cultivated fields that is their respective fallow periods and cropping years. Employing these data in a mathematical equation*, the calculated R value varied between 0.25 (3F:1C) and 0.86 (1F:6C).

Somewhat similar but more elaborate measure of landuse intensity was also developed by Allan (1965). See the equation below:

$$L = \frac{C+F}{C}$$

where L is the landuse factor
F is the number of fallow periods (in year)
C is the number of cultivation years

On the basis of this formula, Allan (1965) suggested the following landuse catagories.

i) permanent cultivation when L value is < 2
ii) semi-permanent cultivation when L value is b/n 2.5-3
iii) recurrently cultivated land when L value is b/n 3-10
  a) short term " " " " " " " 3-5
  b) medium term " " " " " " " 5-7
  c) long term " " " " " " " 7-10
iv) shifting cultivation " " " " " " > 10

The above outlines implicitly and explicitly indicate the transformation of landuse pattern from shifting cultivation

---

$$* \; R = \frac{C}{C+F}$$

where R = landuse intensity index
C = cultivation years
F = fallow period (in years)

NB: The higher the R value, the higher the intensity of cultivation to semi-permanent and then to permanent farming practices with increasing population size and density. These changes in landuse and their negative consequences are aggravated by the introduction of cash crops.

On the other hand, permanent arable production has been attempted in humid areas. In this regard various studies were conducted and alternative options were made. For example, Young (1976) noted that continuous annual crop production at a sustainable level is possible by applying manure between 5 and 10 tones per hectare, but it is not often possible to obtain such quantity of manure. This is mainly due to limited livestock farming which itself is affected by the wide spread of tropical livestock diseases (e.g. Trypanosomiasis) and its carrier tse-tse fly. The use of compost, green manure, mulches and a combination of these and others are viable alternative measures to the problem in question; but high labour imputs and low outputs limit the intensive use of these measures (Webster, 1980).

The other alternative measures which can halt the problem of rapid lowering in soil productivity include agroforestry, planted fallow and application of commerical fertilizers.

Studies of Hurni (1983) in Thailand and of Dese (1984, quoted in Hagman, 1991) in Rwanda indicated that agroforestry is one of the alternative measures to replace traditional fallow system of farming. Likewise, planting quick growing leguminous perennials on exhausted crop fields enhance the rate of nutrient restoration than natural fallows and hence are effective to reduce fallow periods (Young, 1976). The possible measures indicated just above are certainly worth of consideration within the existing natural and socio-economic conditions. The application of commercial fertilizer may also to some extent mitigate the decline in soil productivity, but inturn raise the cost of production. In general, these and other alternative measures to fallowing have been identified through research works. However, hitherto they have not been widely implemented in the humid tropics, because of mainly the socio-economic limitations prevailing in these areas.

1.6 Method of Data Collection and Analysis

To achieve the objectives stated in Section 1.3, relevant method of data collection, experimentation and analysis are given below.

1.6.1 Site Selection

In order to assess the effect of fallow periods and cultivation years (intensity of cultivation) on the fertility and productivity of the soils, site selection was made on the basis of soil units, slope gradient, management practices, length of fallow period and cultivation years.

Soil Units

Th dominant soil units in the study area includes Haplic Lixisols, Albic Lixisols, Fluvic Haplic Lixisols and Gleyic-Umbric Lixisols. Haplic and Albic Lixisols are the basis of this study, because they cover the largest part of the catchment and also are more marginal soils than others. An other specific feature of these soils is the presence of stone line which limits the effective rooting depth particularly of arable crops (we will revert to this later on in Section 2.4.1). The preliminary soil map of the study area does not delineate Haplic or Albic Lixisols from Fluvic Haplic Lixisols (see Fig. 6). Several maize fields and fallow lands were augured to check the presence of the gravelly layer (stone line) upto 60 centimeters depth in the soil profiles; the procedure was recommended by J. Hagmann who had surveyed the soils of the study area in 1988. While carrying out this task, the preliminary soil map and the results of sixteen profiles described by Hagman were also used.

Slope of the Land

Slope steepness of each sample plot/site was measured using clinometer and the result shows that Haplic and Albic Lixisols mainly occur on-slopes ranging between 23 to 30 percent. Thus, all on-farm plots and fallow sites were selected and set within the range of this slope class (see Fig. 1).

Management Practices

Another criterion taken into consideration when selecting and setting the on-farm plots/sites was management practice. When a fallow land is brought into cultivation, the initial land preparation involves slash and burn, followed by minimum tillage when farmers sow maize. Land preparations after the first year of cultivation of a crop field include burning maize straw and weeds in situ, and subsequently ploughed twice. Hacking, thinning (Bebeka) and Weeding are usually practiced after three weeks, six weeks and eight weeks respectively. There after weeding is frequently practiced throughout the growing period. In the experiment these and other traditional farming methods were kept similar. Also, to avoid the influence of manuring and house hold refuse, all test plots or sites for collection of soil samples were located far away from home steads and gardens.

Length of Fallow Periods and Cultivation Years

The collection of these data was on the basis of field observation of the writer and through informal discussion, particularly with the owner of maize fields/fallow land (see Table 1). Since these data form the basis of the investigations discussed in Section 1.3 and stated in the

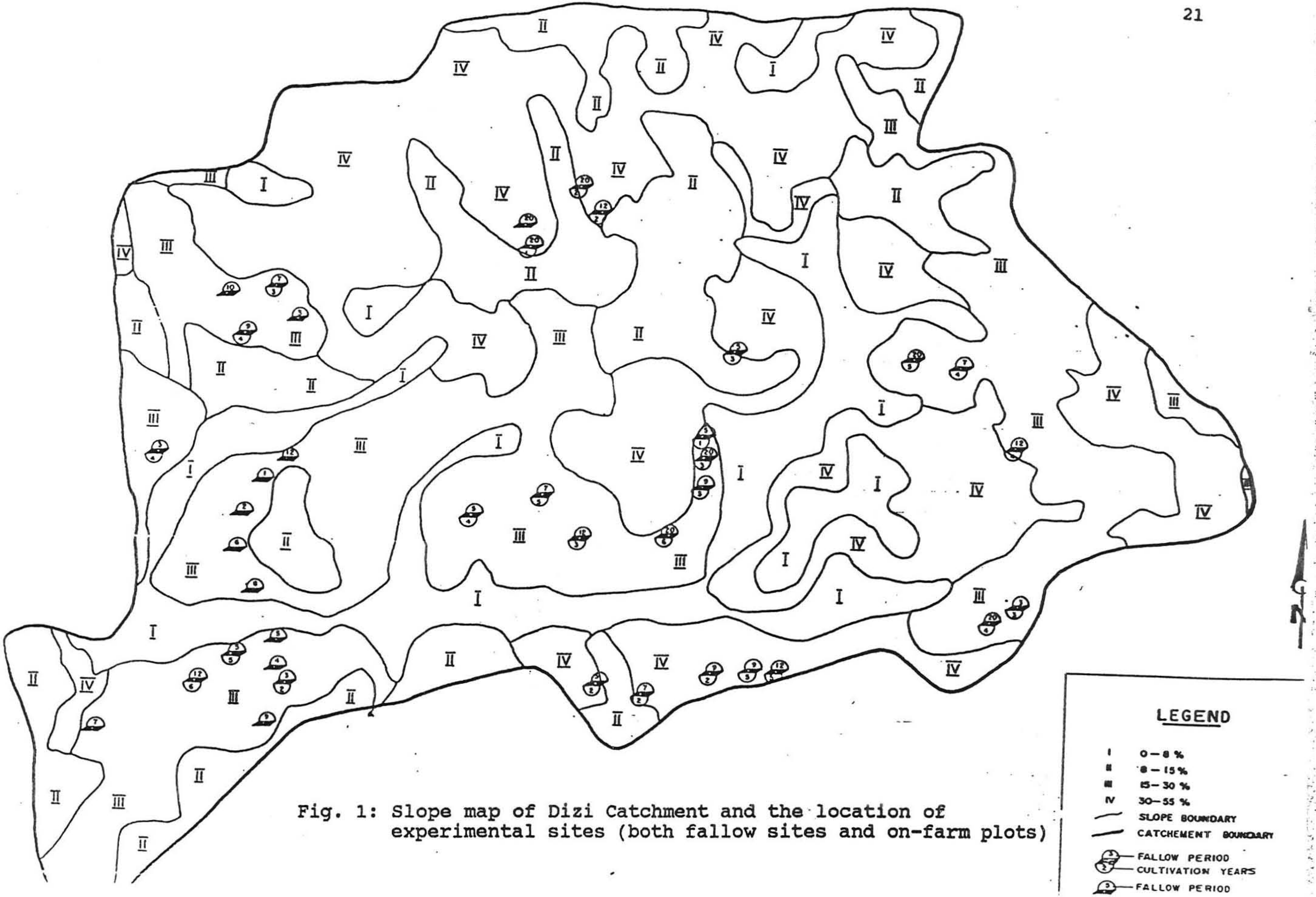


Fig. 1: Slope map of Dizi Catchment and the location of experimental sites (both fallow sites and on-farm plots)

objectives, an attempt was made to cross check and ensure the accuracy of the information collected. For example, from the vicinity of each selected site, at least three elderly farmers, who were expected to have a good memory of their local landuse history, were informally interviewed. A total of fifty nine sites were selected to carryout field experiments and collect relevant data.

1.6.2 The Setting of the On-Farm Plots

On the basis of the above criteria, in the selected fifty nine sites, twenty seven on-farm plots (each replicated three times) were set (see Fig. 1 and 2).

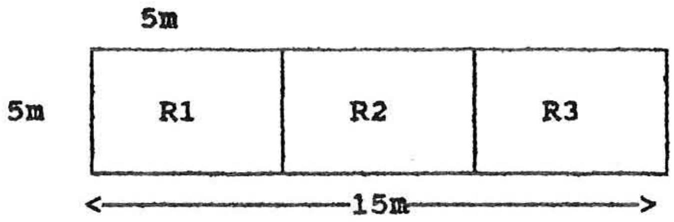


Fig. 2: The layout of the on-farm plots

R = Replicate

Similar plots were used for soil productivity studies in Gununo (Belay, 1990). Maize was selected for this study, because it is the most important food crop in the study area. To make the yield data comparable, the spacing between rows of maize plants was 75cm, while the spacing between maize plants was 30cm.

TABLE 1
Matrix Showing Fallow Periods and Cultivation Years and the Corresponding Landuse Intensity Indexes Using Allan's (1965) Landuse Factor with the Available Data

		CULTIVATION YEARS														
		1 year		2 years		3 years		4 years		5 years		6 years		7 years		
		On-farm Plot	L-* Value	On-farm Plot	L-Value	On-farm Plot	L-Value	On-farm Plot	L-Value	On-farm Plot	L-Value	On-farm Plot	L-Value	On-farm Plot	L-Value	Average L-Value
FALLOW PERIOD	3 years	-	4	P-26	2.5	P-17	2	P-16	1.75							2.7
	5 years	P-20	5	P-22	3.5	P-15	2.7	P-9	2.25	P*-1	2					3
	7 years	-	7	P-23	4.5	P-2	3.3	P-12	2.75	P-21	2.4					3.99
	9 years	-	10	P-19	5.5	P-10	4	P-14	3.25	P-7	2.8					5.11
	12 years	-	13	P-5	7	P-25	5	P-13	4	P-6	3.4	P-11	3			5.9
	>20 years	P-27	21	P-4	11	P-3	7.7	P-18	6	P-24	5	P-8	4.3			9.2
Average	9.3	-	10	-	5.7	-	4.1	-	3.3	-	3.12	-	3.7			4.9

* P - On-farm plot
* L - Value = Landuse intensity index
Source = Field work

TABLE 2
Fallow Period of the Selected Sites (in years)

F*-1	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-9	F-10	F-12	F-13	F>20

* F - Fallow period
Source = Field work

1.6.3 Measurement of Crop Growth (height), Yield and Biomass

From each on-farm plot, six maize plants (two maize plants from each replicate) were randomly selected and their height was measured every week throughout the growing period and then averaged.

From each on-farm plot (each replicated three times) an area of 1.5m x 1.8m ($2.7m^2$) was delineated. Then all maize plants were uprooted and dried in the sun for at least five days; afterwards, harvested grain yields and biomass were measured and registered.

1.6.4 Evaluation of the Physical Properties of the Soils

At each plot site and at each selected fallow land, a profile was described using the procedure outlined in the Guidelines for Soil Profile Description (FAO, 1977). Accordingly, structure was described through observation of grade, size and shape of peds. Soil texture was determined by the hydrometer method in the National Soil Service Laboratory. Infiltration rate and accumulated water intake were measured using double ring infiltrometer and bulk density was determined using core sample following the procedure given in Landon (1984).

1.6.5 Evaluation of the Chemical Properties of the Soils

In determining the status of soil fertility of various fallow periods and cultivation years, soil samples were collected in two ways. The first soil sample collection was made during soil profile description in December 1989. From the two top horizons (AP and BA) of each described profile about 500 grams of soil were collected. Next, composite soil samples of the surface soils were collected in October 1990.

From each on-farm plot*/site of fallow land**, soil samples were collected from fifteen points using a cylinderical auger (20 cms depth). Then the collected soil samples thoroughly mixed in a bucket and about 500 grams was sampled. Other than organic matter and nitrogen, all soil analyses were made at the field station using Hatch Company Portable Laboratory. The chemical properties tested and the methods employed are given in Table 3.

---

* The on-farm plots were scattered throughout the catchment. Thus, it was found difficult to harvest all maize plants of each on-farm plot. Because of this, from each replicate of all on-farm plots an area of $2.7m^2$, consisting about 21 maize plants was purposively considered to be a representative sample.

** As stated in section 1,3, the first objective of this study is to assess the effect of various length of fallow periods on the fertility regeneration of soils. To achieve this objective twelve sites of different length of fallow periods were selected (Table 2). The collection of the data was based only on the physical and chemical properties of the soil samples. The selection of the sites was the same as in Section 1.6.1 (the location of these site is given in Fig. 1). Most of the fallow sites (over 91%) were closer to established settlements as compared with the on-farm plots located/distributed in the fields under cultivation when the data were collected.

TABLE 3

Soil Chemical Properties Evaluated and Method of Analysis

Soil Properties and Expression of Values	Methods of Analysis
Organic matter (OM) %	Walkly and Black Method
Total Nitrogen %	Kjeldahel Method
Ammonium ($NH4^+$) ppm	Nessler Method
Phosphate ($PO4^-$) ppm	Ascorbic Acid Floride Method
Potassium (K^+) me/100g	Tetraphenylborate Method
Nitrate ($NO3^-$) ppm	Cadmium Reduction Method
Calcium (Ca^{++}) and Magnesium (Mg^{++}) me/100g	EDTA Titration Method
Cation exchange capacity (CEC)	Sum of exchangable cations:↓ Ca+Mg+K+2 (lime requirement)
pH	1:2.5 soil Slurry (pH in water)

1.6.6 Formal Interviews

As mentioned before, information on the length of fallow periods and cultivation years were collected through informal interviews and discussions with the respective owners of the selected sites/crop fields. These data were also compared with the responses given by the elderly local farmers. The aim of this survey is to collect more comprehensive information about the problem of the study area.

To this end, a two page questionnaire consisting closed and open questions was set (see Appendix III). In this survey, all household heads (130) found in the study area were formally interviewed.

1.6.7 Method of Data Analysis

All data collected using the procedures outlined above (Section 1.6.1 to 1.6.6) were organized and described using discriptive statistics such as tables, figures, mean and coefficient of variation.

Statistical methods were also used. On the basis of the scatter plots of data, Cobble Douglas (log linear) equation* was used to model most of the relationships between dependent variable on one hand and independent variable/variables (fallow periods and cropping years) on the other. Analysis of variance for regression was used to test wether the data employed in the model fitted significantly or not. Linear correlation analysis was used to evaluate the strength of relationships between variables and all along significance tests were made at 5 percent probability level.

---

* $y = bo\, x_1^{b1}\, x_2^{b2}$

where y = dependent variable (e.g. organic matter, maize yield)

bo = constant

x_1 and x_2 = independent variables (e.g. fallow periods and cropping years)

b_1 and b_2 = coefficients

2. THE STUDY AREA

2.1 Location

The study area constitutes part of "Sore Awraja" of Illubabor administrative region and cover an area of 6.67 square kilometer (667 ha). It is found about eleven kilometer north of Metu along the road to the town of Algie. It lies between 8°8′ and 8°9′ north latitude and 35°6′ and 35°8′ east longitude (see Fig. 3).

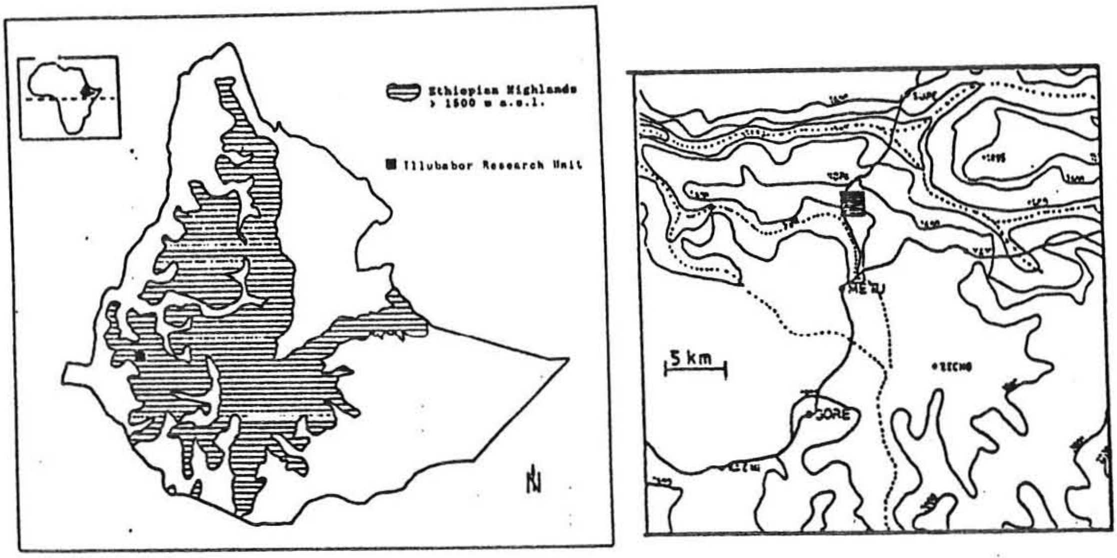


Fig. 3: Location Map of Dizi Catchment

2.2 Climate

Since data collection about the study area has been started recently (1988), climatic data recorded for a long period of time are not available. Therefore, temperature and rainfall data recorded by the Institute of agricultural Research, Metu sub-center (located about 8 kilometers from the study area) is included in this study, in addition to the two years data of Dizi Station.

2.2.1 Temperature

The annual mean, minimum and maximum temperatures are 20.7°c, 13°c and 28.5°c respectively (Table 4). As a whole, the rise and fall in temperatures are influenced by the angle of the sun and cloud cover. For example, the lowest monthly mean minimum (9.5°c) and mean (19.1°c) temperatures were registered in January ('Bonna'or dry season) which is often a period of the lowest angle of the sun. These temperature values are low because of the low angle of the sun and clear sky occurred in these periods. On the other hand, "Genna" (the main rainy season) is a period of high sun and thick cloud cover. This time, temperatures are moderate, inspite of the highest angle of the sun; because the thick cloud cover reduces insolation. The hottest period is just before the main rainy seasons. However, because of the combined effect of sun's angle and cloud cover, monthly mean temperature variations are not significant. Similar temperature distributions are observed in Table 5.

TABLE 4

Monthly mean, minimum, and maximum temperatures and monthly mean rainfall distributions, at Dizi Station (1989-1990)

Months	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
Mean min. T°C	9.5	11.2	13.1	13.6	14.6	14.5	14.7	14.5	14.6	12.8	11.2	11.2	13
Mean max T°C	28.9	30.5	30.6	31.2	29.9	28.1	28.1	25.8	27.1	27.6	24.7	29	28.5
Mean T°C	19.1	20.8	21.8	22.4	22.4	21.3	21.4	20.1	20.9	20.2	18	21.1	20.7
RF (mm)	6.45	28.45	83.45	53.5	142.95	205.5	259.6	433.6	210.1	107.45	10.2	58.65	1599.7

Source of Data: SCRP

2.2.2 Rainfall

The mean annual rainfall is 1886 mm (Table 5). Although, there was no month with rainfall below 20 mm, the annual and monthly rainfall variations are high (see Fig. 5 and Table 6). (Rainfall data of IAR, Metu sub-centre (1982-88) has been used in this study). During the observation period (1982-1988), the highest annual rainfall (2397.2 mm) was in the year 1985 while the lowest (1413.1 mm) was in 1982 (Table 6). Also, the highest monthly rainfall (314.9 mm) was in the month of July, while the lowest (20.7 mm) was in January. Monthly rainfall variations can be depicted by the proportion of rainfall amount received in each season. Accordingly, 'Genna' (June, July and August), 'Birra' (September, October and November), 'Bonna' (December, January and February) and 'Arfasa' (March, April and May) seasons received rainfall of 49 percent, 27 percent, 3.8 percent and 20.6 percent respectively. In connection with this, Table 5 shows that there is no month with rainfall below 20.6 mm and for about nine months of the year, mean monthly rainfall is between 63 mm and 314 mm. This indicates that in and around the study area long growing period prevails. In a nut shell, considering the mean annual rainfall of 1886 mm and the altitudinal range of 1500 to 1760m, the study area falls under broad wet weinadega agroclimatic zone given in Hurni (1986b).

TABLE 5

Monthly Mean, Minimum and Maximum Temperatures (1986-1988) and Monthly Mean Rainfall Distribution (1982-1988) at IAR, Metu Sub-Center

Months	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Average
Mean min. T°C	9.9	11.6	12.6	13.4	13.7	14.1	14.3	14.5	14.3	13.3	10.1	9.6	12.6
Mean max. T°C	31.4	10.6	31.6	31.5	28.6	26.1	25.5	26.1	26.5	27.4	29.3	29.4	27.7
Mean T°C	20.7	21.1	22.2	22.5	21.2	20.1	19.9	20.3	20.4	20.4	19.7	19.5	20.6
RF (mm)	20.7	20.9	11.6	81.7	184	295.5	314.9	313.8	291.7	154.2	63.9	29.2	1886

Source of Data: IAR, Metu Sub-Center (Illubabor)

TABLE 6

Annual rainfall (1982-1988) at IAR, Metu Sub-Center

Year	1982	1983	1984	1985	1986	1987	1988
Mean ann. RF (mm)	1431.1	1906.6	1685.9	2385.4	1919.3	1593.1	2291.1

Source of Data: IAR, Metu Sub-Center

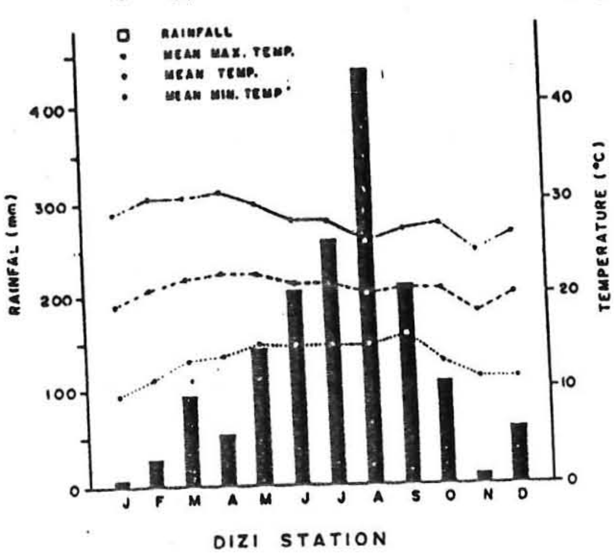


Fig.4: Monthly mean minimum, mean maximum and mean temperatures and monthly mean rainfall, Dizi Station, 1989-1990

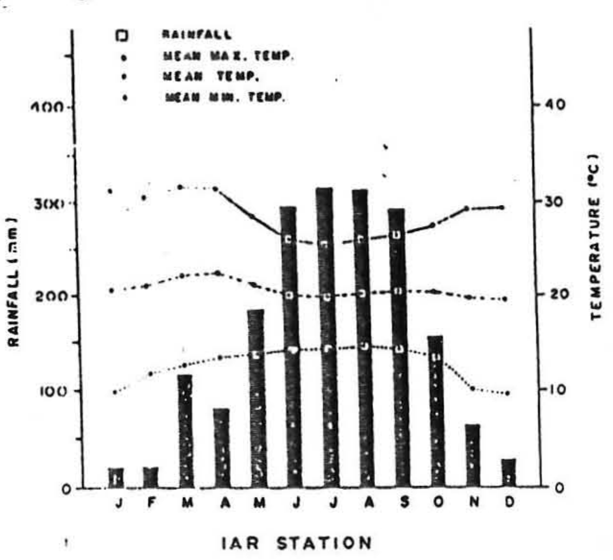


Fig.5: Monthly mean minimum, mean maximum and mean temperatures (1986-1988) and monthly mean rainfall (1982-1988), IAR, Metu Sub-centre.

2.3 Geology and Terrain Characteristics

The precambrian rocks with ages over 600 million years form the basis of surface rock formation in the study area. These rocks consist of various types of igneous and metamorphic rocks and include rocks of Alghe group such as gneisses, amphibols-pyroxene and pyroxene granite-gnesis

(Kazmin, 1973 and 1975). In fact hard and fresh rocks exposed to the surface are hardly found. Thus, various phases of the crystalline basement rocks are the basic parent material from which the soils of the study catchment developed.

The catchment exhibits considerable topographic irregularities. The relief is up to 260 meters, from 1500 to 1760 m a.s.l. The terrain of the study area is very rugged, and numerous hills and interfluves are dissected by streams draining into the catchment. The slopes of hills and interfluves vary between 10 to 70 percent, while the valley floors are much gentler.

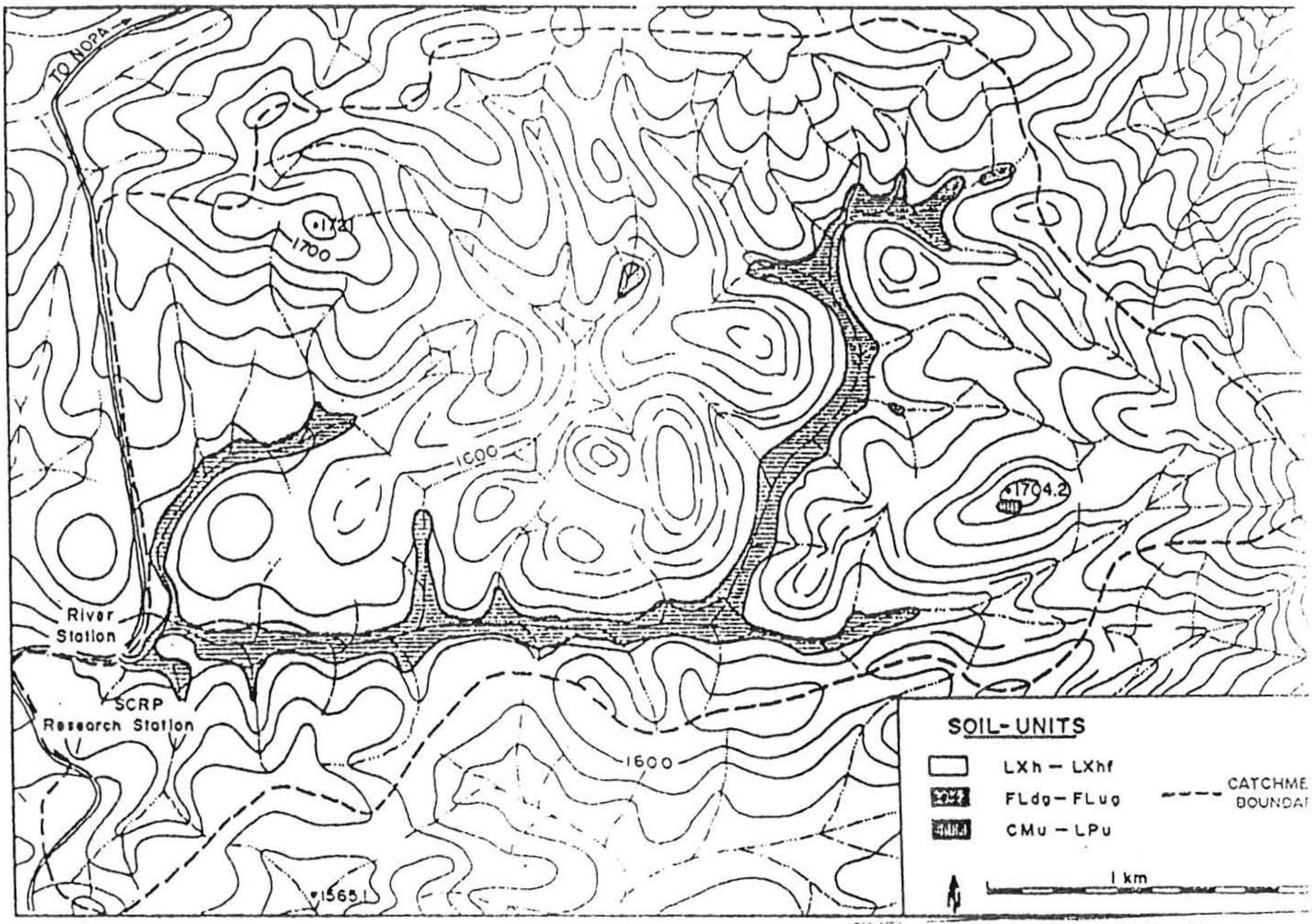
2.4 Soils and Soil Erosion

2.4.1 Soils

The soils of the study area are derived mainly from old igneous (granites) and metamorphic (gneisses) rocks (the latter are more dominant). Among the identified soil units which are found in the study area, Haplic Lixisols, Albic Lixisols, Fluvic Haplic Lixisols and Gleyi-Umbric Fluvisol are dominent.

Haplic and Albic Lixisols are soils developed on regolith materials (see their distribution in Fig. 6). They cover mainly the upper middle slopes, steep slopes and crest of ridges. In general, they have high base saturation as compared with their cation exchange capacities, low available phosphorus and nitrate nitrogen. Also, the occurrence of stone line (Gravely layer) characterizes these soils which is situated between 10 and 60 cms from the surface and limits root growth particularly annual crops. The stone line mainly consists of quartz which is resistant and residual aggregate (Hagman, 1991). In other words, it is the remaining materials of intensively weathered granite or schists or gneisses or a combination of these and others. The other explanation given to the formation of stoneline is biological activities. Biological organisms especially termites which bring soil materials selectively to the surface, and at the same time concretion of quartz gravels are buried to the depth to which the termites have affected the soil (Burning, 1970). Albic Lixisols have similar physical and chemical properties as Haplic Lixisols, but they have Albic E horizon and also have no diagnostic characteristics (Hagman, 1991).

Fluvic haplic Lixisols are mainly found in the middle and lower slopes (usually between 10 and 20 percent slope). These soils could have been developed by colluvium deposits or by wash materials from the adjacent slopes. They have better physical and chemical propsites in that nutrients are homogeneously distributed throughout the profile as compared



Lxh -Haplic Lxisols
Lxf -Ferric Lixisols
Lxa -Albic Lixisols
FLd -Dystric Fluvisols
FLU - Umbric Fluvisols
Fxg - Gleyic Lixisols
CMU - Humic Cambiols
LPU - Umbric Leptisols

Fig. 6: The preliminary soil map of Dizi Catchment

Source: Hagman, [illegible]

with either Haplic or Albic Lixisols. Also, no stone line is observed with in 200 cms from the surface.

Another soil unit which is confined to swampy areas are Gleyi-Umbric Fluvisol. These soils are enriched with alluvial materials every year, and thus apart from drainage impediment these soil have a high agricultural potential.

2.4.2 Soil Erosion

As noted in Section 2.2.2, the study area receives high rainfall for at least six or more months of the year. At the same time, rainfall intensity and erosivity are quite high. So far, among the seven research units of Soil Conservation Research Project (SCRP), the highest erosivities have been measured at Dizi Station (SCRP, 1988) see Fig. 7.

In the study area which is already characterized by high rainfall erosivity and erodibility of the soils as well as rugged terrais and steep slopes, increased human intervention seem to have accelerated soil erosion. Of course, so far, data on the extent and magnitude of soil erosion is limited. Nevertheless, there are signs of pronounced soil erosion problems in the cultivated fields. For instance, numerous rills are observed on the cultivated slopes starting from the on-set of rainfall upto the time crops are well established to cover the soils. Another observable fact is that in some recently cultivated slopes which had been fallowed for more than 20 years, the colour of top soils has been altered from dark brown to red brown within three years of continuous cultivation. Moreover, much of the cultivated ridges and steep slopes are seriously eroded wherein even the bed rocks at some points are exposed to the surface.

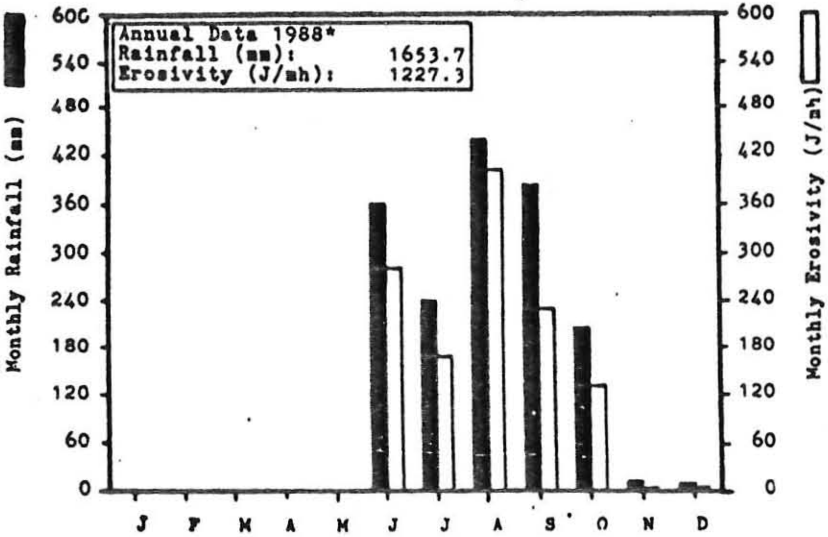


Fig. 7: Monthly Rainfall (mm) and Erosivity (R), Dizi Research Station, 1988.

Source: SCRP 1991

Table 7 shows that soil loss and runoff are influenced by landuse types and slope gradient. Runoff and soil loss are almost negligible under coffee forest (1 ton/h/year); but while soil losses are very low, runoff is significantly high under grass fallow. Thus, from both soil loss and runoff point of view, perennial plants/crops are effective soil conservation measures. Soil loss and runoff are considerably high under maize fields. The variation of soil loss and runoff on the two maize fields is mainly attributed to differences of slope angle.

TABLE 7

Soil Loss and Runoff Results of Four Test Plots for the Months of August, September, October and November, 1988, Dizi Catchment

Test Plots	Landuse types	Slope (%)	Soilloss (t/ha)		Runoff (%)
Test Plot 1	Maize field	18	18.03	112.0	10.7
Test Plot 2	Grass fallow	32	0.87	328	31.3
Test Plot 3	Coffee forest	42	1.22	36.1	3.4
Test Plot 4	Maize field	42	153.34	884.4	84.2

Source: SCRP, 1991

2.5 Drainage

The dendritic drainage pattern of the study area is a reflection of topographic features and climatic conditions. The catchment is drained by Dizi river (the catchment is named after the name of this river) and its several tributaries (see Fig. 8). This river itself is one of the many tributaries of Baro river. Much of the valleys of Dizi river are marked by swamps and alluvial deposits. The swamps are continuously enriched with alluvial deposits. Thus, they have a high agricultural potential, but have not been fully exploited.

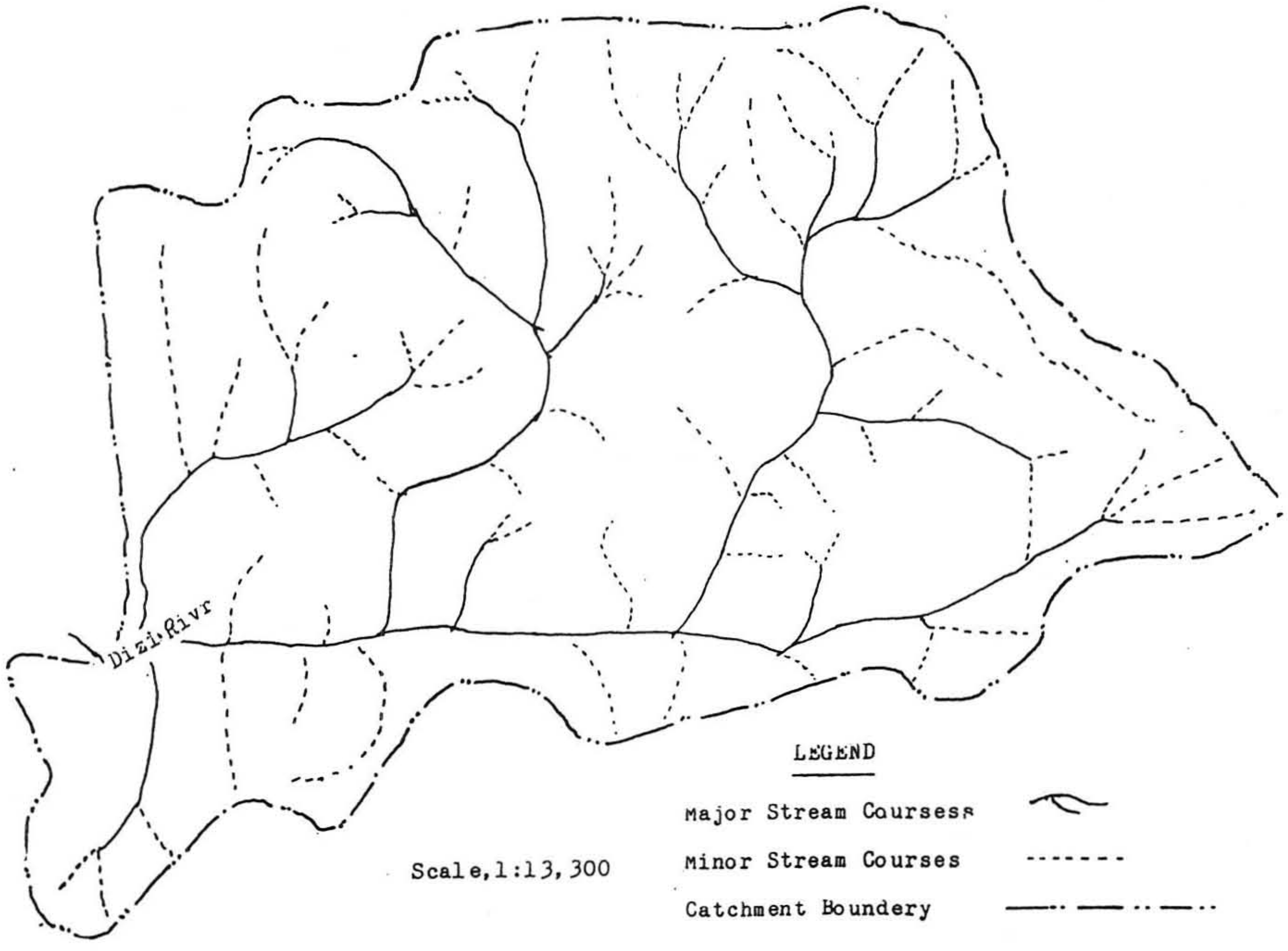


Fig. 8: **Drainage pattern, Dizi Catchment**

2.6 Vegetation

The climatic conditions in and around the study area favour the growth of various tropical forest formations. Among these formations, Omorphillous mountain forests, tropical evergreen forests, mixed ever green and deciduous forests can be mentioned (Wood, 1977). At present most of the vegetation consist of secondary forests, coffee forests, grass and bush fallows. The available evidence suggests that the bulk of forests and sometime coffee forests have been diminished from time to time. Accordingly, in and around the study area, forest coverage in 1957 accounted 37 percent of the total surveyed area and in 1982, it was reduced to 15 percent (Solomon Abate in prep.).

There are different types of plants which range from the simplest Mosses (*Sebaea brachyphylla*) to the biggest 'Kiltu' (*Ficus ovata*). Some of the major plants identified by the writer* include the following: *Echnops ellenbeckii*, *Echnops Spinosus*, *Ficus ovata*, *Myrica stalicifolia*, *Entadopsis abyssinica*, *Ekebergia Capensis*, *Cordia africana*, *Dichrostachs cinerea*, *Senecio gigas*, *Ocimum sure*, *Croton macrostachys*, *Trema guineenis*, *Ficus sure*, *Cambretum paniculatum*, *Vernonia amygdalina*, *Mumusops kummel*, *Recinus*

---

* Plant scientific names were identified by referring to the Glossary of Ethiopian Plant Names/Wolde-Michael, 1984) and the corresponding local names.

communis, Beddleja polystachya, Hagenia abyssinica, Snowdenia Polystacha, Cassipourea malosana, Morus meosygia, Alea welwitschii, Grewia ferruginea, Elusine jaegeri, Schefflera abyssinica, Deinbodlia kilimandsahrica, Erythrina brucei, Erithrina abyssinica, Apodytus dimidiata, Pittosporum viridifolium, Bridelia micrantha, Rhus abyssinica, Landolphia owarensis, Allophylus abyssinica, Stereospermum kunthianum, Dracaena steudneri, Acacia lahai, Acacia gerrardii, Aningeria adolifriederici, Salvia species, Sesbania sesban, Corespsis braniana, Cucumis prophetarum and Coffea arabica. These and other types of plants favorably grow throughout the catchment unless and otherwise they are deliberately cleared or fired either for cropping annual crops or for fuel or timber or for various other reasons.

2.7 Population, Landuse and Agriculture

2.7.1 Population Growth and Density

The population density of Dizi catchment is 81 persons/km^2, and this is more than twice the threshold population density under shifting cultivation indicated by Kpakole and Bahun (1984). Fig. 9 shows that 49 percent of the population is composed of groups of less than 18 years. The crude population growth rate is 4.25 percent and this figure isquite high as compared with regional and national growth rates of 2.25 percent and 2.9 percent respectively (CSO, 1984).

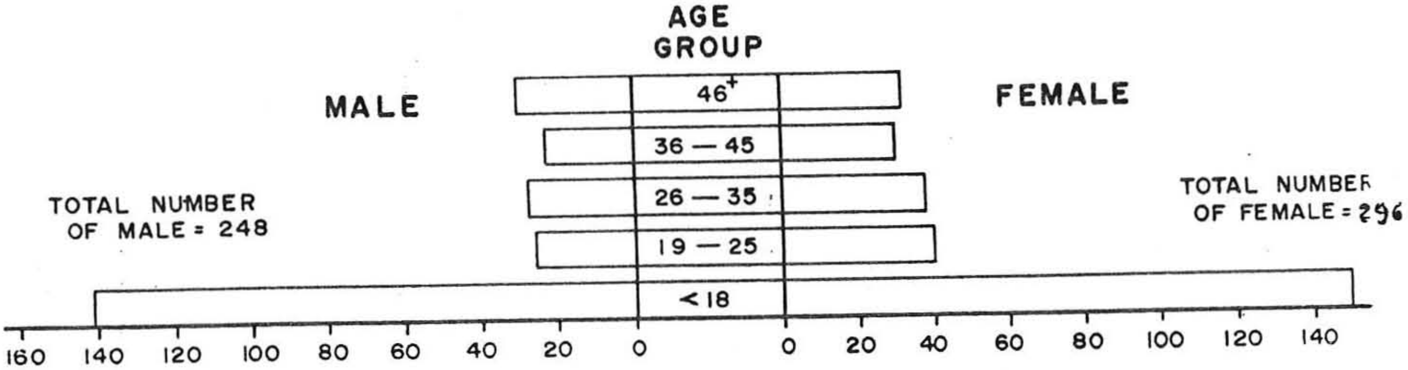


Fig. 9: Age and Sex Composition of the Population, Dizi Catchment

Source: Field survey

2.7.2 Landuse and Agriculture

2.7.2.1 Aspect of Coffee Cultivation and its Relation With Traditional Farming System

Information collected from various elderly local farmers indicates that long before the Italian occupation of Ethiopia, the land in and around the study area was significantly covered with forests. land was ample and then farmers were able to cultivate crops with long fallows. At that time, coffee was part of the natural vegetation and its utility was limited to local consumption. As time passed on, the increasing domestic and external demand for coffee accentuated the development of coffee cultivation. For example, before and during the Italian occupation, coffee was used to be sent via Gore and Gambella to the Sudan and in turn salt and other goods were brought into these areas.

After the withdrawal of Italians, the development of coffee cultivation was enhanced because of increasing demand and subsequent rise in price. This conducive situation motivated land lords, local "Balabats" and even farmers to be involved in the cultivation of coffee on a much larger scale. According to the responses of local farmers, the extension of coffee cultivation and increasing population pressure have caused reduction of both fallow area and fallow period.

The development of coffee in this agro climatic zone is important not only in that it offers income to the farmers and form the main source of foreign currency of Ethiopia, but also is one of the appropriate alternative conservation measures to soil degradation problems. However, since the past 15 years or so the prevailing conditions have not encouraged the development of coffee cultivation. It appears that unfavorable market situation has been one of the main reasons which create disincentive towards coffee development. Local and regional market centers are almost totally controlled by a single governmental enterprise (coffee marketing enterprise). Check points at various roads also contribute to this end. Local and regional price for good quality coffee was below Birr 3 per kilo which may be very low as compared with the escalating price of other commodities. On the other hand there is no pronounced shortage of cultivable land as it was evidenced by the field survey. Survey results indicate that about 86.1 percent of the respondents have owned cultivable land between 1 to 5 hectares but 93.2 percent of them produced only between 1 and 3 quintals of coffee beans (Table 8 and 9).

TABLE 8

Land Holdings (in ha) by Households, Dizi Catchment

Land holding (ha)	Farmers	
	Number	Percentage
1-2	45	34.6
3-5	67	51.5
6-7	11	8.5
8+	7	5.4
Total	130	100

Source: Field survey

TABLE 9

Annual Coffee Production (in quintals) by Households, Dizi Catchment

Coffee Production (qu)	Farmers	
	Number	Percentage
< 1	63	48.5
1-3	58	44.7
3+	9	7.8
Total	130	100

Source: Field survey

2.7.2.2 Fallow-Cropping Cycle

In the study area fallow-cropping cycles are mainly influenced by the population pressure and the distance from homesteads/settlements. Generally the longer the distance from homesteads, the longer will be the fallow period. And the longer the land has been left fallow, the more its vegetation will resemble forest (Stauder, 1971). But, the increase of population pressure and to some extent the extension of coffee cultivation have caused reduction in the fallow periods and fallow areas.

In the study area fallow lands can be categorized into three: they are grass fallow ('Beji'), bush fallow ('Oso') and forest fallow ('Chaka'). The latter type is not common. Under normal conditions and limited human and livestock intervention a cultivated crop field ('Masi') is transformed into its successive fallow phases in time i.e. 'Masi', 'Beji', 'Oso', 'Chaka'. Nevertheless some 'Beji' lands are not easily transformed into their subsequent stages of fallow when they are used intensively under short cropping-fallow cycles and grazed by livestock. Because of this, the regenerating plants which usually grow in succession will be discouraged and thus soil fertility recuperation can be retarded. In this regard, Osafo (1984) wrote that grass fallow can not regenerate soil fertility as do bush or forest fallows, because grasses are short rooted and also they take up most of the nutrients by themselves without returning much to the soil. Grass fallows (beji') not only regenerate the soil as do bush and forest fallows, but also recultivating them is also difficult. Therefore, 'beji' (grass fallow) are not usually preferred unless and otherwise the farmers lack alternatives to recultivate bush or forest fallows.

According to the local farmers responses, decline in soil fertility/productivity of a cultivated crop field is accompanied by the growth of various weeds. The type of weeds usually increase with increasing years of cultivation. This is to say, the longer the cultivation years of a crop field, the more it will be exposed to various weed seeds brought by runoff water, wind and other agents. Among weeds grow 'kertefe' (Cucumis prophetarum) and 'Ada' (Snowdenia polystachya) are good indicator of the depletion of the soils' fertility. These and other weed types dominantly grow starting from the final years of cultivation of a field to the first and second years of fallow. Later on these plants are replaced by other higher form of plants, commonly by 'Sokoru' (Echinos ellenbekii) and in subsequent years by still other higher form of plants. In such a way in time, a depleted crop field reverts into 'Beji', 'Oso' and 'Chaka' in ascending order.

However, adequate soil fertility regeneration which is achieved through long fallow period has been interrupted mainly because of the increase of population. To indicate the present landuse intensities of the study area, it may be relevant to use Allan's (1965) formula using the available data (see Allan's landuse intensity classification, p. 16).

The results indicate that the landuse intensity indices in the study area range from 2.7 to 9.2. This means that the landuse intensity index range from semi permanent to long term recurrently cultivated land. The mean landuse index was 4.8 (short term recurrently cultivated land) (see Table 1, p. 23). In fact the collected data were not adequate enough to draw a final inference, but it is the writer's opinion that the landuse intensity indices of the study area would be less than the calculated values.

2.7.2.3 Landuse and Crop Production

More than 80 percent of the inhabitants of the study area are Oromos. Their livelihood is largely based on the cultivation of arable crops and cash crops (e.g. Coffee). Table 10 shows the major landuse types and their size and proprortions. Apart from few areas which are situated along with the edges of river valleys and on some steep lands, forest without coffee is hardly found in the study catchment. Coffee forest accounted about 30 percent and bush fallow and grassland were 24 percent of the total catchment's area. On the other hand about 34 percent of the total area was under arable crop production.

TABLE 10

Landuse Pattern in Dizi Catchment for the Year 1990

Type of cover	Area (ha)	% of cultivated land	% of the catchment
Arable land	-	-	-
Maize	170.1	75	25.5
Teff	22.7	10	3.4
Sorghum	20.4	9	3.1
Others	13.6	6	2.0
Total	226.8	100	34.0
Coffee forest	260	-	30
Bush fallow	133.4	-	20
Grass fallow	26.7	-	4
Swamp	46.7	-	7
Complex landuse*	33.4	-	5
Total	440.3	-	66.0

Source: Solomon Abate (in prep.)

* Complex landuse is undifferentiated landuse (mixed landuse)

Arable crops which grow in the study area include cereals, root crops and pulses. Among cereals, maize (Zeamays, (Eragrostis teff) and highland sorghum (Sorghum bicolor) are the most important crops accounting 75 percent, 10 percent and 9 percent respectively of the total cultivated area (see Table 10).

Root crops such as 'Godere' (Clocasia antiquorum), Sweet Potato, 'Deme' (Ipomoer batatas) are the main supplementary food crops. They are usually cultivated around homesteads on a much smaller scale, but are productive and yield was estimated to be as high as 160 quintals. In fact, the extension of these crops can be one of the alternatives to alleviate cultivation-induced soil degradation which is manifested in the study area. Nevertheless, the cultivation of these crops is more labour intensive. Difficulties involving in land preparation, frequent weeding and hacking as well as guarding these crops from the attacks of wild animals are some of the main factors that have retarded their development.

Crop rotation involving crops such as beans and peas are quite limited, because they are more susceptible to plant diseases (e.g. 'Wage') and also easily attacked by wild animals.

Pulses which are still cultivated on a much smaller scale includes various species of 'Adenguare' or 'Defe' (Vigna unciculata). They are sometimes intercropped with maize, usually around homesteads protected by fences. These crops are fast growing and can be harvested in less than eight weeks and thus are useful and form emergency food sources at the time of scarcity of other food crops.

Apart from coffee which is the most important cash crop, the other income generating crops, include various types of fruits, such as orange, banana and mango.

2.7.2.4 Livestock Farming

As it was evidenced by field observation there is no shortage of either grass or grazing land in and around the study area, but livestock rearing activities are limited. This is mainly because of the pervalence of 'Gendi' (Trypanosomiasis) and its carrier tse-tse fly. The average livestock density in Tropical Livestock Units (TLU) was 32 per square kilometer. Table 11 shows that about 47.7 percent of the respondents did not own oxen which indicate a wide spread shortage of means of labour. Also about 90 percent of the household heads did not own either sheep or goats or donkey or mules. Moreover, the low livestock size and density may be a major factor which contribute to low level of application of manure in the cultivated fields.

TABLE 11

Distribution of Farm Animals by Households*

Type of FA*	Households and their respective size of FA														Total N° of Live-stock
	Household with no FA		Household with 1 FA		Household with 2 FA		Household with 3 FA		Household with 4 FA		Household with 5 FA		Household with 6 FA		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Ox	62	47.7	56	43.1	12	9.2	-	-	-	-	-	-	-	-	80
Cow	61	46.9	58	44.6	9	6.9	1	0.8	-	-	1	0.8	-	-	84
Calf	123	94.6	5	3.8	-	-	2	1.5	-	-	-	-	-	-	11
Sheep	90	69.2	27	20.8	5	3.8	8	6.2	-	-	-	-	-	-	61
Goat	123	94.6	7	5.4	-	-	-	-	-	-	-	-	-	-	7
Mule	122	93.8	7	5.4	1	0.8	-	-	-	-	-	-	-	-	9
Donkey	117	89.1	5	3.8	4	3.1	1	0.8	1	0.8	1.0	0.8	1	0.8	31
Horse	118	90.8	11	8.5	1	0.8	-	-	-	-	-	-	-	-	13

* Total number of households in the catchment were 130
FA = Farm Animals

Source: Field survey

2.7.2.5 Agricultural Calender in Dizi Catchment

The cropping calender in and around the study area is largely influenced by the climatic conditions, especially by rainfall distribution (see Fig. 10). 'Birra' (Sept., October and November) is the harvesting season for rainfed crops (e.g. maize, sorghum and teff) and also a period of sawing teff, weeding and land preparation for coffee and irrigated maize 'Bonna' (Dec., Jan. and Feb.) is a period of coffee harvesting and also land preparation (clearing, burning and ploughing) for arable crops. In 'Arfasa' (March, April and May) rainfed maize is sawn, hacked, 'Bebeka' (thinned) and weeded. Other cereals, pulses, root crops, coffee, vegetables and fruits are planted or sawn, hacked and weeded from Arfasa onwards.

One of the most serious problems facing farmers in and around the study area is guarding crops from the attack of wild animals such as wild pig, monkey etc. According to responses of the local farmers that since the last two decades wild animal population has increased significantly. Because of this, the farmers are forced to guard intensively their crops almost throughout the year.

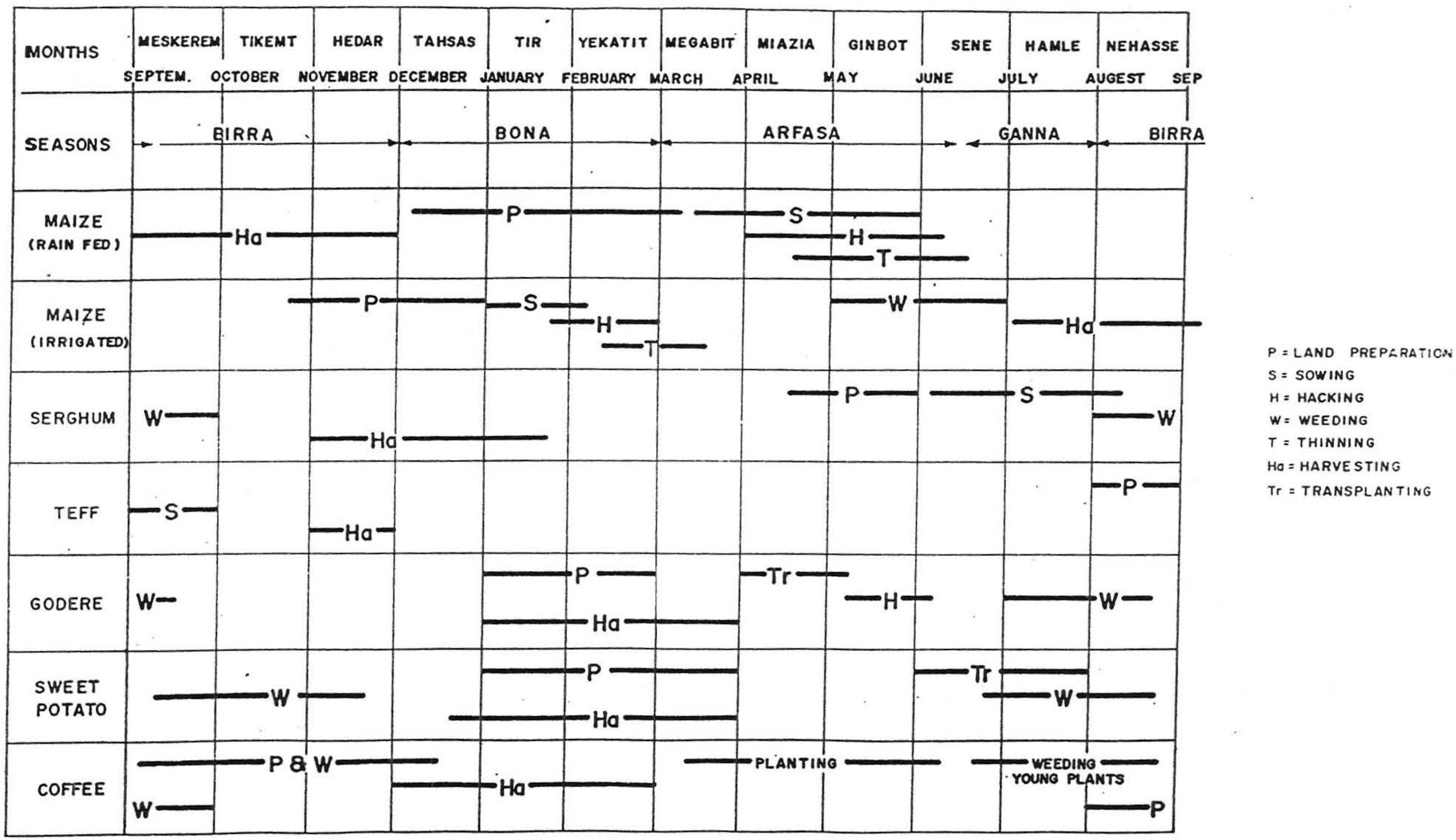


Fig. 10: Agricultural calendar, Dizi Catchment

Source = Field work

3. RESULT AND DISCUSSION

3.1 The Effect of Fallow Period and Intensity of Cultivation on the Fertility of Haplic and Albic Lixisols

The fertility of soil is the ability of soil that provides physical conditions favorable to root growth and supply enough water and nutrients to enable a crop to make the most of other environmental features of a site (Webster et.al, 1980, p. 61). From this definition we learn that fertility of soil refers to the physical and chemical properties of soil favorable for plant growth. In the ensuing sections, we shall see the effect of fallow periods (years) and intensity of cultivation on the physical and chemical properties of Haplic and Albic Lixisols occurring in the study area.

3.1.1 The Effect of Fallow Periods on the Major Physical Properties of the Soils

In this section, we examine the effect of fallow period on the two major physical properties of the soils, namely structure, and bulk density.

The most important structural features of the soil are stability, size and shape of the peds and their penetrability by water, air and roots (Landon, 1984, p. 98). Stocking (1986, p. 20) noted that cultivation induced structural deterioration can be improved through natural fallowing in the humid tropics, and as it will be clear from the following discussion, this is also true to the Haplic and Albic Lixisols of the study area. The observed top soil

(Ah) structural characteristics were weak to moderate grades, medium to fine class (size), and sub-angular to granular types of shapes in the case of the soils fallowed for short period of time (≤ 4 years), whereas these same features were moderate to strong, medium to fine and granular to crumb in the case of the soils that were fallowed between 5 and 20 years (see appendix IV).

Bulk density refers to the overall density of a soil i.e. the mass (weight) of mineral soil divided by the overall volume occupied by the soil and pore spaces. It is influenced by structure, texture, organic matter and the intensity of cultivation (Brady, 1985:50). This study showed moderate and statistically significant relationship with fallow period ($r=-0.57$), suggesting an increase in porosity of the soils, a condition favorable for crop growth. This reduction in bulk density or increase in porosity may be explained by constant increase in organic matter which comes from leaves and litter fall on the soils and the contribution of plant roots. The highest (1.59 g/cm^3) and the lowest (0.88 g/cm^3) bulk density values were respectively measured in grass fallow land laid for eight years and secondary forest which was left unused for over twenty years. It is likely soil compaction caused by grazing animals may have also contributed to the high bulk density value of the grass fallows.

3.1.2 The Effect of Fallow Periods on Chemical Properties of the Soils

As has already been mentioned in Section 2.4.1, the soils of the study area (Haplic and Albic Lixisols) are deeply weathered and leached. Considering these and other environmental limitation (Sec. 1.5.1), the growing of annual crops with low level of inputs to maintain the fertility of the soils requires the recycling of nutrients through plant soil system (fallowing). Understandably, upon fallowing, organic matter is consistently being produced from leaves twigs and litter fall of the regenerating plants growing on fallow lands. The added organic matter, in turn, stores most of the available nutrients and the nutrients held in it are slowly released.

TABLE 12

Correlation Between Fallow Periods Vs Soil Physical and Chemical Properties for Fallow Sites

	OM	N	NH_4^+	NO_3^-	PO_4^- (Bray)	PO_4^+ (Olsen)	Ca	Mg	K
FP	.7260*	.8701*	.2851	.3617	.0066	.0837	.6462*	.6907*	-0.1887

	CEC	BS	pH	BD	SA	SI	CL
FP	.2371	.4912	.5919*	-0.5687*	-0.3382	.4541	-0.3078

FP = Fallow Periods (years), OM = Organic Matter (%), N = Total Nitrogen (%) Ammonium (NH_4^+) ppm, NO_3^- = Nitrate (ppm), PO_4^- = Phosphorus Bray Method (ppm), PO_4^- = Phosphorus (Olsen Method) (ppm), Ca = Calcium (me/100g), Mg = Magnisium (me/100g), K = Potassium (me/100g), CEC = Cation Exchange Capacity (me/100g), BS = Base Saturation (%), BD = Bulk Density (g/cm^3), SA = Sand (%), SI = Silt (%), CL = Clay (%).

* Significant

The results showed that values of organic matter and nutrients on-fallow sites vary with the length of fallow period. This is consistent with the work of Nye and Greenland (1960, quoted in Webster, 1980, p. 177) in which they reported that in Nigeria, the maximum contribution of organic matter, total nitrogen, calcium and magnesium came from leaves, twigs and litter fall and this was achieved mainly in the earlier periods of fallowing. In the latter stage (years) of fallowing, organic matter and nutrients rates tend to be in equilibrium, with regeneration, storage and decomposition (Ruthenberg, 1980:62). Somewhat similar trend in the level of organic matter and other nutrients is also observed in the soils (Haplic and Albic Lixisols) examined in the study area.

3.1.2.1 Effect on Organic Matter and Total Nitrogen

Soil analysis made on samples collected from sites with different fallow periods (years) indicate that organic matter varies between 3.90 percent for two years of fallow and 6.32 percent for twenty years of fallow. In the same manner the total nitrogen content varies between 0.16 percent for twelve years of fallow (grass fallow) and 0.34 percent for twenty years of fallow (forest fallow).

Although, organic matter and total nitrogen levels increased with the increase in fallow period, the rates of restoration of both were observed to be affected by the recurrence of previous fallow-cropping cycles, grazing intensity and the vegetation grown on the fallow lands. For instance, the average organic matter and total nitrogen contents among the grass fallow lands ranging in age between 3 to 8 years were 4.3 and 0.18 percent respectively. On the other hand, bush fallows which differed in their rest periods (years) between 5 to 9 years had average organic matter content of 5.7 percent and total nitrogen content of 0.25 percent. The measured average organic matter and total nitrogen contents of bush-forest fallow lands over 20 years of age were 6.32 and 0.34 percent respectively (see appendix II). As a whole, organic matter and total nitrogen levels on fallow lands between 12 and 20 years were very high, while for those fallowed between 1 to 10 years these same contents fall into high to very low, when seen in relation to ILACO's broad system of organic matter rating (Hagman 1991:97) and Kjeldhl's system of nitrogen rating (London, 1984:138). Almost similar values were obtained among the on-farm plots (Sec. 3.1.2.2), except that they had higher average values of these contents and higher restoration rates.

Employing Cobble Douglas equation (log-linear) (see below) on the analyzed data Fig. 11 is drawn to show the trend of increase on organic matter level with increasing fallow periods.

$$OM = 3.99\ FP^{0.14}$$

Where OM = Organic Matter (%)
FP = Fallow Period (years)

Within this test, the relationship between organic matter and fallow period is significant at 5 percent probability level (F=6.882, probability > F, 0.0250). The coefficient of determination, (R^2) is 0.4076 which implies that about 40.76 percent of the organic matter was explained by the effect of fallow period.

From the trend of increase of organic matter with fallow period (see Fig. 11), it could be stated that the average rate of increase in organic matter is 9.1 percent when the fallow period is doubled (for example from 1 to 2 years or 4 to 8 years). This means, the absolute level of organic matter increase with fallow period i.e. the rate of increase

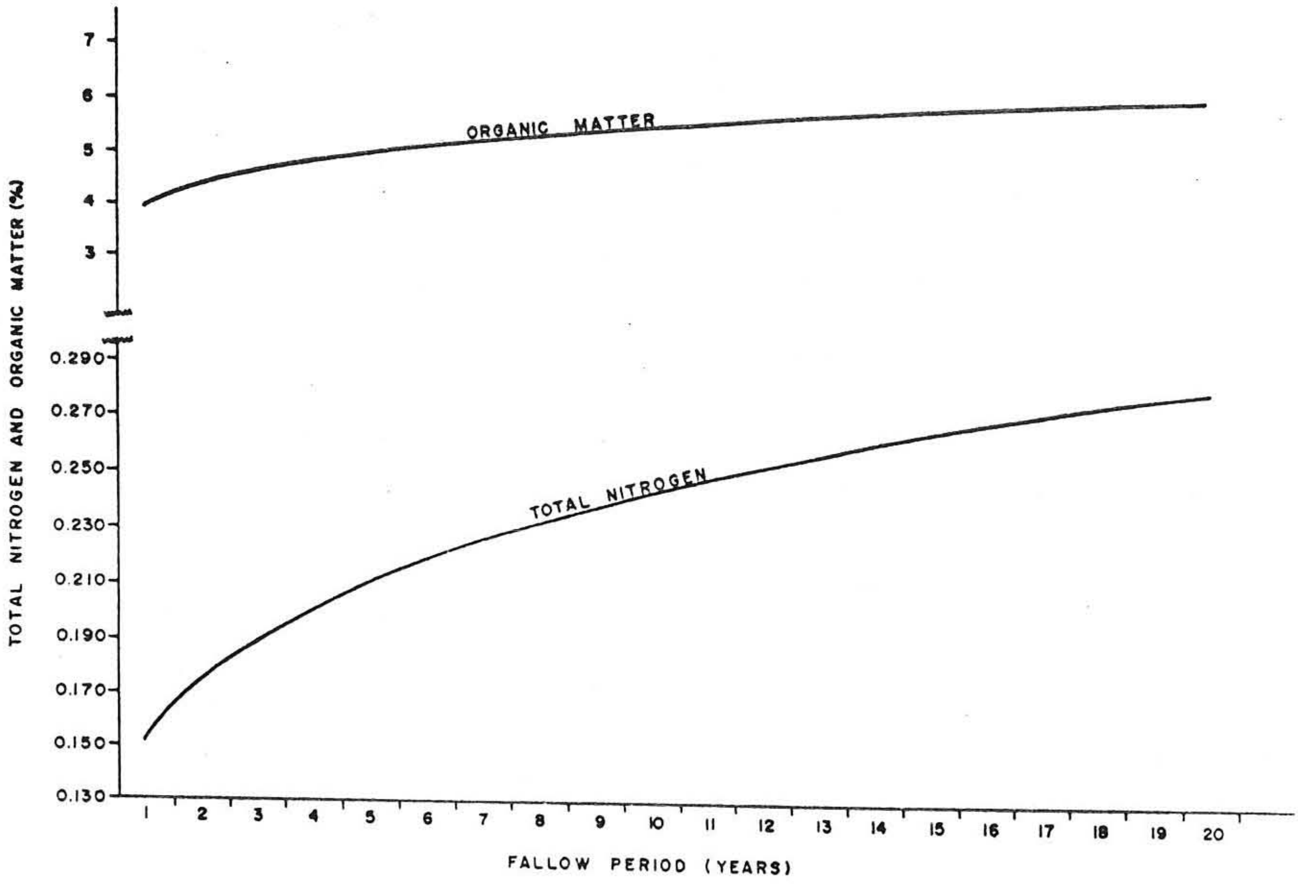


Fig. 11: Relationship Between Organic Matter and Total Nitrogen Vs Fallow Periods

in organic matter varies from 9.1 percent in the second year of fallow to 1.3 and 0.7 percent in the tenth and twentieth years of fallows.

Similar trend of restoration for total nitrogen was observed using the same equation as for organic matter (see also Fig. 11).

$$N = 0.15\ FP^{0.21}$$

Where N = Nitrogen (%)
FP = Fallow Period (in years)

The relationship between total nitrogen level and length of fallow period is significant at 5 percent probability level (F = 8.80, Prob>F, 0.014). The coefficient of determination (R^2) is 0.4681 which indicates about 46.81 percent of the variation in total nitrogen is explained by fallow periods. The average total nitrogen content increases by 13.3 percent with doubling of fallow periods, a value greater than the increase of organic matter. But similar to organic matter, the absolute level of total nitrogen increases with fallow periods at diminishing rate. For example total nitrogen rate restoration varies from 13.3 percent in the second year of fallow to 1.9 percent in the tenth year of fallow.

The following important findings emerge from what has been presented above:

(1) the rate of restoration of organic matter and total nitrogen contents were rapid in the early periods of fallow (years) and (2) total nitrogen appears to have increased more rapidly than organic matter.

3.1.2.2 Effect on Exchangeable Bases, pH, Available Phosphorus, Ammonium and Nitrate

Table 12 shows that there is weak to moderate positive correlations between fallow periods on one hand and calcium ($r=0.65$), magnesium (0.69), and pH (0.59). On the other hand, calcium restoration rate with fallow periods was estimated using log-linear equation:

$$Ca = 3.27\ FP^{0.21}$$

where Ca = Calcium (me/100g)
FP = Fallow Period (in years)

The relationship between rate of calcium restoration and fallow period is significant at 5 percent probability level ($F = 5.8$, prob>F:0.445). Results indicate that about 34.5 percent of calcium restoration is explained by the length of fallow period and calcium content increases at declining rate. For example, the rates of increase change from 15 percent in the second years of fallow to 2 percent in the tenth years of fallow (see Fig. 12).

The trend of magnesium restoration did not fit non-linear equation, but simple linear regression equation best fitted the scatter plots of magnesium contents. This relationship is given below:

$$Mg = 1.28 + 0.17FP$$

where Mg = Magnesium (me/100g)
FP = Fallow Period (years)

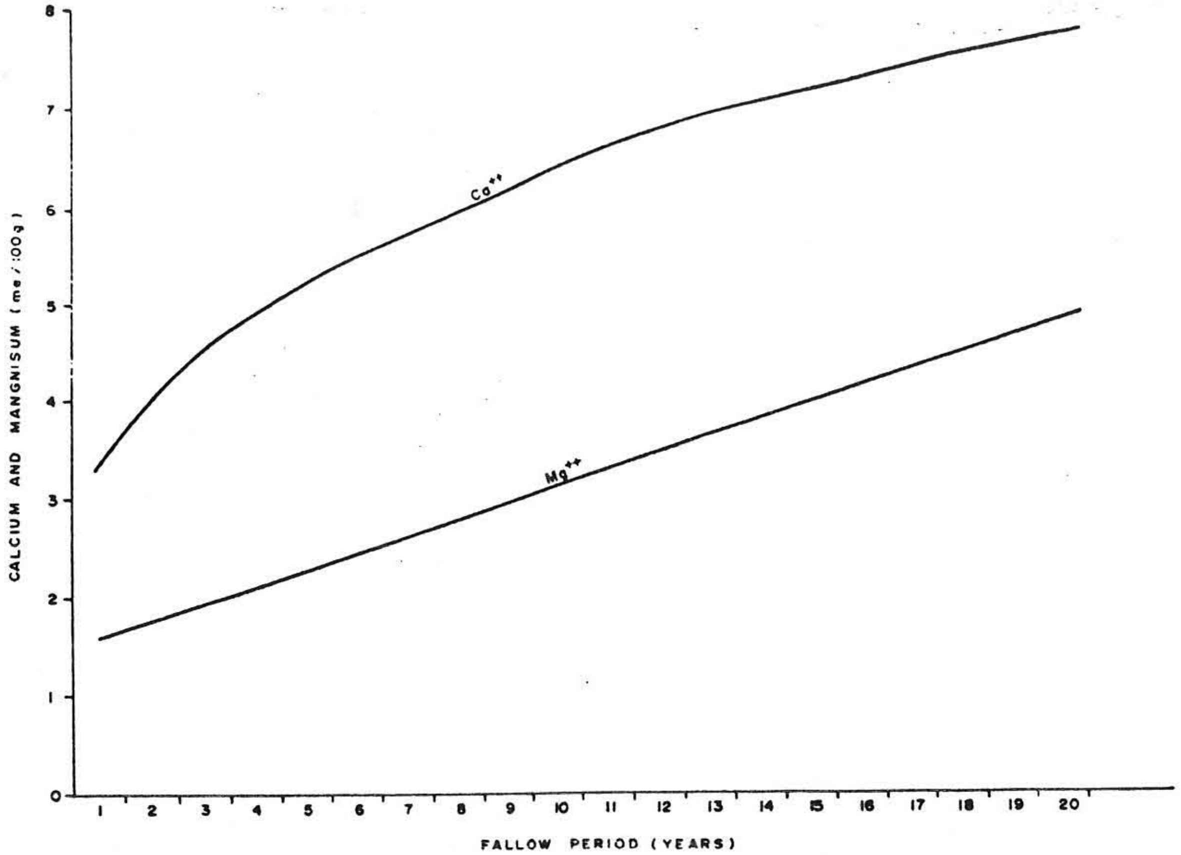


Fig. 12: Relationship Between Calcium, Magnesium and Length of Fallow Periods

The relationship between magnisium and fallow period is statistically significant at 5 percent probability level (F=9.12, probability > F0.0129). The relationship between these two variable is positive with 'r' value of 0.69 and 'R^2' of 0.4771. This means, about 47.71 percent of variation in magnesium level is attributed to the effect of fallow periods (see Fig. 12).

The other measured soil properties had weak and statistically insignificant relations with fallow periods at 5 percent probability level. Table 12 shows, potassium, phosphorus, ammonium, nitrate, cation exchange capacity and base saturation, each has coefficient of correlation of -0.19, 0.007, 0.29, 0.36, 0.24, and 0.49 with fallow periods respectively.

3.2 The Combined Effect of Previous Fallow Periods and Intensity of Cultivation on the Fertility of Haplic and Albic Lixisols

As has already been presented in Sec. 3.1 the number of fallow years had considerable effect on the degree of improvement of some of the physical and chemical properties of the soils. On the other hand, intensity of cultivation (cropping years) had detrimental effect on these same soil properties. In the succeeding sections the individual and combined effects of fallow periods and cultivation years will be considered and discussed.

3.2.1 Effect on the Major Physical Properties of the Soils

The physical soil properties assessed in this case were structure, bulk density, and infiltration rate.

The evaluated soil structure of the on-farm plots showed improvements with the length of previous fallow periods and deterioration with the increase in cropping years.

Generally, those plots which were previously fallowed for short period (3 to 5 years) and subsequently cultivated from 2 to 5 years had plough horizon structure ranging between moderate to weak in grade, fine to medium in size and granular to sub-angular in shape of aggrigate. On the other hand, plots with longer previous fallow period (6 to 20 years) had structural features ranging from moderate to strong in grade, fine to very fine in size and granular to crumb in shape of peds in the earlier period of cultivation; and moderate to weak in grade, fine to medium in size and granular to sub-angular blocky in shape in the latter years of cropping (see Appendix IV).

Bulk density show negative and significant (at 5 percent probability level) relationship with fallow period while the relationship is positive with cropping years. The coefficient of correlation 'r', between fallow periods and bulk density is -0.56 while the 'r' value between cultivation years and bulk density is 0.44. This shows, bulk density of the soils tended to decline (increase in porosity of soils) with fallowing and increases with cultivation years.

The other evaluated physical property of the soils of the on-farm plots was infiltration rate. Infiltration rate is directly influenced by factors such as structure, texture, bulk density, pore volume and organic matter content, most of which are influenced by the length of fallow period and cultivation years. To see the influence of the length of fallow period and intensity of cultivation on infiltration rate of the soils of the on-farm plots, double ring infiltrometer was used following the procedures outlined in Landon, (1984, p. 62). The commonly reported limitation of this method is that the water filled in the infiltrometer (measuring cylinder) exerts more pressure on the soil than does natural rainwater. Thus, the measured results could have been higher than what could have been expected in rain water infiltration rate and it was keeping this in mind that the measurements were conducted. The results of infiltration measurement show positive (r=0.63) and statistically significant (at 0.05 level of probability) relationship between fallow period and infiltration rates. But the relationship between cultivation years and infiltration rates is negative (r=-0.3) and statistically insignificant at 0.5 level of probability (see Table 13).

Although variations of infiltration rate was registered among the on-farm plots, it is unlikely that these variations would be a serious problem for crop production since the study area receives high and reliable rainfall distribution for over seven months of the year (see Sec. 2.2.2). However, the relatively low infiltration rates measured in some intensively cultivated fields, indicate a significant threat of soil erosion and degradation because more runoff can be generated in such fields.

3.2.2 Effect on the Major Chemical Properties of the Soils

The intent in this section is to address the combined effect of fallow period and intensity of cultivation on the chemical properties of the soils of the on-farm plots. The on-farm plots, as pointed out, are those which were fallowed for varying length of time (years), but under cultivation during the survey period. This means, both previous fallow periods and subsequent cropping years have been involved in affecting the chemical make up of the soils of the on-farm plots. In the following sections, we examine these influences.

TABLE 13

CORRELATION MATRIX

VARIABLES	FP	CY	MY	BM	H	OM	N	NH_4^+	NO_3^-	PO_4^- (Bray)	PO_4^- (Olsen)	CaMg
FP												
CY	0.13											
MY	0.73*	-0.41*										
BM	0.67*	-0.41*	0.89*									
H	0.63*	-0.49*	0.92*	0.87*								
OM	0.62*	-0.42*	0.90*	0.83*	0.84*							
N	0.56*	-0.51*	0.87*	0.79*	0.78*	0.88*						
AM	0.10	-0.30	0.24	0.30	0.30	0.34	0.26					
NI	0.23	-0.03	0.16	0.09	0.15	0.12	0.16	0.06				
PBM	0.23	0.04	0.28	0.17	0.29	0.10	0.16	0.12	-0.24			
POM	0.33	0.34	0.12	0.05	0.08	0.07	0.02	0.21	0.41*	0.38		
CAMG	0.57*	-0.25	0.78*	0.66*	0.76*	0.70*	0.68*	0.21	0.06	0.32	0.09	
CA	0.39*	-0.34	0.67*	0.50*	0.67*	0.59*	0.56*	0.32	0.01	0.37	-0.02	0.91*
MG	0.58*	0.08	0.51*	0.55*	0.46*	0.51*	0.52*	-0.15	0.16	0.02	0.25	0.59*
K	-0.09	-0.10	0.18	0.08	0.26	0.15	0.15	0.33	0.43*	0.14	0.27	0.27
CEC	-0.09	-0.05	0.08	0.04	0.07	0.17	0.05	0.06	0.19	-0.25	0.01	0.11
BS	0.59*	-0.14	0.67*	0.57*	0.64*	0.55*	0.60*	0.16	0.00	0.42*	0.11	0.84
PH	0.50*	-0.09	0.48*	0.40*	0.51*	0.34	0.39*	0.06	0.05	0.51*	0.12	0.67*
BO	-0.46*	0.45*	-0.44*	-0.52*	-0.47*	-0.46*	-0.44*	-0.18	0.09	0.16	0.26	-0.33
IR	0.63*	-0.30	0.79*	0.77*	0.76*	0.77*	0.62*	0.28	-0.08	0.22	0.21	0.66*
SA	-0.21	-0.02	-0.00	0.00	0.05	-0.06	-0.07	-0.11	-0.13	0.10	-0.24	-0.01
SI	0.37	-0.17	0.28	0.32	0.28	0.35	0.38	0.17	0.01	-0.08	0.05	0.37
CL	-0.27	-0.29	-0.48*	-0.52*	-0.54*	-0.48*	-0.46*	-0.05	-0.01	-0.03	0.16	-0.57*

FP = Fallow Period
CY = Cultivation Years
MY = Maize Yield
BM = Biomass
H = Maize Height
OM = Organic Matter
N = Nitrogen
NH_4^+ = Ammonium
NO_3^+ = Nitrate
PHO$^-$ = Phosphorus (Bray Method)
PO4$^-$ = Phosphorus (Olsen Method)
* - Significant

CaMg = Calcium and Magnesium
Ca^{++} = Calcium
Mg^{++} = Magnesium
K^+ = Potassium
CEC = Cation Exchange Capacity
BS = Base Saturation
PH = Soil Reaction
BD = Bulk Density
IR = Infiltration Rate
SA = Sand
SI = Silt
CL = Clay

CONTD..... TABLE 13: CORRELATION MATRIX

VARIABLES	CA^{++}	MG^{++}	K^{+}	CEC	BS	PH	BD	IR	SA	SI	CL
MG	0.21										
K	0.34	0.02									
CEC	0.11	0.08	0.13								
BS	0.75*	0.54*	0.32	-0.39*							
PH	0.60*	0.41*	0.22	-0.51*	0.86*						
BD	-0.23	-0.34	0.16	0.26	-0.44*	-0.38*					
IR	0.51*	0.51*	-0.02	-0.01	0.57*	0.43*	-0.45*				
SA	0.04	-0.16	0.03	-0.08	-0.01	0.12	0.25	0.12			
SI	0.27	0.36	-0.03	-0.07	0.36	0.20	-0.53*	0.15	-0.82*		
CL	-0.47*	-0.37	-0.08	0.19	-0.54*	-0.53*	0.41*	-0.45*	-0.33	-0.24	

3.2.2.1 Effect on Organic Matter and Total Nitrogen

The average organic matter and total nitrogen content of the on-farm plots were 4.97 and 0.23 percent with the coefficient of variation of 20.40 and 22.33 percent respectively (Table 14). Organic matter regeneration with fallow period and degradation with age of cultivation were predicted using non-linear function:

$$OM = 3.42\ FP^{0.27}\ CY^{-0.22}$$

where OM = Organic Matter (%)
FP = Fallow Period (year)
CY = Cultivation Years

The above model is statistically significant at 5 percent probability level in explaining the variation of organic matter level (F=30, prob>F, 0.0001). In this equation, about 71.5 percent of the variation of organic matter is explained by the effect of fallow and cultivation years, the former being important (see Table15). The trend of organic mattic level of the o-farm plots is given in Table 13 which

TABLE 14

Mean and Variability Statistics of the Measured Dependent and Independent Variables for Samples of the On-farm Plots

Variables	Mean	Standard Deviation	Coefficeint of variation (%)
Fallow Period (FP)	10.2963	5.9795	58.0747
Cultivation Years (CY)	3.4444	1.4233	41.3275
Maize Yield (MY)	3111.3629	1123.8422	36.1206
Biomass (BM)	13618.7963	3870.3139	28.4206
Maize Height (H)	2.9904	0.5421	78.1284
Organic Matter (OM)	4.9743	1.0152	20.4060
Nitrogen (N)	0.23332	0.0537	22.8229
Ammonium (AM)	93.0407	12.3987	13.3261
Nitrate (NI)	18.0074	9.5624	53.1027
Phosphate (Bray)(PB)	88.0037	61.9259	70.3643
Phosphate (Olsen)(POM)	25.2259	11.9489	47.3676
Calcium and Magnesium (Ca+Mg)	10.35926	2.2259	21.4875
Calcium (Ca)	6.7481	1.8809	27.8736
Magnesium (Mg)	3.57407	1.6125	28.3279
Potassium (K)	0.7219	0.3181	44.0649
Cation Exchange Capacity (CEC)	16.3519	2.3789	14.5486
Base Saturation (BS)	68.7778	17.4341	25.3485
PH	5.9185	0.6833	11.5458
Bulk Density (BD)	1.1781	0.1409	11.9622
Infiltration (IR)	62.7370	22.7811	36.3121
Sand (SA)	38.2963	6.8826	17.9720
Silt (SI)	36.4444	6.1289	16.8173
Clay (CL)	24.8889	3.6515	14.6711

n-27

TABLE 15

Result of Parametric Estimates for Organic Matter Levels

Variable	Parametric estimate	Beta coefficient	Standard error	Multiple correlation	Partial R-square	Model R-square	F-Value	Prob>F
Intercept	1.2284	0.0000	0.1033	-	-	-	141**	0.0001
FP	0.2793	0.7525	0.0406	0.70	0.49	0.49	47**	0.0001
CY	-0.2203	0.4691	0.0514	0.84	0.22	0.71	18**	0.0001

* Significant ** Highly significant

shows the regeneration of organic matter content with fallow periods* (fixed cultivation year i.e. 1 year).

Generally, very rapid increase in the organic matter content is predicted to be in the early periods of fallow and this becomes insignificant with further increase in fallow years. For instance, the amount of increase in organic matter is 16 percent when the fallow period is increased from the first and second year, whereas the amount of its increase diminishes to only 0.5 percent when the fallow period is extended from 19 to 20 years (see Fig. 3). This means, after certain fallow period, any further fallowing will have no significant positive effect on the level of organic matter. This is probably because the soil-plant system reaches to a new equilbrium after long fallow period wherein no major change could take place.

---

* The on-farm plots were set on cultivated maize fields during the study period, but had been previously fallowed for different years. Therefore, since data on organic matter content of the soils had not been evaluated before the fields/plots set for cultivation, its restoration rate (amount was estimated from the model with fixed cultivation i.e. 1 year. In fact, the estimated rate/amount is expected to be lower than the absolute organic matter content stored before the fields set for cultivation.

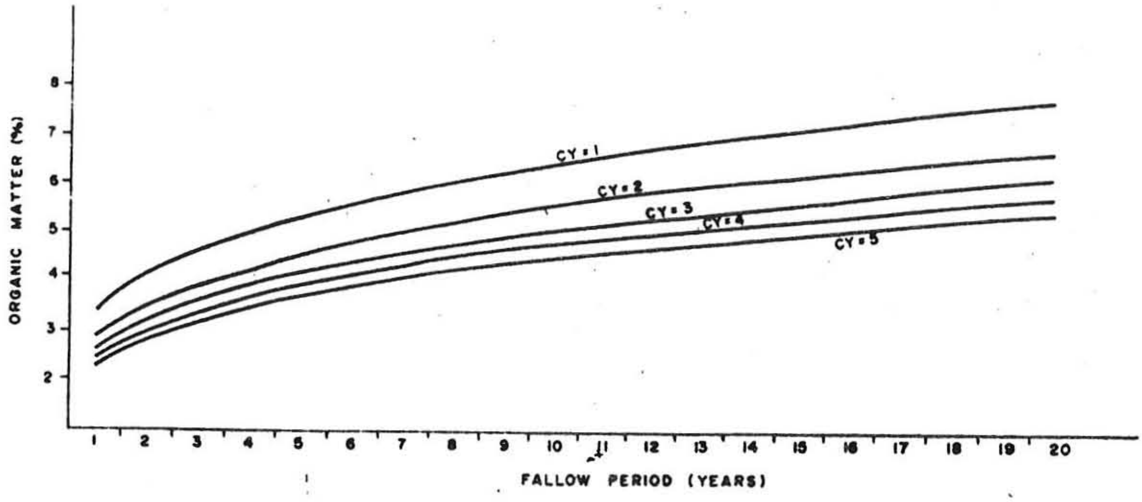


Fig. 13: Relationship between organic matter and fallow periods with fixed cultivated years

Another fact emerging from Fig. 13 is the effect of cultivation years on the level of the organic matter of the investigated soils. Generally, the short cultivated fields (e.g. 1 year) have higher organic matter content than the long cultivated plots (e.g. 5 years), even if the previous fallow period is the same. This can be observed in Fig. 13 where the line showing the trend of increase in organic matter (CY=1) lies on the top of all other lines (2,3,4 and 5 years of cultivation).

The relationship between the levels of organic matter for the on-farm plots with different cultivation years and fallow periods is shown in Fig. 14.

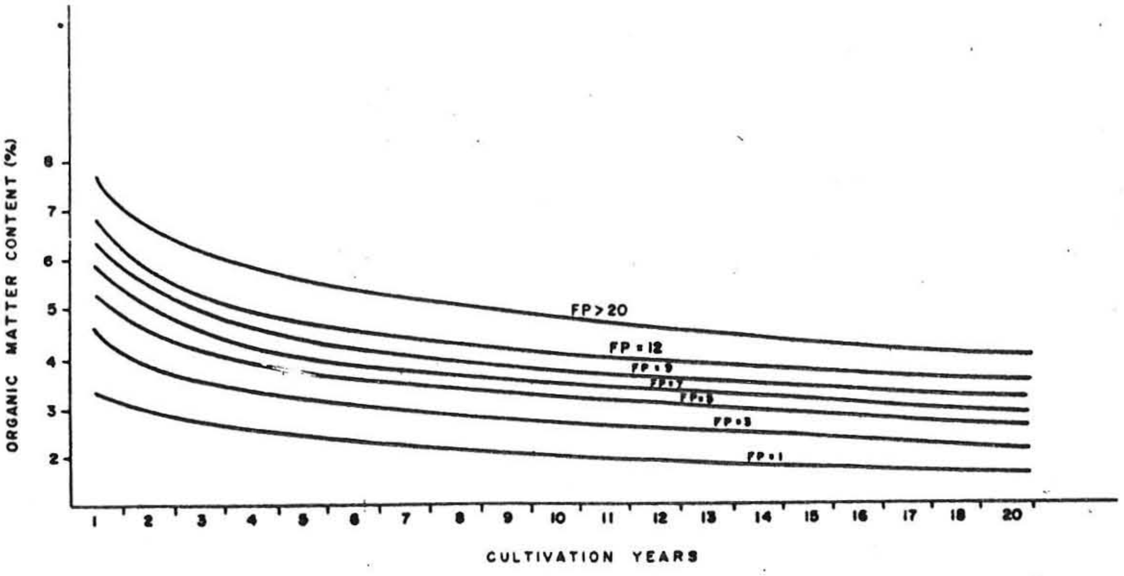


Fig. 14: Relationship between organic matter and cultivation years with fixed fallow periods

From the above figure, one can see a decrease in organic matter content with length of cultivation years, again at declining rates. During the first years of cultivation, the organic matter decreases at higher amount but diminishes in the latter years of cropping. For example, when the cultivation years increase from 1 to 4 years, the organic matter level declines by 12 percent; but when the cultivation years increased from 11 to 12 years, the decline in organic matter is 2.5 percent. The diminishing fall in the level of organic matter with increasing period of cultivation may probably be because of very limited organic matter left for any further depletion.

TABLE 16

Result of Summary Parametric Estimates for Total Nitrogen Levels

Variables	Parametric estimates	Beta coefficient	Standrad error	Multiple cor.	Partial R-square	Model R-square	F-value	Prob>F
Intercept	1.7690	0.0000	0.1126	-	-	-	** 246.78	0.0001
EP	0.2788	0.6947	0.0443	0.64	0.41	41	** 39.63	0.0001
CY	-0.2785	-0.5502	0.0561	0.84	0.29	0.71	** 24.68	0.0001

FP = Fallow Period
CY = Cultivation Years
* = Significant
** = Highly significant

The above equation was used to draw Fig. 15 and Fig. 16. Accordingly, Fig. 15 shows the relationship between total nitrogen and fallow periods (fixed cultivation years). Total nitrogen rate of regeneration was estimated to increase, on the average by 17.6 percent with increasing fallow periods. However, the rate of restoration of total nitrogen falls from 17.6 to 2.7 percent when the fallow periods increase from 1 to 2 years and 10 to 11 years respectively (see Fig. 15).

The disparities in total nitrogen content denoted by curve lines in Fig. 15 show the impact of cultivation years in lowering total nitrogen levels. For instance, total nitrogen content of a plot continuously cultivated for 5 years is less than 70 percent of a plot cultivated only for 3 year (both being fallowed for one year). Likewise, a plot fallowed for 10 years and cultivated for 1 year has a 60 percent total nitrogen content more than a plot fallowed for the same years but cultivated for 5 years.

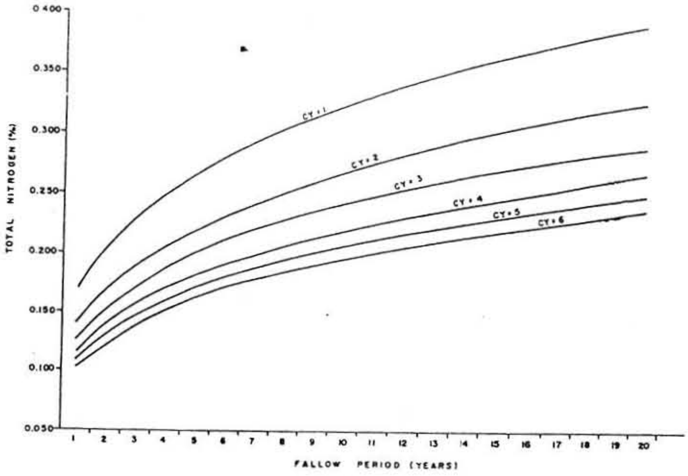


Fig. 15: Relationship Between Total Nitrogen and Fallow Period with Fixed Cultivation Years

On the other hand Fig. 16 shows the impact of the intensity of cultivation with fixed fallow periods on the total nitrogen content. Total nitrogen decreased by 17.4 percent in the first two consecutive years and for plots cultivated from 10 to 11 years the decreasing rate of total nitrogen is 2.7 percent.

The vertical differences between the curve lines in Fig. 16 show the effect of previous length of fallow period on the depelation of total nitrogen status. Infact, total nitrogen decreases with cropping years, but the absolute level of total nitrogen is higher on plots with longer fallow periods than short fallowed fields.

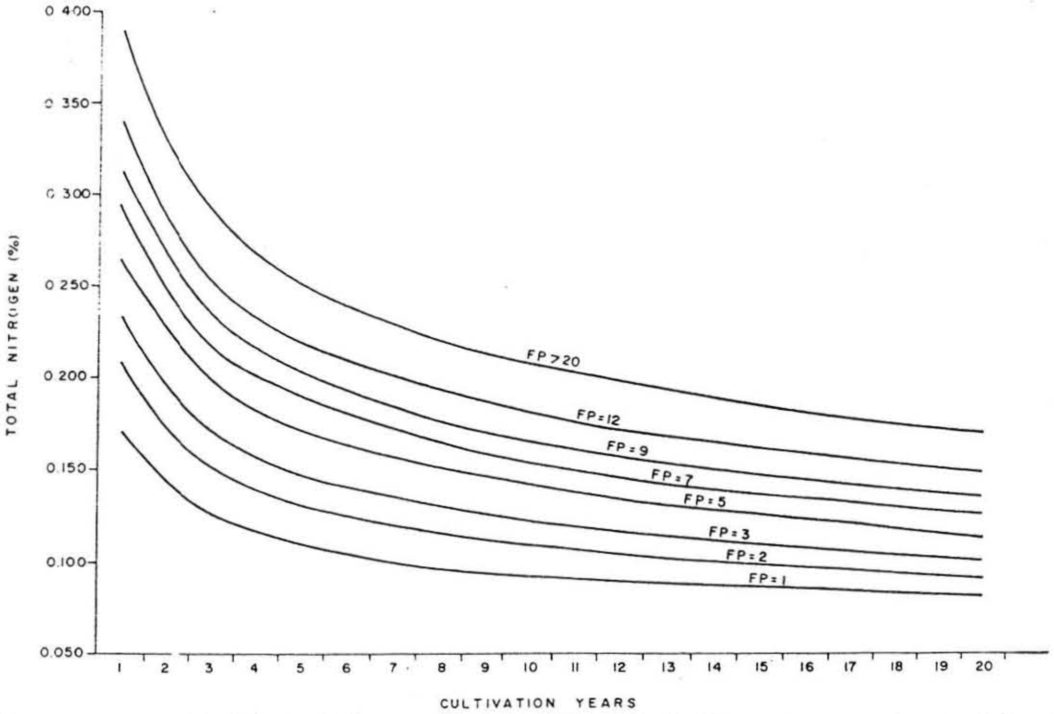


Fig. 16: Relationship Between Total Nitrogen and Cultivation Years with Fixed Fallow Periods

3.2.2.3 Effect on Exchangeable Bases, pH, Available Phosphorus, Ammonium and Nitrate

Table 13 along with others, shows the relationship between the two independent variable (fallow periods and age of cultivation), and exchangeable bases i.e. calcium, magnesium, potassium; pH, available phosphorus, ammonium and nitrate. The relationships of fallow periods are positive and weak to moderate with calcium (r=0.39), magnesium (r=0.57), P (r=0.50), percentage base saturation (r=0.58), available phosphorus (r=0.23) and nitrate (r=0.23). Curves rating fallow period with calcium and magnesium are shown in

Fig. 17. But the relationship between calcium/ magnesium and cropping years are not statistically significant at 5 percent probability level.

On the other hand, the relationships of cultivation years are negative and weak with these same chemical soil properties, except with magnesium and phosphorus with the 'r' values ranging from -0.03 for nitrate to -0.34 for calcium. The relationships of cultivation years with available phosphorus (r=0.33) and with magnesium (r=0.07) are positive and weak.

The weak to moderate relationships, be it positive or negative between most of the aforementioned soil chemical properties and the independent variables i.e., fallow periods and cultivation years indicate that these same soil chemical properties were not significantly affected by the independent variables.

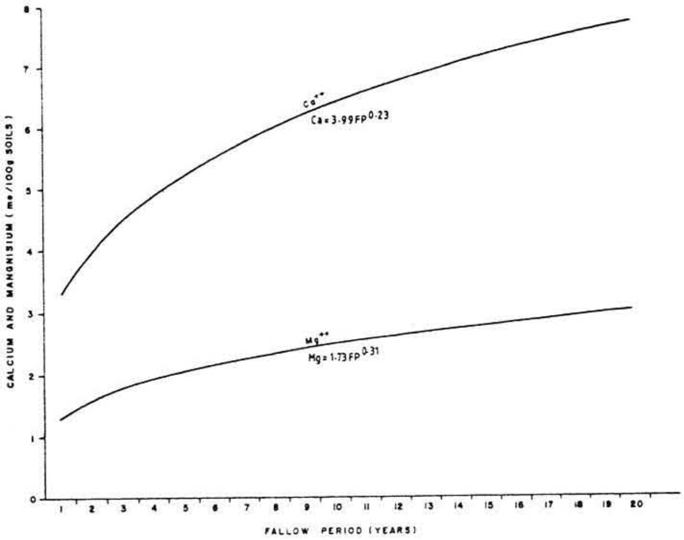


Fig. 17: Relationship between calcium and magnesium vs fallow periods for the on-farm plots

3.3 Comparative Assessment of Organic Matter Contents and Some Measured Soil Nutrients of the Fallow Fields and the On-farm Plots

In the preceding discussion (Sec. 3.1.2 and 3.2.2) we have examined the effect of fallow periods and cultivation years (with varying previous fallow periods) on the soils' fertility. Results of soil analysis have shown that there is a considerable change in organic matter and nutrient regeneration rates between fallow sites (fallow lands) and cultivated fields (on-farm plots). The regeneration rate of organic matter on cultivated fields (on-farm plots) was 8.5 percent greater than current fallow sites. Moreover, from the trend of increase of organic matter, it is learnt that the maximum actually measured organic accumulation (6.34%) was achieved in the on-farm plots (previous fallow lands) in less than 20 years (see Fig. 13). But this amount of organic matter accumulation is estimated to be attained in over 30 years on current fallow lands (see Fig. 11).

Similarly, rate of accumulation of total nitrogen in the on-farm plots (currently under cultivation) was 4.3 percent greater than in the current fallow sites. For magnesium and calcium rates of regeneration were also about 4.5 percent and 1.6 me/100g more in the former than in the latter (compare Fig. 12 and 17). Moreover, the average of each measured soils chemical properties in the previously fallow lands (now cultivated fields) was more than in the currently fallow lands (compare Table 14 and 17). With regard to these results, some explanation is in order.

In the study area a considerable proportion of cultivated fields are away from homesteads/settlements. Field observation and soil analyses indicate that the longer the distance away from homesteads, the more will be nutrient regeneration rates and vise versa. But now-a-days, cultivated fields have been extending from the middle part of the catchment to the peripheral areas i.e. away from the homesteads, most of which were under forest or bush cover.

TABLE 17

Mean and Variability Statistics of the Measured Dependent and Independent Variables for Samples, Fallow Sites (Current Fallow Lands)

Variables	Mean	Standard deviation	Coeff. of variation (%)
Fallow Period, FP (years)	7.25	5.2071	70.8221
Organic Matter (OM)(%)	5.1233	0.8965	17.4985
Total Nitrogen, N (%)	0.2216	0.0592	26.7148
Ammonium, NH_4^+ (ppm)	112.4167	14.6812	13.0592
Nitrate, $No3^-$ (ppm)	15.5	3.4509	22.2639
Phosphorus, Brady, P (ppm)	90.3417	179.8029	199.0254
Phosphorus, Olsen, P (ppm)	18.9833	19.9133	104.8990
Calcium, Ca^{++} (me/100g)	5.7250	1.9189	33.5180
Magnesium, Mg^{++} (me/100g)	2.5583	1.3277	51.8977
Potassium, K (me/100g)	0.6708	0.4167	62.1199
Cation Exchange Capacity ECE (me/100g)	15.2417	2.7747	18.2047
Base Saturation, BS (%)	60.1667	21.3061	35.4126
PH	5.9083	0.4122	6.9766
Bulk Density, BD (g/cm^3)	1.1950	0.1848	15.4644
Sand (%)	43.6667	7.6910	17.6130
Silt (%)	30.8333	6.9260	22.4673
Clay (%)	25.5000	3.2051	12.5690

n = 12

The fields close to homesteads had been recurrently cultivated with short crop fallow cycle since long time and most of them were under fallow during the field work. This is reflected by the type of vegetation grown on these fallow lands. Grass was the dominant vegetation cover of most of the selected sites, with patches of bushes here and there (see Appendix I). True grass cover is effective in controlling soil erosion, but grasses, being lower form of plants and short-rooted, their capacity to transform nutrients from sub-soils is much lower than trees and bushes. Fallow lands close to homesteads were dominantly under grass cover during the field survey and had been relatively degraded so that their restoration capacity upon fallowing was considerably reduced. Thus, the farmers are abandoning the more degraded nearby areas with lower rates of nutrient regeneration and advanced to the better productive peripheral areas.

The peripheral areas where some of the on-farm plots were set had been either cultivated with long fallow period or preserved to be potential areas for coffee cultivation by land lords or 'local balabats' before the revolution. These areas were less recurrently cultivated and less affected by grazing animals and had well regenerated physical and chemical properties of the soils. However, the peripheral areas, being steep sloped, are very susceptible to soil erosion and subsequent degradation. Hence, if the present trend of farming practice is allowed to continue and extend to these areas, the observed higher nutrient rate of regeneration which is also manifested itself in higher maize crop production per unit area would easily be reverted into even lower nutrient regeneration rate in shorter time than that observed in the current fallow lands.

3.4 The Effect of Fallow Periods and Intensity of Cultivation on the Productivity of Haplic and Albic Lixisols

In the preceding discussion (Sec. 3.1 to 3.3) an attempt has been made to evaluate the effect of fallow periods and cropping years on the major physical and chemical properties of the soils. In the investigation, both fallow periods and intensity of cultivation affected some of the properties of the soils. But soil fertility was one way of assessing the productivity of soils. The other aspect of evaluation of the productivity of these soils was interms of crop yields. In fact, soil productivity is the capacity of soil for producing a specified plants/crops or sequence of plants under specified system of management; productivity emphasizes the capacity of soil to produce crops and should be expressed in terms of yield (Brady, 1985 p. 614). Furthermore, stocking (1985, p. 402) argues that yield is a useful proxy to productivity, because of its ability to be measured, its meaningfulness to farmers and planners and its ability to be quantified in monetary terms. This method of evaluation becomes effective provided external factors remain similar.

3.4.1 Effect on Maize Yield

The relationship between maize yield and fallow periods/cultivation years is given below:

$$MY = 1455.34\ CY^{-0.38}\ FP^{0.48}$$

Where MY = Maize Yield (kg/ha)
FP = Fallow Period (in years)
CY = Cultivation Years

The above relationship is significant in explaining the trend of maize increase and decrease with fallow periods and cultivation years respectively (F=41.7, Prob>F,0.0001). According to the above estimate, about 77.4 percent of the variation in maize production is explained by the effect of fallow period and cultivation years (see Table 18). Result of the above equation was employed to draw Fig. 18 and 19. Fig. 18 shows the effect of fallow periods (with fixed cultivation years) on maize production. Accordingly, maize yield was predicted to increase by 28 percent with every double increase in fallow periods (e.g. 1,2,4,8,16 years). For instance, the rate of increase varies from 28 percent between the first and second years of fallow to 4.8 percent between 10 and 11 years of fallow period.

TABLE 18

Result of Analysis of Variance and Summery of Parametric Estimates for Maize Yield

Source of Variation	DF	Sum of Squares	Mean of Squares	F-Value	Prob>F
Model	2	3.22	1.61	41.66	0.0001
Error	24	0.93	0.04		
Total	26	4.15			

Parametric Estimates

Variables	Parametric estimates	Beta coefficient	Standrad error	Multiple cor.	Partial R-square	Model R-square	F-value	Prob>F
Intercept	7.2830	0.0000	.1605	-	-	-	** 2058	0.0001
FP	0.4890	0.7984	.0631	.7513	.5647	.5647	** 67	0.0001
CY	-0.3807	-0.4625	.0799	.8811	.2116	.7764	** 22	0.0001

On the other hand, the observed differences of maize yield among the on-farm plots denoted by curve lines in Fig. 18 show the degradative effect of cultivation years on the soils fertility (Sec. 3.2.2). From this we realize that on plots with the same fallow periods, maize yields were higher in those plots with short cultivation years. This is most probably because of the fact that the short cultivated plots were less affected by the impact of the intensity of cultivation.

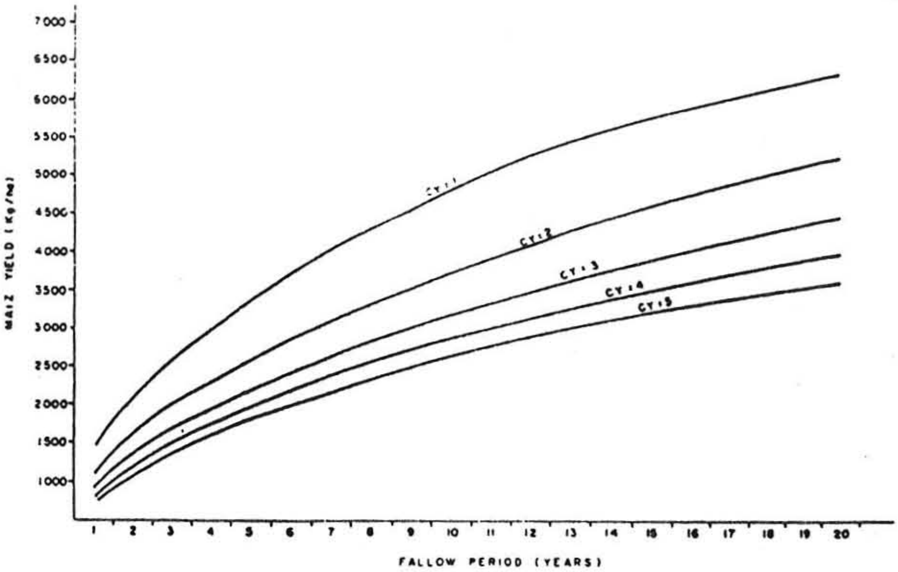


Fig. 18: Relationship between maize yield and fallow period for fixed cultivation years

On the contrary, Fig. 19 shows the detrimental effect of continuous years of cultivation on maize yield. This means, maize yield on the on-farm plots decreases by 20 percent with every double increase in cropping years. It was estimated that maize yield decreasing rate varies from 20 percent in the first and second years of cultivation to 3.7 percent between 10 and 11 years of cultivation.

The variabilities in maize yield production per unit area between plots of the same cultivation years was due to the differences in their previous fallow periods. Similar variations are also observed regarding maize height and biomass production (Sec. 3.4.2).

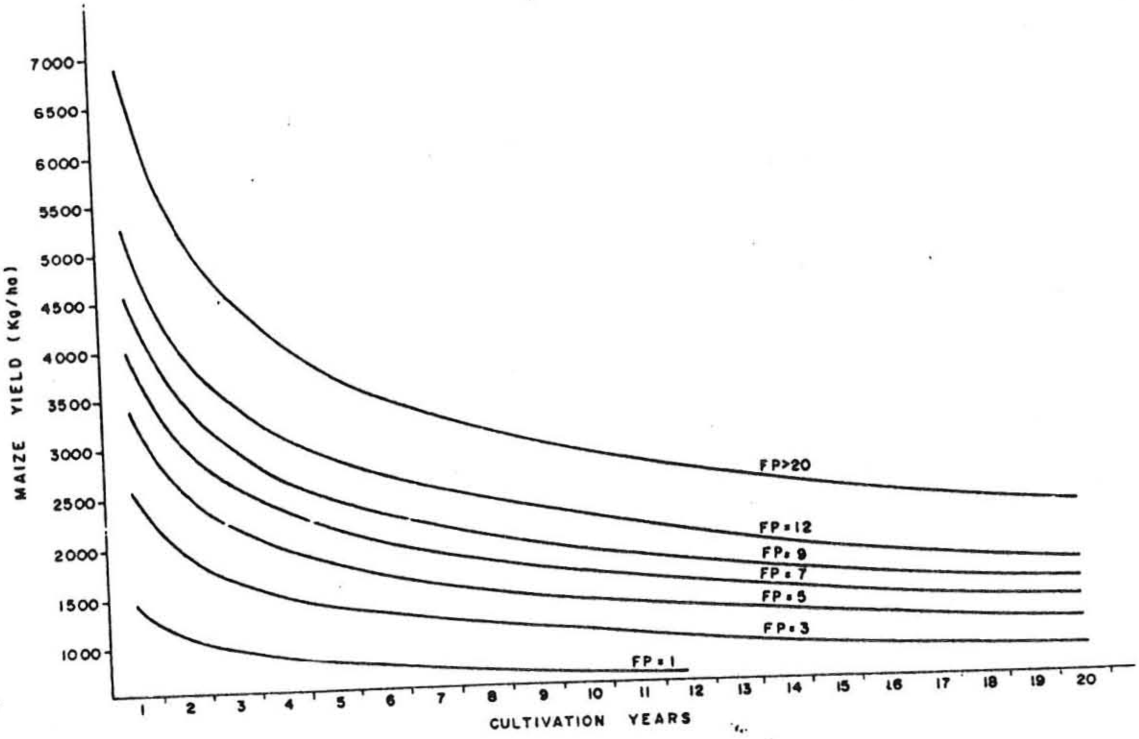


Fig. 19: Relationship Between Maize Yield and Cultivation Years for Fixed Fallow Periods

3.4.2 The Effect on Crop Growth and Biomass Production

In Table 14, it is shown that the average maize height at harvest is 2.99 meters with coefficient of variation of 18.3 percent. The lowest measured height (2.16 meter) was from a plot fallowed for 5 years and cultivated for 5 years while highest (4.08 meter) was from a plot fallowed for 20 years and cultivated for 1 year (Appendix 2). The differences in maize height between the on-farm plots was tested using analysis of variance (Table 19) and it was significant at 5 percent probability level.

TABLE 19

Results of Analysis of Variance and Summery of Parametric Estimates for Crop Growth (maize height)

Analysis of Variance

Source of Variation	DF	Sum of Squares	Mean of Squares	F-Value	Prob.>F
Model	2	0.65	0.32	43.47	0.0001
Error	24	0.18	0.01	-	-
Total	26	0.82	-	-	-

Parametric Estimates

Variables	Parametric estimates	Beta Coefficient	Standard error	Multiple correlation	partial R-square	Model R-square	F-value	Prob>F
Intercept	0.88	0.0000	0.07	-	-	-	156.04**	0.0001
FP	0.21	0.72	0.07	0.66	0.43	0.43	56.62**	0.0001
CY	-0.22	0.59	0.03	0.88	0.35	0.78	38.96**	0.0001

Crop growth (maize height) was predicted using the following relationship:

$$H = 2.41\ FP^{0.21}\ CY^{-0.22}$$

where H = maize height
FP = fallow period (years)
CY = cultivation years

The above model is significant at 5 percent probability level (Table 19) and about 78.4 percent of the variation in maize height is explained by the effects of fallow period and cropping years. The beta index (Table 19) shows that previous fallow period was more important in affecting maize growth. The coefficient of fallow period i.e. 0.21, which means maize height increased by 15 percent for every doubling (100%) increase in fallow period. In other words, the rate of maize height increases at declining rate with further increase in fallow periods. The reverse trend was predicted regarding the effect of cultivation years on maize growth.

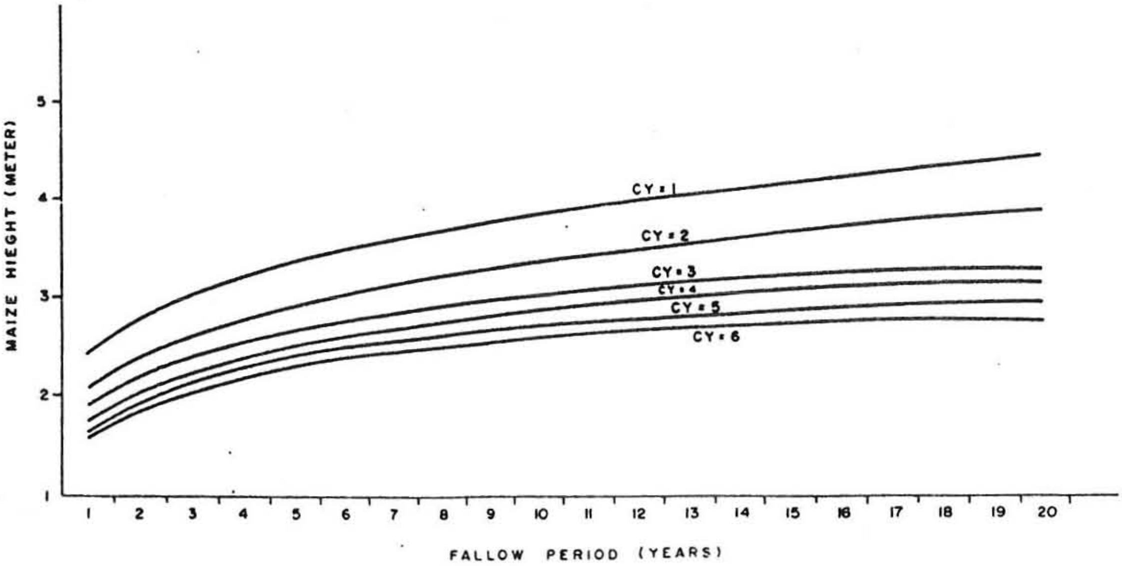


Fig. 20: Relationship Between Maize Height and Fallow Periods for Fixed Cultivation Years

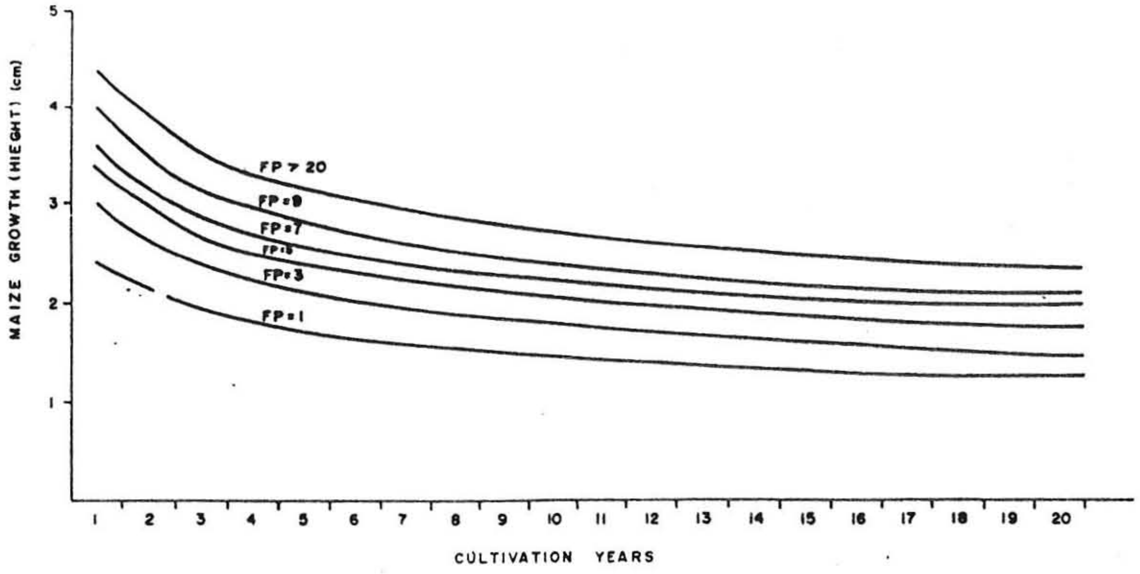


Fig. 21: Relationship Between Maize Height and Cultivation Years for Fixed Fallow Periods

The biomass production was also evaluated for the on-farm plots. The average biomass production was 13618 kg/ha with coefficient of variation of 28.4 percent. The highest biomass production 25223 kg/ha measured from a plot fallowed for twenty years and cultivated for one year, whereas the lowest (8486 kg/ha) was from a plot previously fallowed for three years and cultivated for three years.

The variations in biomass production between the on-farm plots were again tested using analysis of variance (Table 20) and significant at 0.05 probability level. It was

TABLE 20
Results of Analysis of Variance and Summery of Parametric Estimates for Crop Biomass (maize)

Analysis of Variance					
Source of Variation	DF	Sum of Squares	Mean of Squares	F-Value	Prob.>F
Model Error	2 24	1.51 0.44	0.75 0.019	40.49** -	0.0001 -
Total	26	0.95	-	-	-

Parametric Estimates								
Variables	Parametric estimates	Beta Coefficients	Standard errors	Multiple correlations	partial R-squares	Model R-squares	F-value	Prob>F
Intercept	9.05	0.0000	0.1111	-	-	-	6628**	0.0001
FP	0.35	0.78	0.04	0.73	0.53	0.53	63.02**	0.0001
CY	0.28	-0.49	0.06	0.88	0.24	0.77	25.22**	0.0001

estimated using the following relationship:

$$B = 8509\ FP^{0.3471}\ CY^{-0.2778}$$

where = B - biomass (kg/ha)
FP - fallow periods (years)
CY - cultivation years

About 77 percent of the variation in biomass production was estimated to be due to the previous fallow and cultivation years (Table 20).

Based on the results, biomass production on the on-farm plots increases by 20 percent with geometric progression increase in fallow periods and decreases by 15 percent with increase in cultivation years in similar fashion (see Fig. 22 and 23).

As have been in the previous cases, the variation in biomass production which are shown by curve lines in Fig. 22 and 23 is expected to be due to the combined effect of fallow and cultivation years.

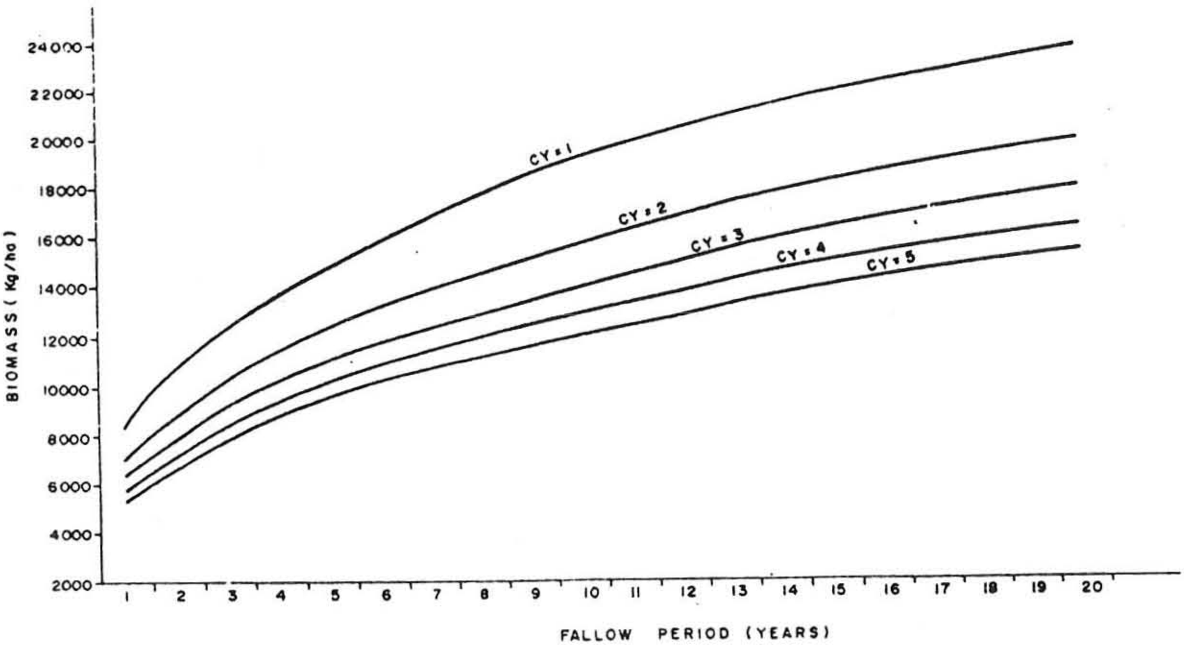


Fig. 22: Relationship Between Biomass Production and Fallow Periods for Fixed Cultivation Years

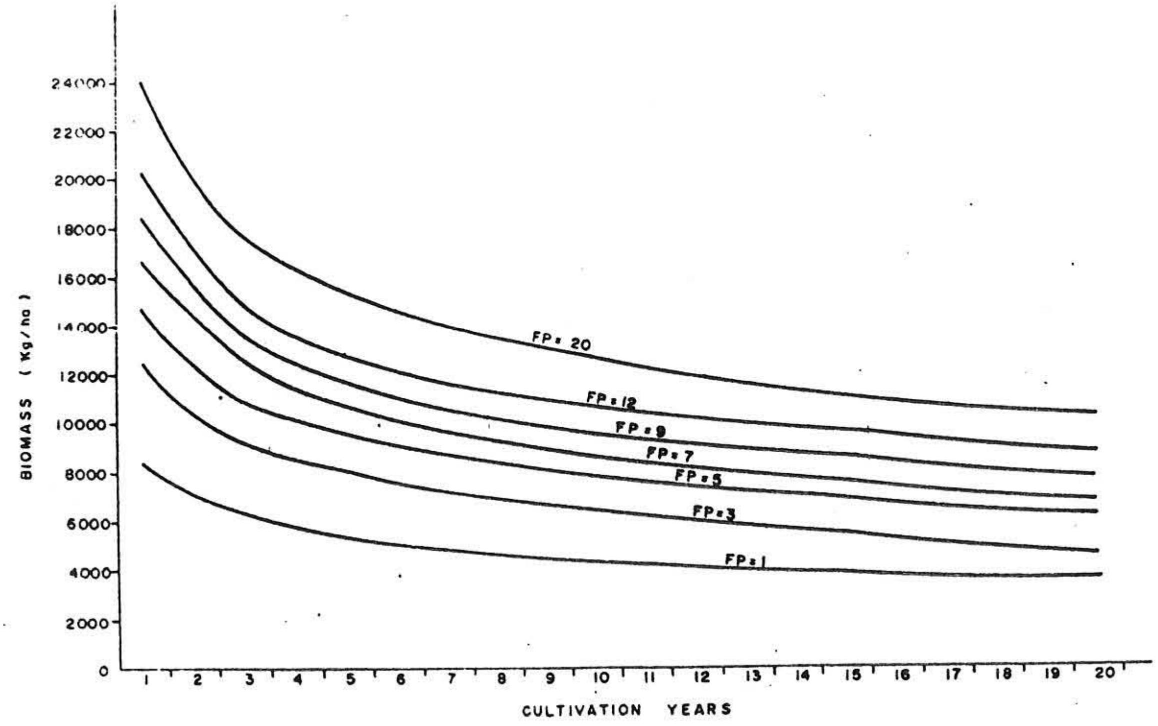


Fig. 23: Relationship Between Biomass Production and Cultivation Years for Fixed Fallow Periods

3.5 Summary

From the discussion presented so far (Sec. 3.1 to 3.4), the outcomes summarized below are important:

1. Relationship of fallow period vs soil productivity (crop yield, height and biomass)
   - positive relation, i.e.. increase of productivity of the soils with fallow periods,
   - but the rate of increase in soil productivity shows a progressive decline in time.

Reasons

- productivity of the soils increases with fallow periods because of the positive effect of fallowing in improving the physical and chemical properties of the soils (Sec. 3.1 to 3.3),

- the declining rates in the increase of soil productivity with fallow periods, particularly after 10 and 11 years of fallow, may be because, the soils reach a new nutrient regeneration equilibrium to the existing environmental characteristics.

2. Relationship of Cultivation Periods (Years) Vs Soil Productivity (Crop Yields)

- negative relation, i.e. decrease in productivity of the soils with increasing cultivation periods,

- but the decrease in soil productivity declines progressively in time, being faster in the early cultivation years and slower in the latter periods. (particularly after 1 to 4 years and becomes slow thereafter).

Reasons

- productivity of the soils declined with increasing years of cultivation, because cultivation years had the negative effect of inducing undesirable physical soil properties (e.g. high bulk density) and reducing soil fertility status, i.e. deplating/exausting the soils chemical make-up. It is also most likely that when fields are set for cultivation, erosion was accelerated because of the reduced vegetation cover,

- the declining rates of productivity loss with cultivation, particularly after 1 to 4 year, may be because the soils had progressively smaller reserve of nutrients for use by plants.

3. The Difference Between the Fallow Site and the On-farm Plots Upon Being Fallowed

- We have seen that the fallow sites (most of which were close to the homesteads) had lower levels of nutrients than the on-farm plots (most of which were located at greater distances from homesteads), given the same fallow period. The fallow sites had also lower rates of nutrient restoration than the on-farm plots upon being fallowed. The possible reason would be that the fallow sites, owing to their proximity to the established settlements, had suffered long cultivation-fallow cycles and thus, lost their original high level of soil fertility. The on-farm plots, on the other hand, because of their location at greater distances from the established settlements, had sustained short-lived cropping-fallow cycles and therefore relatively retained the original level of organic matter and nutrients.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

In wet weinadega agroclimatic zones of Illubabor highlands, which include the study area, i.e. Dizi catchment, farming has been going-on since long time by small scale farmers with long fallow without pronounced soil degradation and with sustained production. But the situations have been changing mainly in response to population pressure resulting from natural increase, long continued spontaneous immigration and recent settlers. Conceivably, the increaseof population pressure has resulted in a high man-land ratio or high population density per unit area and this in turn reduced fallow periods and increased intensity of cultivation.

This study had two objectives: (1) assessing the effect of fallow periods on soil fertility, evaluated in terms of soil physical and chemical properties, (2) evaluating the compounded effects of fallow periods and cultivation years on the soil fertility and productivity. The loss or gain of productivity was measured in terms of crop yield. Data on the soil and crop characteristics were collected through field and laboratory tests.

The experiment on sites with different fallow periods show that fallowing improves the physical and chemical properties of soils. The rate of replenishment of the soils was rapid in the earlier fallow period (from 1 to 11 years), but slows down with further increase in fallow periods.

The compounded effects of fallow periods and cultivation years were also investigated in the on-farm plots. Results of the experiments on the plots also reveal that previous fallow period have the effects of inducing favorable physical and chemical properties of the soils. The rate of regeneration of soil nutrient was similar to what was observed in the fallow sites i.e. being faster in the earlier fallow periods but slows down in the latter periods. It was also observed that the previous cultivation years had affected nutrient status of the soils. Those intensively cultivated plots/fields had lower status of soil nutrients than the plots cropped for short periods (years).

On the other hand, the findings of the investigation in the on-farm plots show the detrimental effects of cultivation years on soil physical and chemical properties and thereby on crop yields. Generally, the increased period of cultivation resulted in undesirable physical properties (e.g. high bulk density) and loss of nutrients. The destruction of favorable physical properties and loss of essential nutrients were higher in the early cultivation years (e.g. 1 to 4 years) and thereafter decrease in a slower rates. The decline in soil chemical properties was even more rapid in the early cultivation years than the rates of restoration in the early fallow period.

The length of previous fallow periods had also effects on the levels and rates of deterioration of the soils' physico-chemical properties upon being cultivated. Generally, soils with previous long fallow periods, when used for cultivation loose their favorable physical and chemical properties over longer periods of time than plots/fields with short previous fallow periods. This is because, thelong fallowed fields had more stable physical conditions and more soil nutrients than short fallowed soils.

The results that came into view from the analyses of data were the differences in the rate of soil nutrient regeneration with fallow periods i.e. between the on-fallow sites and the on-farm plots (previously fallowed fields).

Generally, the rates of restoration of the on-farm plots (under cultivation during the survey period) were higher than the rates of the fallow sites. The lower organic matter status and lower rate of restoration of the fallow sites/fields than those of the on-farm plots, was possibly because the fallow sites/fields, before being fallowed, had suffered recurred or short cropping-fallow cycles for a long period of time and therefore, the soils were reduced to lower fertility and productivity. On the other hand, the on-farm plots most of which are not only far from the established settlements, but were lesser recurrently cultivated than the fallow fields. Hence, they relatively retainedū higher organic matter/nutrients than the fallow sites.

From the above, it is realized that there has been a change in intensity of cultivation i.e. from long fallow to short fallow. The latter system, generally reduces the soils to a higher degradation and loss of fertility and productivity. A large proportion of the study area at present experiences short fallow-cropping system. Therefore, if the present landuse practice remains as it is, the whole study area and similar areas in the agroclimatic zone will be reverted not only to low level of productivity but also to low rates of nutrient regeneration capacity.

4.2 Recommendations

We have seen that fallowing has the effect of improving soil physical and chemical properties. Intensity of cultivation, on the other hand, reduces soil productivity (ability to yield crops) through detrimental effects on physical and chemical properties of the soils. Indeed, intensification of agriculture, mainly through short duration of cropping-fallow cycles, results not only in soil with low productivity status, but also with low nutrient regeneration capacities even if laid fallow. This emphasizes the need for longer fallow and reduced intensity of cultivation in order to maintain sustained production.

Nevertheless, the increasing population requires change from shifting cultivation with long fallow to short fallow practice and even intensified permanent cultivation system in the future. Should production be sustained, such a system must be accompanied by elaborate synthesis of various conservation measures that are not only effective in combating soil degradation, but also viable under the prevailing human and natural environment of the study area and adjacent regions.

The writer of this study recommend, the following landuse, soil conservation and management possibilities

Change of Landuse Possibilities:

* Encourage the growing of perennial cash crops on increasing larger areas. The deep-rooted perennial crops can facilitate nutrient recycling by brining them up from a considerable depth in the soil profile. They can also protect the soils from erosion more effectively than annual crops. In this respect, the indigenous coffee plant can be encouraged. However, its development has been retarded because of mainly low local price relations and volatile (insecure) land tenure.

High dependence on coffee and susceptibility to the risk of its price variation can be mitigated through diversified perennial crop production such as orange, banana and mango which have already introduced and showed promising results, could be included in the system on a larger scale. Others like, cocoa and rubber crops can also be tried. Along with the development options pointed above, favourable marketing systems should be devised.

* Root crops such as Irish potatoes, sweet potatoes and taro (Godere) have also shown considerable yeilds. The yield for sweet potatoe, for example, was estimated to be as high as 160 quintals per hectare which is about three times higher than maize yield. But, this requires change in dietery habit and storage facilities.

* Intensifying cultivation of annual food crops on alluvial soils (a long numerous stream valleys) to reduce shortage of food. The full utilization of swampy land through adequate drainage technique at the end of the main rainy season and irrigation practice, during the dry season, may ameliorate the intensity of cultivation of rain-fed practice of farming. Moreover, arable fields can also be used for perennial cash crops.

* Considerable area in the study catchment is at one time under fallow where luxuriant grass is possible. This indicates that a wider possibility of livestock raising. In fact, livestock rearing, other than being a source of animal power for farm operation, meat for consumption and income

for various cash needs, can provide manure which is in short supply in and around the study area. But, the prevalence of tropical livestock disease such as Trypanosomiasis and its carrier tse-tse fly limit the development of livestock farming. Veterinary services aimed at controlling the disease and eradication of tse-tse flies can widen the possibility of livestock rearing.

Soil Conservation and Management Possibilities

* Agro-forestry where annual crops are integrated particularly with fruit bearing trees/bushes is another alternative measure. In this respect, hedge of leguminous or line of trees (fruit bearing) can be planted with annual crops. This measure not only enhence nutrient recycling and control erosion, but also enables the farmers to generate additional income.

* On fields cultivated with annual crops, soil fertility can be ameliorated by mulching and green manuring. Mulching with crop residues and weeds (which are aboundantly available in the study area) can increase organic matter content and organically derived nutrients such as nitrogen and phosphorus and also provide effective cover against soil erosion.

Commercial fertilizers can also be tested and used.

* Recently (1988), Soil Conservation Research Project has introduced mechanical conservation measures at experimental level. These are level bund, level fanya-juu, graded bund, graded fanya-juu and grass strip. It is too early to comment on the merits and demerits of these structures. But, the graded structures seem to be appropriate for the study and similar areas.

Other Measures to be Taken

* The increase in the size of population has resulted in change from long to short fallow period, already. Consequent on this, there has been considerable soil degradation and loss of productivity. Thus, large scale immigration of people to the study and similar areas through resettlement programme have to be controlled to avoid further intensification of cultivation and associated problems.

* One of the most serious problems that farmers face at present is the destruction of crops by wild animals such as baboons, monkeys and wild pigs. Although protecting the crops against wild animals probably takes the largest proportion of time and labour investment in the whole processes of crop production, about one third of maize crop in the fields was estimated to be destroyed by wild animals. This indicate that all the above recommended alternative

measures to the problem, may not be effective enough unless some sort of mechanisms are devised to control these destructive wild animals.

REFERENCES

Adugna Negeri (1984): "The Effect of Liming and Phosphorus Application on Dry Matter and Grain yield of Bread Wheat (Triticum aestivum) Grown on Red soils of Gimbi and Nedgo Wereda of Wellega Region." M.A. Thesis, Addis Ababa University.

Agboola, A. (1987): "Soil Conservation and Small Scale Farming."A paper presented at the 6th International Soil Conservation Conference, Ethiopia and Kenya, Nov. 6-18, 1989.

Aggrey-Mensah, W. (1984): Degradation of the Ethiopian Highlands and Action to Combat It: Social and Economic Implications, Cost and Benefits. Addis Ababa, FAO/MoA, Joint Project, EHRS Report.

Allan, W. (1965): The African Husbandmen. Oliver and Boyed, Westport, Connecticut (U.S.A.).

Arakeri, H.R and R. Donahue, 1985: Principles of Soil Conservation and Water Management. Oxford and IBM Publishing Col, New Delhi.

Aregay Waktola (1988): "Ethiopian Experience in Soil and Water Conservation Proceedings." Ethio-German Research Conference on the Problem of Man and His Biosphere. Addis Ababa 4-16.

Baum, E. (1968): Landuse in the Kilombero Valley: From Shifting towards Permanent Farming. In Ruthernberg (ed.), Small Holder Farming and Small Holder Development in Tanzania. Nunichean, C. Hurst and Col, London.

Belay Tegene (1990): "Erosion: Its Effect on Properties and Productivity of Eutric Nitosols in Gununo Area, Southern Ethiopia, and Some Techniques of Its Control." PhD Thesis, University of Berne.

Brady, N.C. (1985): The Nature and Properties of Soils. Eurasia Publishing House Ltd., New Delhi.

Bridges, E.M. (1979): World Soils, Cambridge University Press.

Bunting, B.T. (1969): The Geography Soils. Hachinson University Library, London.

Bunting, A.H. and Edward Bunting (eds.) (1984): The Future of Shifting Cultivation in Africa and the Task of Universities; Proceedings of International Workshop on Shifting Cultivation, Teaching and Research at University Level. Ibadan, Nigeria, July 4-9, FAO, Rome.

Buring, P. 1970. Introduction to the Study of Soils in Tropical and Sub-tropical Regions. Oxford and IBH Publishing Co. New York.

Butzer, K.W. 1981: Rise and Fall of Axum: A Geoarcheological Interpretation. American Antiquity, Vol. 46, No. 3, 471-495.

Constable, M. (1984): Degradation of the Ethiopian Highlands and Actions to Combat It: Economic Implications, Cost and Benefits. Addis Ababa, FAO/MoA Joint Project, EHRS Report.

CSO, 1984: Population and Housing Census, Analytical Report in Illubabor, Addis Ababa.

Daniel Gemechu (1969): The Location and Topography of Ethiopia. Addis Ababa University Press, Addis Ababa.

_________________ (1988): "Some Aspects of Environment and Crop Macro Climate in Southwestern Ethiopia;" Proceedings of the Workshop on Famine Experience and Resettlement in Ethiopia. IDR, (unpublished).

Dietrick, R.V. (1967): Cotton Farming in Sukumaland. In Ruthenberg (ed.). Small Holder Farming and Small Holder Development in Tanzania. Munichean C. Hurst and Co., London.

FAO (1977): Guidelines for Soil Profile Description. Rome.

FAO (1988): Soil Map of the World, Final Version, Rome.

Fearnside, P.M. (1987): Human Carrying Capacity of Brazilian Rain Forest Region. Geographic Review, Vol. 17, No. 4.

Gbadegesin, A. (1989): "Soil Organic Matter and Moisture Conservation in the Savanna Soils of South-West Nigeria." A Paper Presented at 6th International Soil Conservation Conference. Ethiopia and Kenya, Nov. 6-18, 1989.

Greenland, D.J, and R. Lal, (eds.) (1977): Soil Conservation and Management in the Humid Tropics. John Wiley and sons, Chichester, Eng.

Hagman, J. (1991): The Soils of Dizi/Illubabor: Their Genesis, Potential and Constraints for Cultivation, Research Report 18, SCRP, Addis Ababa.

Hatch Agricultural Division (1979): Soil Fertility Manual. Potash and Phosphate Institute, Atlanta (U.S.A.).

Hunter, J.M. and G.K. Ntiri, (1978): Speculation on the Future of Shifting Agriculture in Africa. The Journal of Developing Areas. pp. 183-208.

Hurni, H. (1983): Agro-forestry Improvements for Shifting Cultivation Systems. Mountain Research and Development, Vol. 3, No. 4.

_________ (1985): Erosion, Productivity and Conservation Systems in Ethiopia. A Paper Presented at the 5th International Soil Conservation Conference, Nov. 3-9, Maracay, Venezuela, 20pp. (Published in proceedings 1987).

__________ (1986): "Degradation and Conservation of the Soil Resources in the Ethiopian Highlands," A Paper Presented at the 1st International Workshop on African Mountains and Highlands, Addis Ababa, October, 13-27.

__________ (1986): Guidelines for Development Agents on Soil Conservation in Ethiopia. CFSCDD, MoA, Addis Ababa.

Kazmin, V. (1973): Geological Map of Ethiopia. Imperial Government of Ethiopia, Ministry of Mine, Addis Ababa.

__________ (1975): Geological Map of Ethiopia. Ministry of Mine and Energy, Addis Ababa.

Kloos, H. and Aynalem Adugna (1988): Settler Migration, Proceedings of the Workshop on Famine Experience and Resettlement in Ethiopia. IDR (published in proceeding, (1990).

Koutsoyiannis, A. 1979: Theory of Economics, An Introductory Exposition of Econometric Methods. The Macmillan Press Ltd., Hong Kong, P. 134.

Kpakole, K.G. and A. Bahun, (1984): Ecological Problems Inherent in the Practice of Shifting Cultivation in Africa. In Bunting, A.H. and Edward Bunting (eds.). The Future of Shifting Cultivation in Africa and the Task of Universities; Proceedings of International Workshops in Shifting Cultivation, Teaching and Research at University Level. Ibadan, Nigeria, July 4-9, FAO, Rome.

Lagemann, J. (1977): Traditional Farming System in Eastern Nigeria. African Studies, No. 98. Institute of West Forum, München.

Lal, R. (1985): Research Achievements Towards Soil and Water Conservation in the Tropics: Potential and Prospects In Ildefonso Pla Sentis (ed.); Proceedings of IV International Soil Conservation Conference, Nov. 3-9, Maracay, Venezuela.

________ (1977): A Brief Review of Erosion Research in the Humid Tropics of South-East Asia. In Greenland and Lal (eds.), Soil Conservation and Management in Humid Tropics. John Wiley and Sons, Chichester, Eng. pp. 203-210.

Landon, J.R. (ed.) (1984): Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics. Longman Inc., Newyork.

Moher (1971): The Geology of Ethiopia. Haile Sellassie I University Press, Addis Ababa.

Morgan, W.B. (1955): Farming Practices, Settlement Pattern and Population in S.E. Nigeria. The Geographical Journal 121: 320-33.

Odum, W.A. (1971): Fundamental of Ecology. Sounders, W.B. Company, Philadelphia, U.S.A.

Okigbo, B.N. (1977): Farming Systems and Soil Erosion in West Africa. In Greenland and Lal (eds.), Soil Conservation and Management in the Humid Tropics. John Wiley and Sons, Chichester, Eng. pp. 151-165.

Okigbo, B.N (1984): Problems and Prospects of Shifting Cultivation. In Bunting, A.H. and Edward Bunting (eds.). The Future of Shifting Cultivation in Africa and the Task of Universities, Proceedings of International Workshop on Shifting Cultivation, Teaching and Research at University Level, July 4-9, Ibadan, Nigeria, FAO, Rome.

Oxby, C. and J.H. Boerboom, (1985): Alternatives and Improvements to Shifting Cultivtion on the East Coast of Madagascar. In Changes in Shifting Cultivation in Africa, Seven Case Studies, FAO, Rome.

Ruthenberg, H. (1980): Farming Systems in the Tropics. Oxford University Press, London.

RRC (1985): "Resettlement a Lasting Solution for the People in Drought Affected Areas," Addis Ababa.

Sanchez, P.A. (1976): Properties and Management of Soils in the Tropics. John wiley and Sons, New York.

"Soil Conservation Research Project Volume 9, 1991: Eight Progress Report (year 1988). By K. Herweg and M. Grunder, 66-76 pp; addis Ababa."

Solomon Abate (in prep.). "Landuse Dynamics, Soil Degradation and Potential for Sustainable Agriculture in Metu Area, Illubabor."

Stauder, J. (1971): The Majangir Ecology and Society of South Western Ethiopian People. Cambridge University Press.

Stocking, M. (1984): Erosion and Soil Productivity: A Review of Soil Conservation Programme. ANGLS/FAO, Rome.

____________ (1986): Tropical Red Soils: Fertility, Management and Degradation: Discussion Paper No. 189, School of Developmental Studies, University of East Anglia. Norwich.

Upton, M. (1987): African Farm Management, Cambridge University Press, Cambridge.

Webster, C.C. and P.N. Wilson, (1980): Agriculture in the Tropics. Longman, London.

Westphal, E. (1975): Agricultural Systems in Ethiopia. Agricultural Research Report 826. Joing Publication of College of Agriculture, HSIU, Ethiopia and Agricultural College University of Wageningen, The Netherlands.

Wiersum, K.E. (1985): Development of Ecological Methods of Upland Farming. In Changes in Shifting Cultivation, Seven Case Studies. FAO, Rome.

Wolde-Michael Kelecha (1987): The Glossary of Ethiopian Plant Names. Addis Ababa.

Wood, A.P. (1977): "Resettlement in Illubabor Province, Ethiopia." PhD Thesis, University of Liver Pool.

World Bank (1987): Ethiopia: Recent Economic Development and Future Prospects for recovery and Growth.

Wright, C. (1984): An assessment of Causes, Severity, Extent and Probable Consequence of Degradation in the Ethiopian Highlands. Addis Ababa, FAO/MoA Joint Project, EHRS Working Paper No. 3.

Yasin Ahmed, 1990: "A Historical Study of Land Tenure System in Highland Illubabor." M.A. Thesis, Addis Ababa University.

Young, A. 1976: Tropical Soil Survey. Published by the Press Syndicate of the University of Cambridge, Cambridge (UK).

APPENDIX I

Definition of Terms

Albic Lixisols - Lixisols having an albic E Horizon; lacking gleyic and stagnic properties.

Cultivation year/Cropping year - is the extent of landuse intensity, measured in terms of continual cropping of a cultivated field under traditional fallow system.

Soil Degradation - is a long term loss in its productivity or it is the rate of change in soil quality in relation to crop production.

Fallow Period - is a rest period or a period of natural regeneration of degraded crop fields.

Haplic Lixisols - Lixisols lacking an albic E horizon; lacking ferri properties and plinthite with in 125 cm of the surface; lacking gleyic and stagnic properties within 100 cm of the surface.

Lixisols (a major soil group) - are soils having an argic B horizon which has CEC of less than 24 Cmol kg/ha clay at least in some part of the B horizon and base saturation of 50 percent or more through out the B horizon; lacking mollic A horizon; lacking the E horizon abruptly over lying the slowly permeable horizon.

On-fallow sites/Fallow sites - were sample sites, selected from fallowed fields of different ages.

On-farm plots - were experimental plots set on cultivated maize fields, but were previously fallowed for various years before being set for cultivation.

Regeneration rate/Restoration rate - is the rate improvement of soil chemical soil properties through recycling of soil plant system (fallowing).

Shifting Cultivation - is a period of alteration of cropping with a period in which the land is rested without cropping.

APPENDIX II

Fallow Periods and the Evaluated Soil Physical and Chemical Properties of the Fallow Sites

Site No.	Fallow period (yrs)	Organ. matter (%)	N2 (%)	$NH4^+$ (ppm)	$NO3^-$ (ppm)	$PO4^-$ (Bray) (ppm)	$PO4^-$ (Olsen) (ppm)	Ca^{++} (me/ 100g)	Mg^{++} (me/ 100g)	K^+ (me/ 100g)	CEC (me/ 100g)	BS (%)	PH -	BD g/cm^3	Infi-ltr. cm/hr	Sand (%)	Silt (%)	Clay (%)	Type of Vegetation
F-1	1	4.968	0.189	104	20	77	17	6.0	2.9	1.4	14.4	72	5.8	1.4	-	36	32	26	Grass fallow
F-3	2	3.899	0.189	95	13	52	10.7	2.1	2.0	0.22	14.4	30	5.6	1.4	-	47	27	26	Grass fallow
F-8	3	4.071	0.175	118	12	36.1	11.4	3.0	2.4	0.48	17.2	34	5.2	1.24	-	51	27	22	Grass fallow
F-7	4	4.242	0.182	107	15	18	12	6.0	0.2	0.34	15	43	5.7	1.21	-	44	30	26	Grass fallow
F-5	5	5.242	0.175	127	20	44	10	5.1	2.0	1.23	14.7	56	6.0	1.23	-	37	35	28	Grass to bush fall.
F-4	6	5.830	0.231	107	14	51	5	4.7	2.2	0.55	15.9	47	5.4	1.13	-	44	28	28	Grass to bush fall.
F-13	7	4.382	0.203	104	11	34	19	6.5	1.7	0.6	8.8	100	6.5	1.21	-	49	29	22	Grass fallow
F-12	8	4.451	0.161	123	15	659	81	6.8	2.5	0.88	12.9	78	6.4	1.5	-	53	23	24	Grass fallow
F-6	9	5.934	0.259	109	15	20	15	5.5	1.5	0.13	15.6	46	5.7	1.11	-	37	31	32	Bush fallow
F-9	10	5.934	0.273	95	13	27	17	6.2	4.0	1.2	19	60	6.1	0.98	-	55	25	26	Bush fallow
F-2	11	6.210	0.308	147	16	30	16.7	9.4	4.3	0.63	19.4	74	6.1	1.09	-	41	33	26	Bush to forest fal.
F-10	20^+	6.310	0.343	113	22	36	13	7.4	5.0	0.39	15.6	82	6.4	0.84	-	30	50	20	Forest fallow

Fallow Periods, Cultivation Years and the Evaluated Physical and Chemical Properties of the On-farm Plots

Plot No.	Fallow period (yrs)	Cultivation (yrs)	Maize yield (kg/ha)	Biomass (kg/ha)	Maize height	Organic matter (%)	N2 (%)	NH4$^+$ (ppm)	NO3$^-$ (ppm)	PO4$^-$ (Bray) (ppm)	PO4$^-$ (Olsen) (ppm)	Ca^{++} (me/100g)	Mg^{++} (me/100g)	K$^+$ (me/100g)	CEC (me/100g)	BS (%)	PH -	BD g/cm^3	Infiltr. cm/hr	Sand (%)	Silt (%)	Clay (%)
P-26	3	2	2300	85767	2.61	4.175	0.189	94.1	21.1	95.5	17.4	6.9	3.3	1.0	17.6	64	5.8	1.12	28.2	24	46	26
P-17	3	3	10967	84867	2.26	2.484	0.119	89.2	15.7	84.8	22.7	6.4	1.7	0.6	16.3	53	5.8	1.2	38.6	45	27	28
P-16	3	4	1860	10103	2.36	3.312	0.140	92.6	9.6	69.5	20	3.2	1.5	0.23	13.4	37	5.0	1.31	53.8	50	26	24
P-20	5	1	2990	12433.3	3.29	5.520	0.273	94.4	15.2	42.8	24	4.3	3.4	0.6	16.8	49	5.2	1.03	59	35	39	26
P-22	5	2	3050	13430	2.76	4.880	0.231	94.9	10.3	52.8	24	5.8	4.1	0.4	17.9	58	5	1.23	86.3	41	29	30
P-15	5	3	2450	12076.7	2.71	4.037	0.224	56.2	15.7	60.8	10.7	5.2	3.6	0.7	14.6	65	5.9	1.21	43.1	36	40	24
P-9	5	4	1700	8050	2.47	3.623	0.196	95	43	52	29.4	5.9	2.9	1.3	16.5	61	5.9	1.42	28.8	45	29	26
P-1	5	5	1260	97764	2.16	3.726	0.175	92.3	8.1	4.5	3.6	0.7	12.9	0.7	12.9	68	5.9	1.02	35	36	42	22
P-23	7	2	36867	15656.7	3.26	5.969	0.287	136.6	16.6	108.2	36	9.4	2.3	1.5	16	83	5.9	1.22	81	34	42	24
P-2	7	3	2990	14766.7	2.81	5.342	0.252	85.7	13.8	71.5	22.7	5.9	3.9	0.6	17	62	5.9	1.22	77.5	38	36	26
P-12	7	4	2056.7	9316.7	2.31	4.071	0.196	94.9	19.6	65	24.7	6.7	3.0	0.74	14	72	6.3	1.19	34.7	29	39	32
P-21	7	5	2636.7	13306.7	2.64	4.584	0.203	94.9	19.6	56.1	18.7	4.3	3.5	1.1	22.6	40	4.5	1.31	35.8	42	26	32
P-19	9	2	4246	15683	3.67	6.107	0.245	93.8	15.2	72.8	17.4	11.2	2.6	0.8	22.2	66	5.4	1.21	76	37	41	22
P-10	9	3	3503	14286	2.83	5.555	0.298	86.8	19.4	51.4	18.7	7	3.6	0.6	15.3	73	5.3	1.27	41.3	39	37	24
P-14	9	4	2416	11230	2.64	4.934	0.175	92.6	13.7	112.6	15.4	5.5	1.9	0.5	14	54	6.1	1.25	48.1	45	29	26
P-7	9	5	2113	10760	2.48	5.003	0.203	94.9	12.6	54.1	28.1	6.5	4.1	0.4	18.6	59	5.8	1.23	62	42	36	22
P-5	12	2	4840	20550	3.85	6.314	0.308	92.1	12.8	211	27.4	9	4.7	1.1	15.1	100	7.0	1.16	99.8	51	31	18
P-25	12	3	4013.3	15713.3	3.51	5.899	0.266	90.9	29.9	54.1	14.7	8.6	3.6	0.9	15.9	82	6.4	1.11	70.5	46	32	22
P-13	12	4	2966.7	12560	2.72	5.072	0.273	86.8	15.2	71.2	17.4	7.5	4.7	0.2	18.8	66	6	1.22	65	40	38	22

Contd. Appendix III

Plot No.	Fallow period (yrs)	Cultivation (yrs)	Maize yield (kg/ha)	Biomass (kg/ha)	Maize height	Organic matter (%)	N2 (%)	NH4^{+} (ppm)	NO3^{-} (ppm)	PO4^{-} (Bray) (ppm)	PO4^{-} (Olsen) (ppm)	Ca^{++} (me/ 100g)	Mg^{++} (me/ 100g)	K^{+} (me/ 100g)	CEC (me/ 100g)	BS (%)	PH -	BD g/cm^{3}	Infiltr. cm/hr	Sand (%)	Silt (%)	Clay (%)
P-6	12	5	3450	14426.7	3.47	5.209	0.203	88	12.6	38.1	25.4	7.1	4.9	1.0	17.1	76	6.2	1.23	77	42	36	22
P-11	12	6	2640	12213.3	2.94	3.963	0.196	92.6	7.3	279.9	48.1	7.0	3.6	0.6	15.3	73	6.2	1.48	48	32	38	30
P-27	20+	1	4693	25223	4.08	6.383	0.308	113	22	36	13	7.4	5	0.39	15.6	82	6.4	0.80	91	30	50	20
P-4	20+	2	5646	19096	3.92	6.072	0.343	97.3	23.3	175.5	26.7	10	4.1	0.9	15	100	7.5	1.04	77.5	44	36	20
P-3	20+	3	4560	16106	3.79	6.210	0.273	97.3	17.1	194.4	38.7	8.7	4.6	0.8	14	100	7.2	0.96	113.2	40	36	24
P-18	20+	4	3580	13810	2.99	5.382	0.259	92.6	14.6	84.8	22.7	5.8	2.6	0.3	16.8	55	5.1	1.07	70	29	41	30
P-24	20+	5	3860	16040	3.05	5.520	0.238	89.2	49.7	54.1	69.5	4.9	5.0	0.9	18.4	59	5.6	1.26	75.2	28	40	26
P-8	20+	6	3433	14030	2.92	4.954	0.224	83.4	12.2	43.6	21.8	7.5	4.7	0.63	13.8	100	6.5	1.04	77.5	34	42	24

APPENDIX IV

Survey Questionnaire Prepared for all Household Heads in the Catchment

1. Age:
   a) <18 years b) 19-25 years c) 26-35 years d) 36-45 years e) 45^+ years

2. Sex:
   a) Male b) Female

3. Years of leaving in this area:
   a) <1 year b) 2-5 years c) 6-10 years d) 11-20 years e) 20^+ years

4. Number of your family:
   a) Number of Male ______ b) Number of Female ____

5. Age group of your family members:
   a) <18 years b) 19-25 years c) 26-35 years d) 36-45 years e) 45+ years

6. Number of birth in your family in this year __________

7. Number of death in your family in this year __________

8. What proportion of your farmland do you use measure (in timad)? __________

9. Your farm size (in ha) __________

10. Do you have fallow land? Size (in timad) ____________

11. If yes, for how long was fallowed? (in years) _________

12. Do you have land under coffee? a) Yes ____ b) No ____

13. If yes, size (in timad) ____________

14. Do you have sufficient farm land? a) Yes ___ b) No ____

15. If no, what is the major reason?
    a) high number of family size
    b) nationalized by the government for large scale agricultural development
    c) all
    d) others ____
    ____
    ____

16. Why don't you use crop-rotation?
    a) due to wild animals problem

b) lack of farm land
c) all
d) others ____
____

17. Did you plant new coffee plant this year?
a) Yes _____ b) No _____

18. If no, why not?
a) due to lack of land to be cultivated
b) due to lack coffee seedlings
c) due to decrease in coffee price
d) all
e) others ____
____
____

19. If yes, how many timad did you plant this year? ________

20. How many quintals of coffee did you produce this year?
____

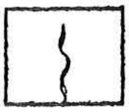
21. What are your major problems related to the farming activities?
a) wild animals
b) soil erosion
c) lack of cultivated land
d) others ____
____
____

22. The number of livestock you own
a) Ox ____ b) Cow ____ c) Calf ____ d) Sheep ____
e) Goat ____ f) Mule ____ g) Doney ____ h) Horse ____

APPENDIX V

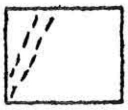
Soil Profile Description

5.1 Legends



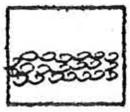
Very fine roots (< 2 mm)

Fine to medium sized roots (1-10 mm)



Tree roots (> 10 mm)

Gravel, stones (7.5-25 cm)

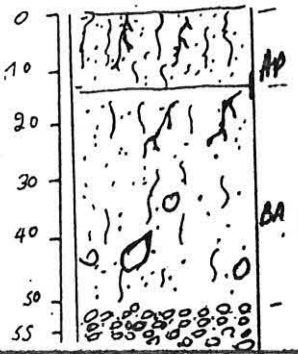


Stone line (gravely layer)

5.2 Profiles of the fallow sites (F1 to F-10)

Profile No.: F-1
Location: Dizi, about 800 m northeast of EP1
Date of Description: 22/6/90
Elevation: 1650m
Aspect: South facing
Slope class: 23%

Slope Position: Middle part of a linear slope
Landuse/vegetation: Grass fallow
Previous Fallow Period: 1 year
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 50 cm



0-13 cm

AP Dark reddish brown (5YR3/4) moist and yellowish red (5YR4/6) dry; loam; moderate, medium to fine sub-angular blocky; plastic and slightly sticky wet, slightly hard dry; common, coarse and fine roots; gradual smooth boundary.

13-53 cm

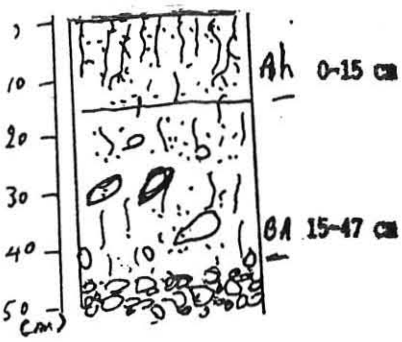
BA Dark reddish brown (2.5YR3/4) moist and reddish brown (2.5YR4/4); sandy clay loam; moderate, medium sub-angular blocky; plastic and sticky wet, hard dry; few coarse and fine roots; clear wavy boundary.

										Exchangeable Cations (me/100g soil)			
Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	K+	Ca++	Mg++	CEC
0-13	Ah	5.8	4.968	0.189	20	104	77	17	72	1.4	6.0	2.9	14.4
13-53	BA	5.4	1.9	-	15	106	37	19	-	0.34	5.8	0.1	-

		Texture=mm			Bulk Density g/cm³	Total Pore Vol.	Accumulated water intake (cm) after				
Depth (cm)	Horizon	Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-13	Ah	36	38	26	1.4	46.2					

Profile No.: P-3
Location: Dizi, about 600 south Yember PA office
Date of Description: 22/6/90
Elevation: 1660 m
Aspect: South facing
Slope class: 23%

Slope Position: Middle slope of a linear slope
Landuse/Vegetation: Grass fallow
Previous fallow period: 2 years
Surface Stoniness: Class 0, no stones
Drainage Class: 0, well drained
Soil Depth: > 50 cm



Ah Dark reddish brown (5YR3/4) moist and reddish brown (5YR5/4) dry; sandy clay loam, weak, medium and sub-angular blocky; slightly plastic and slightly sticky wet; slightly hard dry; common, coarse and fine roots; gradual, smooth boundary.

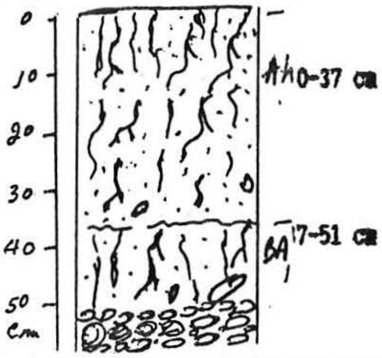
BA Dark red (2.5YR3/6) moist and reddish brown (5YR4/4) dry; sandy clay loam; slightly plastic and slightly sticky wet, hard dry; few fine roots; clear, wavy boundary.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-15	Ah	5.6	3.899	0.189	13	95	52	10.7	30	0.22	2.1	2.0	14.4
15-47	BA	5.8	1.6	-	23	107	31	15	-	0.13	3.5	0.8	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-15	Ah	47	27	26	1.4	45.9					

Profile No.: P-8
Location: Dizi, about 300 m south of the highest peak
Date of Description: 24/6/90
Elevation: 1670 m
Aspect: South facing
Slope class: 24%

Slope position: Middle part of a long convex slope
Landuse/vegetation: Grass fallow
Previous fallow period: 3 years
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 55 cm



Ah Dark reddish brown (5YR3/2) moist and dark reddish grey (5YR4/2) dry; sandy clay loam; weak to moderate, medium and sub-angular blocky; slightly plastic and sticky wet, slightly hard dry; aboundant very fine and fine roots; gradual smooth boundary.

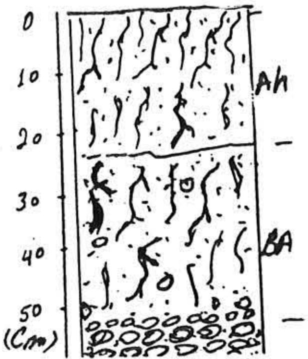
BA Dark red (2.5YR3/6) moist and yellowish red (5YR3/6) dry; sandy loam; weak to moderate, medium and sub-angular blocky; few coarse and fine roots; gradual, smooth boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-37	Ah	5.2	4.071	0.175	12	118	36.1	11.4	34	0.48	3.0	2.4	17.2
37-51	BA	3.7	1.9	-	21	98	9	4	-	0.26	2.3	2.6	-

Depth (cm)	Horizon	Texture-mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm³	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-37	Ah	51	27	22	1.24	52.1					

Profile No.: P-7
Location: Dizi, about 400m northeast of Dizi Stat.
Date of Description: 23/6/90
Elevation: 1674 m
Aspect: North facing
Slope class: 20%

Slope position: Middle part of long convex slope
Landuse/Vegetation: Grass fallow
Previous fallow period: 4 years
Surface Stoniness: Class 0, no stones
Drainage Class: 0, well drained
Soil depth: 52 cm



0-22 cm

Ah Dark reddish brown (5YR3/4) moist and reddish brown (5YR4/4) dry; sandy loam; moderate, medium, and sub-angular blocky slightly plastic and slightly hard dry; aboundant coare and fine roots; clear and smooth boundary.

22-52 cm

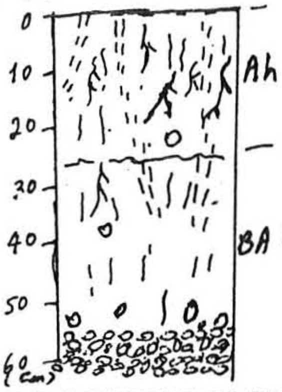
BA Dark reddish brown (2.5YR3/4) moist and red (2.5YR4/6) dry; sandy clay loam; moderate, medium sub-angular blocky slightly plastic and plastic wet, hard dry; few coarse and fine roots; clear, wavy boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CBC
0-22	Ah	5.7	4.242	0.182	15	107	18	12	43	0.2	6	0.2	15
22-52	BA	5.9	2.0	-	22	109	11	39	-	0.12	3.7	1.5	-

Depth (cm)	Horizon	Texture-mm			Bulk Density g/cm³	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-22	Ah	44	30	26	1.21	53.2					

Profile No.: P-5
Location: Dizi, about 900m northwest Dizi school
Date of Description: 15/6/90
Elevation: 1610 m
Aspect: North facing
Slope class: 23%

Slope position: Middle part of a convex slope
Landuse/Vegetation: Bush fallow
Previous fallow period: 5 years
Surface stoniness class: 0, no stones
Drainage class: 0, well drained
Soil depth: > 52 cms



Ah 0-25 cm

Ah Dark reddish brown (5YR3/3) moist and brown (7.5YR5/4) dry; clay loam; moderate, medium and sub-angular blocky to crumb; slightly plastic and slightly sticky wet, slightly hard dry; common coarse and fine roots; clear, smooth boundary.

BA 25-57 cm

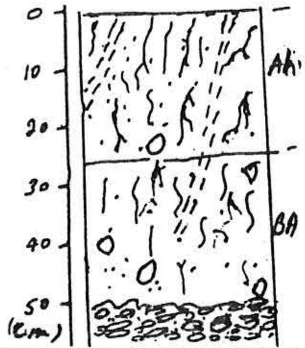
BA Dark red (2.5YR3/6) moist; sandy loam to sandy clay loam; moderate, medium and sub-angular blocky; slightly plastic and sticky wet, slightly hard dry; frequent coarse and fine roots; clear and wavy boundary.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-25	Ah	6.0	5.242	0.175	20	127	44	10	56	1.23	5.1	2.0	14.7
25-57	BA	5.9	1.7	-	10	109	38	11	-	0.74	2.7	2.5	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-25	Ah	37	35	28	1.23	52.2					

Profile No.: F-4
Location: Dizi, about 500m south Yember PA office
Date of Description: 22/6/90
Elevation: 1658 m
Aspect: West facing
Slope class: 23%

Slope Position: Middle part of slightly convex slope
Landuse/Vegetation: Grass to bush fallow
Previous fallow period: 6 years
Surface stoniness: Class p, no stones
Drainage class: 0, well drained
Soil depth: > 55 cms



0-26 cm

26-50 cm

Ah Dark reddish brown (5YR3/3) moist and reddish brown (5YR4/4) dry; clay loam; moderate, medium and sub-angular blocky to crumb; slightly plastic and slightly sticky wet, slightly hard dry, common coarse and fine roots; gradual, smooth boundary.

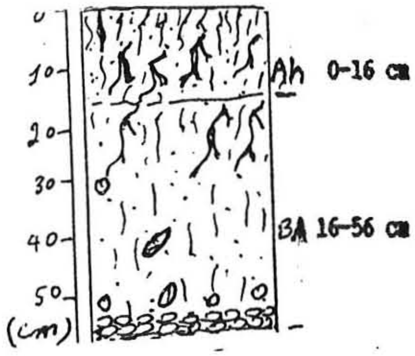
BA Dark reddish brown (2.5YR3/4) moist and reddish brown (5YR4/3) dry; sandy loam to sandy clay loam; slightly plastic and slightly sticky wet, hard dry; few coarse and fine roots; clear wavy boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-26	Ah	5.4	5.831	0.231	14	107	51	5	47	0.55	4.7	2.2	15.9
26-50	BA	5.6	2.1	-	17	98	23	10	-	0.23	2.1	2.6	-

Depth (cm)	Horizon	Texture-mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-26	Ah	44	28	28	1.13	55.9					

Profile No.: P-13
Location: Dizi, about 400m east of Dizi station
Date of Description: 26/690
Elevation: 1615 m
Aspect: East facing
Slope class: 23%

Slope position: Middle part of a linear slope
Landuse/vegetation: grass fallow
Previous fallow period: 7 years
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 56 cms



Ah Very dark brown (10YR2/2) moist and grayish brown (10YR5/2) dry; loam moderate, medium sub-angular blocky to crumb; slightly plastic and slightly sticky wet, slightly hard dry; aboundant fine and very fine roots; gradual, smooth boundary.

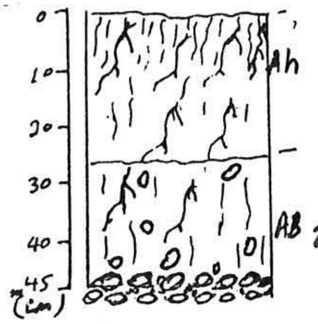
BA Dark reddish brown (5YR2.5/2) moist and pale brown (10YR6/3) dry; moderate, medium and sub-angular blocky; slightly plastic and slightly sticky wet, hard dry; frequent fine and very fine roots; gradual, smooth boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-16	Ah	6.5	4.382	0.203	11	104	34	19	100	0.6	6.5	1.7	8.8
16-56	AB	5.8	1.5	-	19	107	25	16	-	0.25	5.3	1.4	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-16	-	49	29	22	1.21	53.2					

Profile No.: F-12
Location: Dizi, about 700m southwest of Yember PA office
Date of Description: 25/6/90
Elevation: 1640 m
Aspect: West facing
Slope class: 24%

Slope position: Middle part of a slightly convex slope
Landuse/vegetation: Grass fallow
Previous fallow period: 8 years
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 60 cms



0-26 cm

Ah Very dusky red (2.5YR2.5/2) moist and dark reddish brown (5YR3/3) dry; silty clay loam; moderate, medium and sub-angular blocky to crumb; slightly sticky wet, slightly hard dry; aboundant fine and very fine roots; gradual, smooth boundary.

26-45 cm

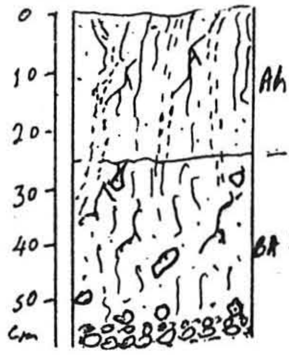
AB Dark reddish brown (2.5YR2.5/4) moist and reddish brown (5YR4/3) dry; moderate, medium and sub-angular blocky; slightly plastic and sticky wet, hard dry; few fine and very fine roots; clear, wavy boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil)			
										K+	Ca++	Mg++	CEC
0-26	Ah	6.4	4.451	0.161	15	123	659	81	78	0.88	6.8	2.5	12.9
26-45	AB	6.4	1.6	-	24	109	265	54.8	-	0.41	6.5	3	-

Depth (cm)	Horizon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-26	Ah	53	23	24	1.5	41.9					

Profile No.: P-6
Location: Dizi, about 900m northwest Dizi school
Date of Description: 23/6/90
Elevation: 1650 m
Aspect: Northwest facing
Slope class: 24%

Slope position: Middle part of a convex slope
Landuse/Vegetation: Bush fallow
Previous fallow period: 5 years
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 70 cm



Ah 0-24 cm

Ah Dark reddish brwon (5YR3/2.5) moist and dark brown (7.5YR4/2) dry; clay loam; moderate to strong, medium and fine crumb; slightly plastic and slightly sticky wet; soft dry; common coarse and fine roots; gradual, smooth boundary.

BA 24-55 cm

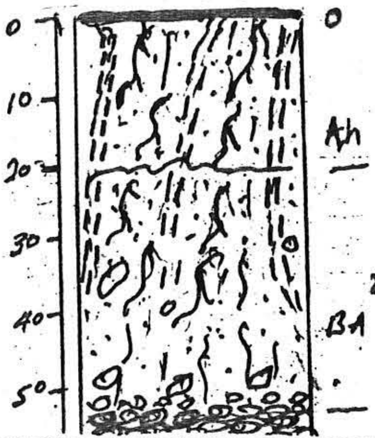
BA Dark red (2.5YR3/6) moist and dark reddish brown (5YR3/4) dry; sandy clay loam, moderate, medium to fine and sub-angular blocky; slightly plastic and slightly sticky wet, slightly hard dry.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-24	Ah	5.7	5.934	0.259	15	109	20	15	46	0.13	5.5	1.5	15.6
24-55	BA	5.6	2.3	-	14	107	37	11	-	0.21	2.2	2.5	

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-24		37	31	32	1.11	56.7					

Profile No.: F-9
Location: Dizi, about 600m northeast of EP1
Date of Description: 24/6/90
Elevation: 1690 m
Aspect: South facing
Slope class: 25%

Slope position: Middle part of a long convex slope
Landuse/Vegetation: Bush to forest fallow
Previous fallow period: 10 years
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 53 cms



0-2 cm An organic horizon formed from dead leaves and litters (with approx. more than 25% OM content)

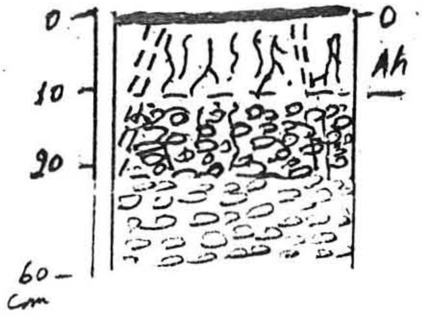
0-20 cm **Ah** Very dark gray (5YR3/1) moist and dark reddish grey (5YR4/2) dry; sand clay loam, moderate to strong, medium to fine and crumb; slightly plastic and slightly sticky wet, soft dry; frequent coarse and fine roots; clear and smooth boundary.

20-53 cm **BA** Dark reddish brown (2.5YR3/4) moist and reddish brown (2.5YR4/4) dry; moderate, medium to fine and sub-angular blocky; slightly plastic and sticky, wet, slightly hard dry; frequent coarse and fine roots; clear smooth to boundary.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-20	Ah	6.1	5.934	0.273	13	95	27	17	60	1.2	6.2	4.0	19
20-53	BA	5.2	2.4	-	12	164	25	6	-	0.63	5.3	1.6	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-20	Ah	55	25	20	0.98	62.2					

Profile No.: P-2	Slope Position: Middle part of a short convex slope
Location: Dizi, about 700m northeast of EP2	Landuse/vegetation: bush fallow
Date of Description: 22/6/90	Previous Fallow Period: 12 years
Elevation: 1666m	Surface stoniness: Class 0, no stones
Aspect: Northwest facing	Drainage class: 0, well drained
Slope class: 28%	Soil depth: > 60 cms



0-4 cm 0 An organic horizon formed from dead leaves an

4-10 cm Ah Very dark brown (10YR2/2) moist and dark brown (10YR3/3) dry; loam; strong, medium and crumb; slightly plastic and sticky wet, soft dry; free tree roots and common coarse to very fine roots; clear, wavy boundary, slightly gravely.

10-60 cm E/B Reddish brown (2.5YR5/4) moist and yellowish red (5YR4/6) dry; sandy loam; weak, medium and sub-angular blocky; slightly plastic and slightly sticky wet, hard dry, very gravelly.

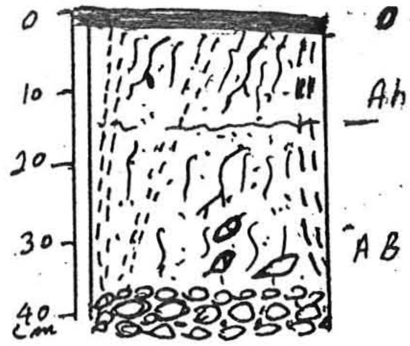
Depth (cm)	Horizon	PH H_2O 1:2.5	Organic matter (%)	Total N (%)	NO_3^- (ppm)	NH_4^+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-10	Ah	6.1	6.210	0.308	16	147	30	16.7	76	0.63	9.4	4.3	19.4
10-60	E/B	5.3	2.5	-	20	124	33	10	-	0.22	1.9	2.8	-

Depth (cm)	Horizon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-10	Ah	41	33	26	1.09	57.4					

rofile No.: F-10
ocation: Dizi, about 200m north of Tegrian
settlement area
ate of Description: 25/6/90
levation: 1660 m
spect: Southeast facing
lope class: 25%

Slope position: Middle part of a long convex
slope

Landuse/vegetation: Forest fallow
Previous fallow period: + 20 years
Drainage class: 0, well drained
Soil depth: > 38 cms



0-5 cm An organic matter horizon formed from dead leaves, litters.

5-14 cm **Ah** Very dark brown (10YR2/2) moist and dark brown (10YR3/3) dry; silty clay; strong, very fine and crumb; slightly plastic and slightly sticky wet, soft dry; common coarse roots and aboundant fine and very fine roots; gradual smooth boundary.

14-37 cm **AB** Dark reddish brown (5YR3/2) moist and reddish brown (5YR4/3) dry; moderate, medium and sub-angular blocky to crumb; slightly plastic and slightly sticky wet, soft dry; frequent coarse and both very fine and fine roots; clear, wavy boundary; slightly gravelly.

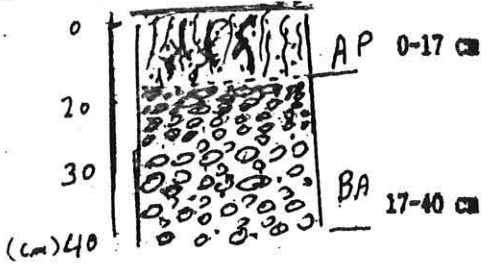
Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-19	Ah	6.4	6.316	0.343	22	113	36	13	82	0.84	7.4	5.0	15.6
10-37	AB	5.6	3.1	-	17	118	51	10	-	0.2	4.2	2.3	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-19	Ah	30	50	20	0.84	71.1					

5.2 Profiles of the on-farm plots (P-1 to P-27)

Profile No.: P-1
Location: Dizi, about 500m northeast of the Station
Date of Description: 20/12/89
Elevation: 1632 m
Aspect: Northern facing
Slope Class:

Slope position: Middle part of convex slopes
Landuse/vegetation: Maize field
Previous fallow period: 5 years
Previous cropping years: 5
Surface stoniness: Class 0, no stones
Soil depth: > 50 cm



Ap Reddish brown (5YR4/4) moist and light reddish brown (5YR6/4) dry; sandy clay loam; weak, medium and sub-angular blocky, slightly, slightly plastic, wet; weak to slightly hard dry; frequent fine roots; clear wavy boundary; slightly gravelly.

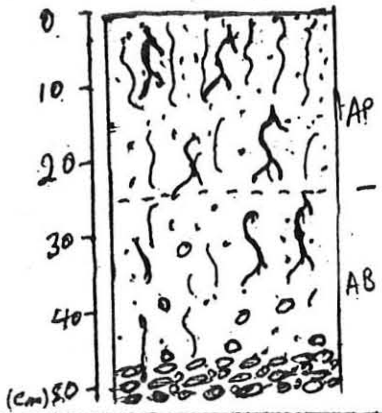
BA Yellowish red (5YR5/6) moist and reddish yellow (5YR6/6) dry; sandy loam; slightly plastic and slightly sticky wet; hard dry; few fine roots; gradual smooth boundary; very gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-17	Ap	5.9	3.726	0.175	8.1	92.3	65.5	25.8	68	0.7	8.1	4.5	12.9
17-40	BA	5	0.82	-	8	92.2	66	26	-	0.6	4.5	3.6	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-17	Ap	42	26	32	1.02	-	21	34.5	44	59.5	86

Profile No.: P-2
Location: Dizi, southern side of the highest peak
Date of Description: 21/12/89
Elevation: 1750 m
Aspect: Southern facing
Slope class: 30%

Slope position: Convex slope, middle slope
Landuse/vegetation: Maize field
Previous fallow period: 7 years
Previous cropping years: 3
Surface stoniness: Class 0, no stones
Drainage class: Class 4, well drained
Soil depth: > 50 cm



0-25 cm **AP** Dark brown (7.5YR3/4) moist and dark reddish brown (5YR3/4) dry; loam; moderate, medium to fine and sub-angular blocky to grannular; slightly plastic, slightly sticky wet; slightly hard dry; frequent fine roots; gradual smooth boundary.

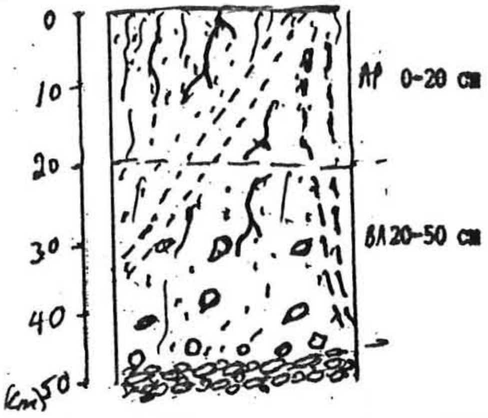
25-50 cm **AB** Reddish brown (5YR4/4) moist and dark reddish brown (2.5YR3/4) dry; plastic and sticky wet, hard dry; few fine roots; clear smooth boundary; slightly gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-25	Ap	5.9	5.342	0.252	13.8	85.7	71.5	22.7	62	0.6	5.9	3.9	17
25-50	AB	5.9	1.9	-	13	80	84	6.7	-	0.4	5.9	3.9	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-25	Ap	38	36	26	1.22	-	57	86	95	109.5	132

ofile No.: P-3
cation: Dizi, about 300m to the north Yember PA
te of Description: 22/12/89
levation: 1620 m
spect: Eastern facing
lope class: 25%

Slope position: Slightly convex
Landuse/vegetation: Maize field
Previous fallow period: > 20
Previous cropping year: 3
Drainage class: 0, well drained
Soil depth: > 50 cm



Ap Very dark greysh brown (10YR3/2) moist and reddish brown (5YR4/3) dry; clay loam; strong, medium to fine and crumb; slightly plastic and slightly sticky wet and soft dry, frequent fine roots; gradual smooth boundary.

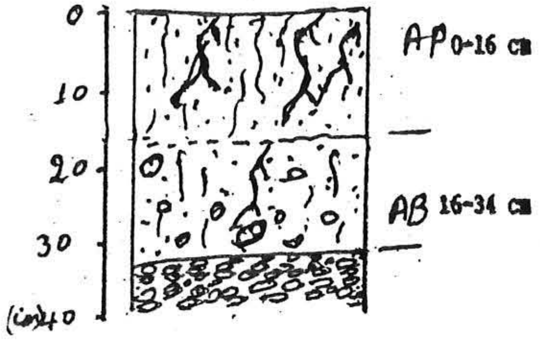
BA Dark reddish brown (5YR3/4) moist and yellowish red (5YR4/6) dry; sandy loam; moderate, medium and sub-angular blocky; plastic and sticky wet and slightly hard dry; few fine to coarse roots; gradual smooth boundary; slightly gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-20	Ap	7.2	6.210	0.273	17.1	97.3	194.4	38.7	100	0.8	8.7	4.6	14
20-50	BA	5	2.9	-	15	86	25	3	-	0.33	2.4	2.2	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm³	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-20	Ap	40	36	26	0.96	-	71.5	120.5	159.5	195	247.5

Profile No.: P-5
Location: Dizi, about 100m north of Tegrian Settlement area
Date of Description: 23/12/89
Elevation: 1680 m
Aspect: Southern facing
Slope class: 27%

Slope position: Middle part slightly convex slope
Landuse/vegetation: maize field
Previous fallow period: 12 years
Previous cropping years: 2
Surface stoniness: Class 0, no stones
Drainage class: Class 0, well drained
Soil depth: > 20 cm



Ap Very dark gray (10YR3/1) moist and dark reddish gray (5YR4/2) dry; clay loam; strong, medium to fine and crumb; slightly plastic and slightly sticky wet, soft to slightly hard dry; frequent coarse to fine roots, diffuse, smooth boundary.

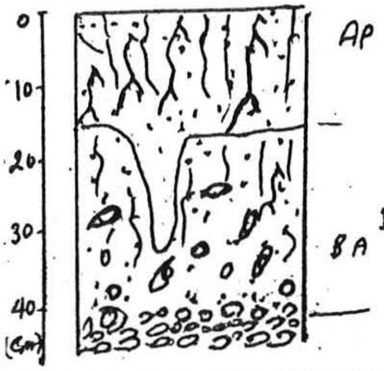
AB Dark brown (7.5YR3/4) moist and reddish brown (5YR4/3) dry; sandy loam; moderate, medium and sub-angular blocky, plastic and sticky wet, slightly hard dry; few fine roots; clear, smooth boundary; slightly gravelly.

Depth (cm)	Horizon	PH H2O 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-16	Ap	7	6.314	0.308	12.8	92.1	211	27.4	100	1.1	9	4.7	15.1
16-34	AB	5.4	1.7	-	15	81	64	5	-	0.6	3.3	1.7	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-16	Ap	51	31	18	1.16	-	48.5	80	116.5	162.5	173.5

Profile No.: P-6
Location: Dizi, about 500m to the northeast of
Yember PA office
Date of Description: 25/12/89
Elevation: 1680
Aspect: Northwestern facing
Slope class: 28%

Slope position: Middle slope convex slope
Landuse/vegetation: Maize field
Previous fallow period: 12
Previous cropping years: 5
Surface stoniness: 0, no stones
Drainage class: 0, well drained
Soil depth: > 46 cms



0-14 cm

Ap Dark reddish brown (5YR3/2) moist and dark brown (7.5YR4/4); loam; moderate, medium and sub-angular blocky; slightly plastic and sticky wet; slightly hard to hard dry; frequent medium to fine roots; diffuse, smooth boundary.

14-46 cm

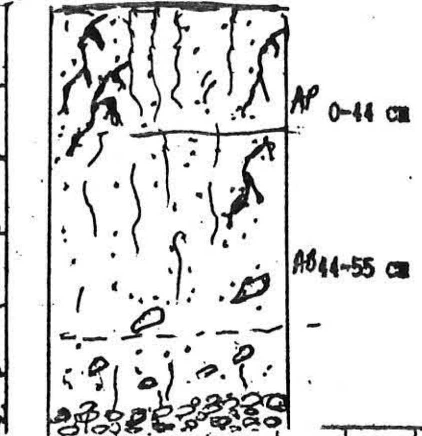
BA Dark reddish bown (2.5YR3/4) moist and dry; sandy loam; moderate, medium and sub-angular blocky; slightly plastic and sticky wet, hard dry; few fine roots; clear wavy boundary; slightly gravelly.

Depth (cm)	Hori-zon	PH H_2O 1:2.5	Organic matter (%)	Total N (%)	NO_3^- (ppm)	NH_4^+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-14	AP	6.2	5.209	0.203	12.6	88	38.1	25.4	76	1.0	7.1	4.9	17.1
14-46	BA	5.3	1.5	-	5	80	37	0	-	0.5	5.5	3.4	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-14	Ap	42	36	22	1.23	-	66.5	73	92.5	133.5	123.5

rofile No.: P-7
ocation: Dizi, about 500m northeast Yember PA Off.
ate of Description: 23/12/89
levation: 1660 m
spect: North facing
lope class: 29%

Slope position: Middle part convex slope
Landuse/vegetation: Maize field
Previous fallow period: 9
Previous cropping years: 5
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 60 cms



Ap Reddish yello (5YR6/6) moist and weak red (10YR4/4) dry; loam; weak to moderate, medium and sub-angular blocky; slightly plastic to plastic and slightly sticky wet; hard dry; common, medium to fine roots; gradual smooth boundary.

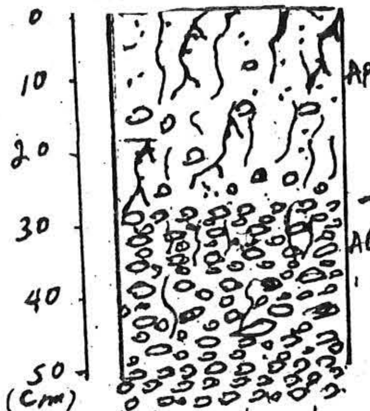
AB Dark reddish brown (2.5YR3/4) moist and reddish brown (5YR4/3) dry; sandy loam; moderate, medium and sub-angular blocky; plastic and sticky wet, hard dry; few very fine roots, clear, wavy boundary; slightly gravelly.

Depth (cm)	Horizon	PH H2O 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-44	Ap	5.8	5.003	0.203	12.6	94.9	54.1	28.1	59	0.4	6.5	4.1	18.6
44-55	AB	5.5	2.0	-	7	83	71	7	-	0.52	6.5	1.8	-

Depth (cm)	Horizon	Texture-mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-44	-	42	36	22	1.23	-	42.5	61.5	82	103.5	126

rofile No.: P-8
ocation: Dizi, about 300m north east of Yember
PA office
ate of Description: 25/11/89
levation: 1670 m
spect: Southeastern facing
lope class: 28%

Slope position: Middle part linear slope
Landuse/vegetation: Maize field
Previous fallow period (years): > 20
Previous cropping years: 6
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 50 cms



Ap Dark reddish brown (5YR3/3) moist and reddish brown (5YR4/3) dry; loam; weak to moderate, medium and sub-angular blocky slightly plastic and slightly sticky wet slightly hard dry; common very fine roots; clear; gradual boundary; slightly gravelly.

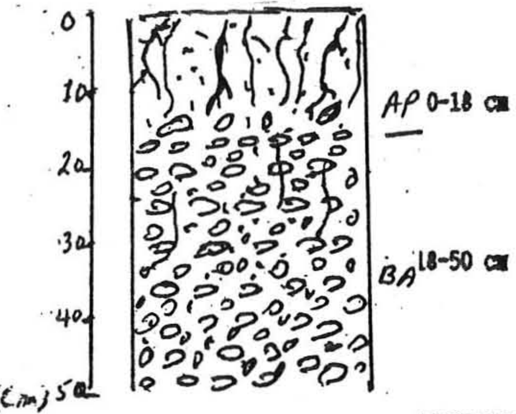
BA Dark reddish brown (2.5YR3/4) moist and dry; sandy clay loam; weak; medium and sub-angular blocky, plastic and sticky wet, hard dry; few very fine roots, very gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-28	Ap	6.5	4.954	0.224	12.2	83.4	43.6	21.8	100	0.63	7.5	4.7	13.8
28-53	BA	6.4	1.7	-	2	82	31	3	-	0.41	4.7	2.5	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-28	Ap	34	42	24	1.04	-	45.5	82	114.5	150.5	98

Profile No.: P-9
Location: Dizi, about 120m west of Yember PA Off.
Date of Description: 26/12/89
Elevation: 1672 m
Aspect: Southern facing
Slope class: 23%

Slope position: Middle part linear slope
Landuse/vegetation: Maize field
Previous fallow period: 5
Previous cropping years: 4
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 50 cms



Ap Dark reddish brown (5YR3/4) moist and reddish brown (5YR4/3) dry; sandy clay loam; moderate, medium and sub-angular blocky slightly plastic and slightly sticky wet, hard dry; frequent fine roots; clear wavy boundary, slightly gravelly.

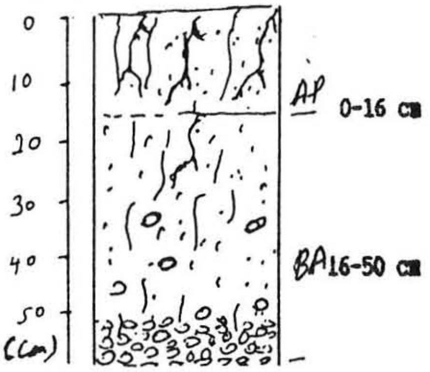
BA Dark red (2.5YR3/4) moist and reddish brown (5YR5/6) dry; sandy loam; weak, medium and sub-angular blocky; slightly plastic and sticky wet, very hard dry; clear, wavy boundary, very gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-18	Ap	5.9	3.623	0.196	43	95	52	29.4	61	1.3	5.9	2.9	16.5
18-50	BA	5.6	1.2	-	20	91	44	14	-	1.3	3.9	2.9	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-18	Ap	45	29	26	1.42	-	17	30	38	48	64

Profile No.: P-10
Location: Dizi, about 330m northeast Yember PA Off.
Date of Description: 26/12/89
Elevation: 1685m
Aspect: Southern facing
Slope class: 25%

Slope position: Middle part, convex slope
Landuse/vegetation: Maize yield
Previous fallow period (years) 9
Previous cropping years: 3
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 50 cms



Ap Dark brown (7.5YR4/4) moist and light reddish brown (5YR6/4) dry; loam; moderate, medium to fine and sub-angular blocky; plastic and slightly sticky wet, very hard dry; common, fine roots; diffuse, smooth boundary.

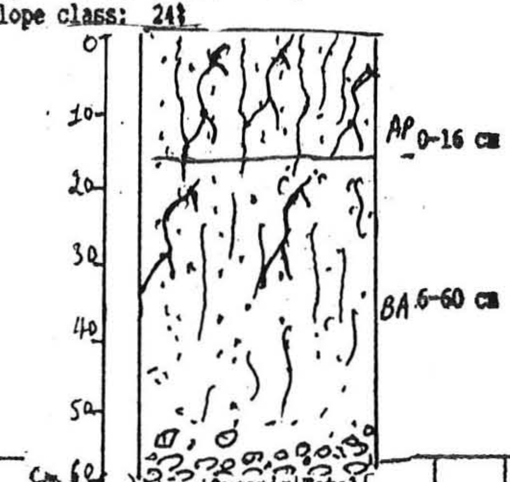
BA Dark reddish brown (5YR3/4) moist and red (5YR4/6) dry; loamy sand; moderate, medium and sub-angular blocky; plastic and sticky wet, hard dry; few fine rots; clear wavy boundary; slightly gravelly.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-16	Ap	5.3	5.555	0.298	19.4	86.8	51.4	18.7	73	0.6	7	3.6	15.3
16-50	BA	5.9	1.9	-	27	87	24	3	-	0.3	3.5	1.4	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-16	Ap	39	37	24	1.27	-	28	43	58	66	85.5

rofile No.: P-11
ocation: Dizi, about 450m northeast of Station
ate of Description: 26/12/89
levation: 1640m
spect: Northwestern facing
lope class: 24%

Slope position: Middle part convex slope
Landuse/vegetation: Maize field
Previous fallow period: 12
Previous cropping years: 6
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 60 cms



Ap Dark reddish brown (5YR3/4) moist and dark reddish gray (5YR4/2) dry; sand clay loam, weak to moderate, medium and sub-angular blocky; slightly plastic and slghtly sticky wet, hard dry; common, fine roots; clear, smooth boundary.

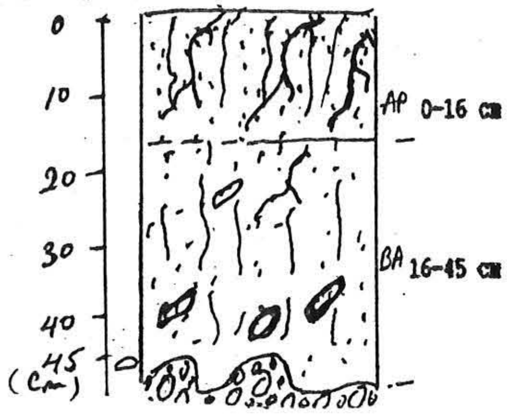
BA Dark reddish brown (2.5YR3/4) moist and yellowish red (5YR4/6) dry; sandy loam; weak to moderate, medium and sub-angular blocky; slightly plastic and sticky wet, very hard dry; frequent, fine roots; clear wavy boundary.

Depth (cm)	Hori-zon	pH H2O 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-16	Ap	62	3.963	0.196	7.3	92.6	296.9	48.1	73	0.6	7	3.6	15.3
16-60	BA	5,3	0.6	-	9	80	211	3	-	0.5	5	2.4	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-16	Ap	32	38	30	1.48	-	33	51	67	77.5	97.5

rofile No.: P-12
ocation: Dizi, about 500m west of the Mosque
ate of Description: 27/12/89
levation: 1650m
spect: East facing
lope class: 29%

Slope position: Middle part of convex slope
Landuse/vegetation: Maize
Previous fallow period: 7 years
Previous cropping years: 4
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 60 cms



Ap Dark reddish brown (5YR3/3) moist and reddish brown (5YR5/3) dry; sandy clay loam; moderate, medium to fine and sub-angular blocky; slightly plastic and slightly sticky wet, very hard dry; common, fine roots; defuse, smooth boundary.

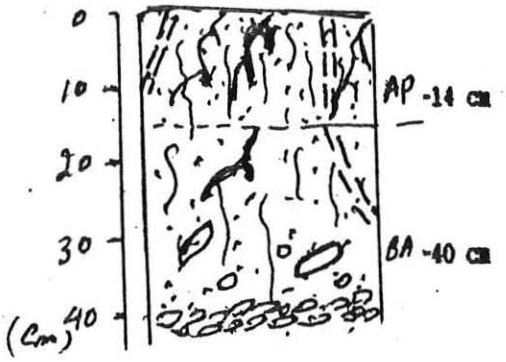
BA Yellowish red (5YR4/6) moist and reddish brown (5YR5/4) dry; sandy loam; weak to moderate, medium to fine and sub-angular blocky; slighly plastic and sticky wet, hard dry, few fine roots; clear, weavy boundary.

Depth (cm)	Hori- zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-16	Ap	6.3	4.071	0.196	19.6	94.9	65	24.7	72	0.72	6.7	3.0	14
16-45	BA	5.8	0.7	-	15	82	31	5	-	0.3	4.4	2.5	-

Depth (cm)	Hori- zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-16	Ap	29	39	32	1.19	-	22.5	34	40.5	49.5	68.5

rofile No.: P-13
ocation: Dizi, about 350m west of the Mosque
ate of Description: 27/12/89
levation: 1665m
spect: North facing
lope class: 30%

Slope position: Middle part of a long convex slope
Landuse/vegetation: Maize field
Previous fallow period: 12
Previous cropping years: 4
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 70 cms



Ap Dark reddish brown (2.5YR3/4) moist and dark reddish brown (5YR3/4) dry; loam; moderate, medium to fine sub-angular blocky to crumb, slightly plastic and slightly sticky wet, very hard dry; coarse to fine roots; clear smooth boundary.

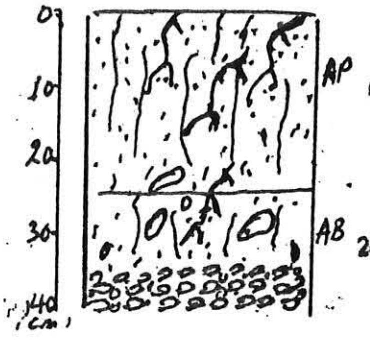
BA Dark reddish brown (2.5YR3/4) moist and red (2.5YR4/6) dry; sandy loam; weak, medium to fine and sub-angular blocky; slightly plastic and sticky wet, hard dry; few fine roots; clear wavy boundary.

epth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil)			
										K+	Ca++	Mg++	CEC
0-14	Ap	6	5.072	0.273	15.2	86.8	71.2	17.4	66	0.2	7.5	4.7	18.8
4-40	BA	5.7	0.9	-	11	79	34	5	-	0.2	5.75	2.65	-

epth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-14	Ap	40	38	22	1.22	-	53.5	58.5	80	96.5	129

Profile No.: P-14
Location: Dizi, about 250m east of the highest peak
Date of Description: 29/12/89
Elevation: 1700m
Aspect: Northwest facing
Slope class: 23%

Slope position: Middle part of a short convex slope
Landuse/vegetation: Maize field
Previous fallow period: 9
Previous cropping years: 4
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 38 cms



0-28 cm

Ap Reddish brown (5YR4/3) moist and dark reddish brown (5YR3/3) dry; loam; weak to moderate, medium to fine and sub-angular blocky; slightly plastic and slightly sticky wet, soft to slightly hard dry; common fine roots; diffuse, smooth boundary.

28-38 cm

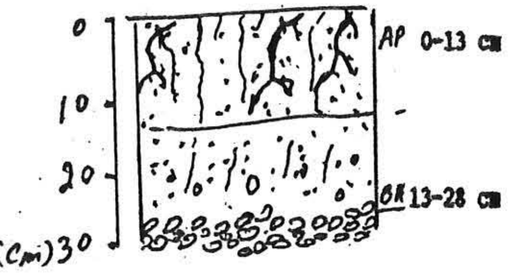
AB Dark reddish brown (2.5YR3/4) moist and weak red (10YR4/4) dry; sandy loam, weak, medium to fine and sub-angular blocky; plastic and sticky wet, slightly hard dry; few fine roots; clear, wavy boundary; slightly gravelly.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-28	Ap	6.1	4.934	0.175	13.7	92.6	112.6	15.4	54	0.5	5.5	1.9	14
28-38	AB	5.8	1.7	-	9	82	21	3	-	0.3	4.25	1.65	-

Depth (cm)	Horizon	Texture-mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-28	Ap	45	29	26	1.25	-	13.5	19	24	30.5	38

rofile No.: P-15
ocation: Dizi, about 300m north of Yember PA off.
ate of Description: 29/12/89
levation: 1642m
spect: East facing
lope class: 22%

Slope position: Middle part of a short convex slope
Landuse/vegetation: Maize field
Previous fallow period: 5
Previous cropping years: 3
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 28 cms



Ap Dark reddish brown (5YR3/3) moist and reddish brown (5YR5/3) dry; loam; weak to moderate, medium and sub-angular blocky; plastic and sticky wet, slightly hard dry; common fine roots; diffuse, smooth boundary.

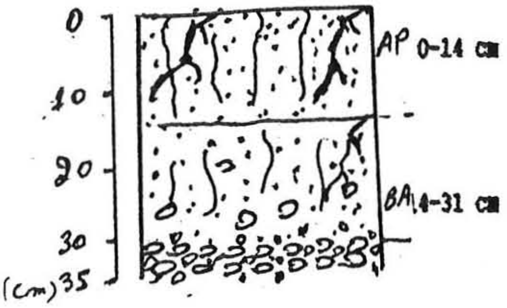
BA Dark reddish brown (2.5YR3/4) moist and reddish brown (5YR5/4) dry; sandy clay loam; weak to moderate medium and sub-angular blocky plastic and slightly sticky wet, hard dry; few fine roots, clear wavy boundary; slightly gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-13	Ap	5.9	4.037	0.224	15.7	56.2	60.8	10.7	65	0.7	5.2	3.6	14.6
13-28	BA	5.8	1.5	-	7	79	51	13	-	0.5	4.4	3.45	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-13	Ap	36	40	24	1.21	-	29	50	57	62.5	89

rofile No.: P-16
ocation: Dizi, near Testplot 1
ate of Description: 30/12/89
levation: 1650m
spect: South facing
lope class: 22%

Slope position: Middle part of long linear slope
Landuse/vegetation: Maize field
Previous fallow period: 3
Previous cropping years: 4
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 31 cms



Ap Dark reddish brown (7.5YR4/2) moist and brown (7.5YR5/4) dry; sandy clay loam; weak, medium and sub-angular blocky; slightly plastic and slightly sticky wet, slightly hard dry; common, fine roots; abrupt, smooth boundary.

BA Dark reddish brown (2.5YR3/4) moist and dark red (2.5YR3/6) dry; sandy clay loam; weak, medium and sub-angular blocky; slightly plastic and sticky wet, slightly hard dry; few fine roots; clear, wavy boundary; slightly gravelly.

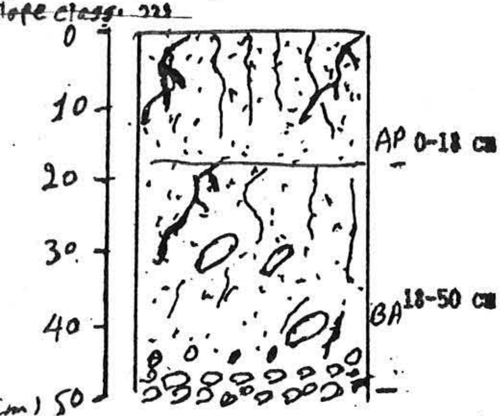
Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-14	Ap	5.0	3.312	0.14	9.6	92.6	69.5	20	37	0.23	3.2	1.5	13.4
14-31	BA	5.3	1.6	-	7	86	25	11	-	0.24	2.85	1.3	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-14	Ap	50	26	24	1.32	-	28	46.5	71.5	85	106.5

rofile No.: P-17

ocation: Dizi, about 600m northeast of the Mosque
ate of Description: 11/1/90
levation: 1675m
spect: South facing
lope class: 22%

Slope position: Middle part of long slightly convex slope
Landuse/vegetation: Maize field
Previous fallow period: 3 years
Previous cropping years: 3
Drainage class: 0, well drained
Surface stoniness: Class 0, no stones
Soil depth: > 50 cms



Ap Reddish brown (5YR4/3) moist and reddish brown (5YR3/4) dry; clay loam to sandy clay loam; weak to moderate, medium and sub-angular blocky; plastic and slightly sticky wet, slightly hard dry; common, fine roots; gradual smooth boundary.

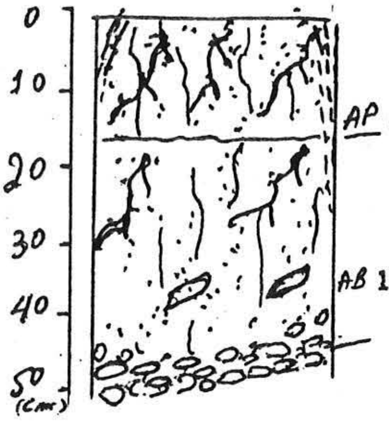
BA Dark reddish brown (2.5YR2.5/4) moist and yellowish red (5YR5/4) dry; sandy clay loam; weak, medium and sub-angular blocky; plastic and sticky wet, hard dry; few fine roots, clear, wavy boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-18	Ap	5.8	2.484	0.119	15.7	89.2	84.8	22.7	53	0.6	6.4	1.7	16.3
18-50	BA	5.5	1.1	-	12	87	31	5	-	0.3	4.1	2.6	-

Depth (cm)	Horizon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-18	Ap	45	27	28	1.2	-	28	38.5	50.5	57	73

Profile No.: P-18
ocation: Dizi, about 620m east of the Mosque
Date of Description: 11/1/90
Elevation: 1600m
Aspect: North facing
Slope class: 26%

Slope position: Middle part of a long convex slope
Landuse/vegetation: Maize field
Previous fallow period (years): > 20
Previous cropping years: 4
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth; > 65 cms



Ap Dark reddish brown (5YR3/3) moist and reddish brown (7.5YR5/4) dry; clay loam; moderate, medium and sub-angular blocky to granular; slightly plastic and slightly sticky wet, slightly hard dry; common fine roots; gradual, smooth boundary.

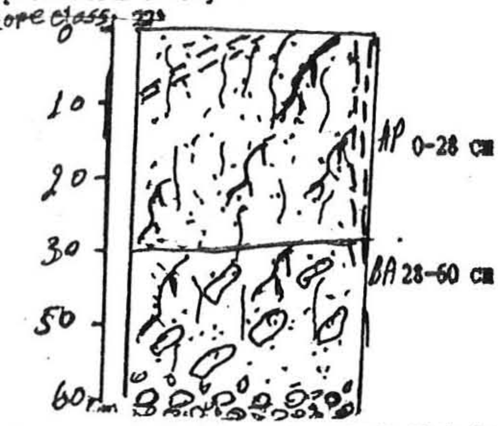
AB Dark reddish brown (2.5YR3/4) moist and reddish brown (5YR5/4) dry; sandy clay loam; moderate medium and sub-angular blocky; slightly plastic and slightly sticky wet, hard dry; few fine roots; gradual, smooth boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-15	Ap	5.1	5.382	0.259	14.6	92.6	84.8	22.7	55	0.3	5.8	2.6	16.8
15-46	AB	5.4	2.1	-	20	89	31	5	-	0.2	3.5	3.8	-

Depth (cm)	Horizon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-15	Ap	29	41	30	1.07	-	47	81.5	101.5	111	153.5

rofile No.: P-19
ocation: Dizi, about 300m northeast of Yember PA Office
ate of Description: 11/1/90
levation: 1680m
spect: North facing
lope class: 22°

Slope position: Middle slope of a short convex slope
Landuse/vegetation: Maize field
Previous fallow period: 9
Previous cropping years: 2
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 60 cms



Ap Dark brown (7.5YR3/2) moist and brown (7.5YR5/2) dry; loam, strong, medium to fine and crumb; slightly plastic and slightly sticky wet, soft dry; common coarse to fine roots; gradual, smooth boundary.

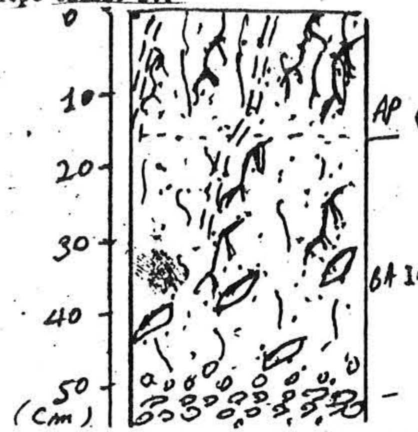
BA Dark reddish brown (2.5YR3/4) moist and reddish brown (5YR4/3) dry; sandy loam to sandy clay loam; moderate, medium to fine and subangular blocky; plastic and sticky wet, slightly hard dry; frequent, fine to coarse roots; gradual, smooth boundary..

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-28	Ap	5.4	6.107	0.245	15.2	93.8	72.8	17.4	66	0.8	11.2	2.6	22.2
28-60	BA	5	1.8	-	15	89	24	7	-	0.5	8.8	2.6	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-28	Ap	37	41	22	1.21	-	63	86	99.5	106	121.5

rofile No.: P-20
ocation: Dizi, about 280m north of Yember PA Off.
ate of Description: 11/1/90
levation: 1645m
spect: East facing
lope class: 24%

Slope position: Middle part of slightly convex slope
Previous fallow period: 5 years
Previous cropping years: 1
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 54 cms



Ap Dark reddish brown (5YR3/3) moist and reddish brown (5YR4/3) dry; loam; moderate, medium and sub-angular to crumb; slightly plastic and slightly sticky wet, slightly hard to soft dry, frequent, coarse to very fine roots; diffuse, smooth boundary.

BA Dark reddish brown (5YR3/4) moist and reddish brown (5YR4/4) dry; sandy clay loam; moderate, medium and sub-angular blocky; slightly plastic and slightly sticky; few fine and coarse roots; clear, wavy boundary.

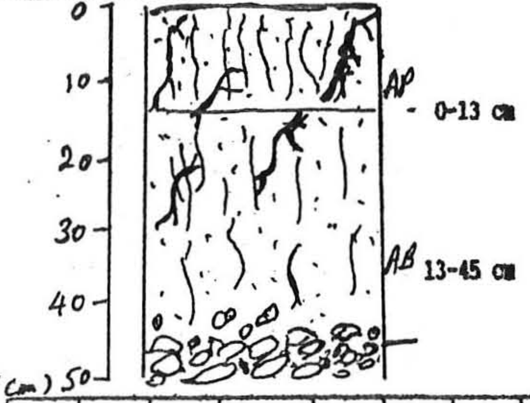
Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-14	Ap	5.2	5.520	0.273	15.2	94.4	42.8	24	49	0.6	4.3	3.4	16.6
14-54	BA	4	2.4	-	14	89	15	1.5	-	0.2	2.4	1.2	-

Depth (cm)	Hori-zon	Texture-mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-14	Ap	35	39	26	1.03	-	35	60	85.5	108	144.5

Profile No.: P-21

Location: Dizi, about 100m north of Yember PA Off.
Date of Description: 11/1/89
Elevation: 1640m
Aspect: West facing
Slope class: 23%

Slope position: Middle part of long linear slope
Landuse/vegetation: Maize field
Previous fallow period: 7
Previous cropping years: 5
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 50 cms



Ap Yellowish red (5YR5/6) moist and yellowish red (5YR6/6) dry; loam; moderate, coarse to medium sub-angular blocky; slightly plastic and sticky wet, hard dry; common fine and very fine roots; gradual, smooth boundary.

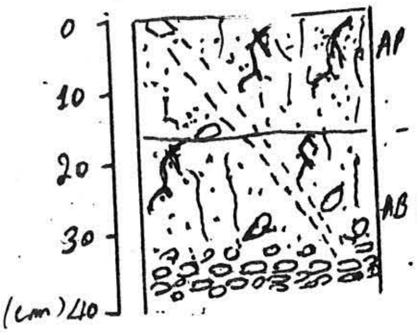
AB Dark reddish brown (2.5YR3/4) moist and strong brown (7.5YR5/6) dry; weak to moderate coarse to medium sub-angular blocky; slightly plastic and sticky wet; hard dry; few fine roots; gradual, smooth boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-13	Ap	4.5	4.584	0.203	19.6	94.9	56.1	18.7	40	1.1	4.3	3.5	22.6
13-45	AB	5.3	1.1	-	22	83	25	8	-	0.4	5.1	1.9	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-13	Ap	36	42	22	1.31	-	22	35.5	45.5	55.5	73

Profile No.: P-22
Location: Dizi, about 300m east of Yember PA Off.
Date of Description: 12/1/90
Elevation: 1620m
Aspect: Northeast facing
Slope class: 24%

Slope position: Middle part of a long convex slope
Previous fallow period: 5 years
Previous cropping years: 2
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 34 cms



0-16 cm

Ap Dark reddish brown (5YR3/3) moist and reddish brown (5YR5/3) dry; clay loam; moderate, medium to fine and sub-angular blocky to granular, slightly plastic and slightly sticky wet; slightly hard dry; common, coarse and fine roots; gradual, smooth boundary.

16-34 cm

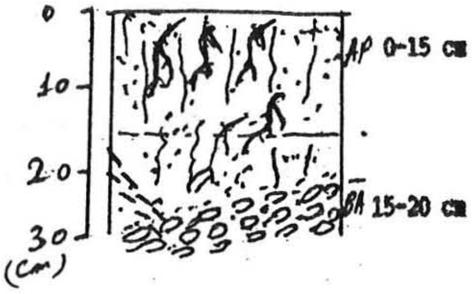
AB Dark reddish brown (2.5YR3/4) moist and reddish brown (2.5YR4/4) dry sandy clay loam; moderate, fine to medium and sub-angular blocky; slightly plastic and slightly sticky wet, hard dry, few coarse roots and common fine roots; clear wavy boundary; slightly gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-16	Ap	5	4.880	0.231	10.3	94.9	52.8	24	58	0.4	5.8	4.1	17.9
16-34	AB	5	2.1	-	22	89	20	16	-	0.2	2.1	2	-

Depth (cm)	Hori-zon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-16	Ap	41	29	30	1.23	-	59.5	108.5	126	153.5	159

Profile No.: P-23
Location: Dizi, about 350m northeast of Yember PA Office
Date of Description: 12/1/90
Elevation: 1650m
Aspect: West facing
Slope class: 26%

Slope position: Middle part of a long convex slope
Landuse/vegetation: Maize field
Previous fallow period (years): 7
Previous cropping years: 2
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 30 cms



Ap Dark yellowish brown (10YR3/4) moist and reddish brown (5YR4/4) dry; clay loam; moderate, medium and sub-angular to crumb; slightly plastic and slightly sticky wet, slightly hard dry; few coarse roots and common fine roots; clear, wavy boundary.

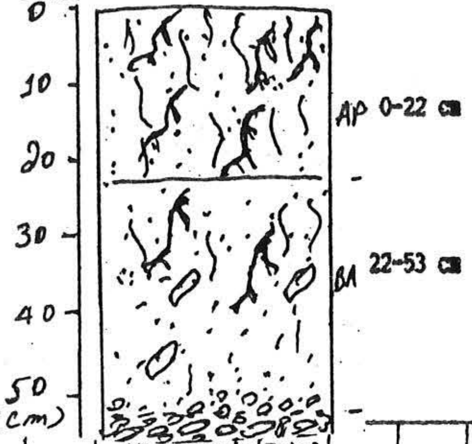
BA Dark reddish brown (2.5YR3/4) moist and yellowish red (5YR5/4) dry; sandy clay loam; moderate, medium and sub-angular blocky; plastic and sticky wet, hard dry; few coarse and fine roots; clear, wavy boundary; slightly gravelly.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil)			
										K+	Ca++	Mg++	CEC
0-15	Ap	5.9	5.969	0.287	16.6	136.6	118.2	36	83	1.5	9.4	2.3	16
15-20	BA	5.9	1.8	-	17	90	45	15	-	1.0	7.1	2	-

Depth (cm)	Horizon	Texture-mm			Bulk Density g/cm³	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-15	Ap	34	42	24	1.22	-	51.5	80.5	105.5	120.5	138.5

Profile No.: P-24
Location: Dizi, about 500m east of Tegrian settlement area
Date of Description: 2/4/90
Elevation: 1640m
Aspect: South facing
Slope class: 23%

Slope position: Middle part of a slightly convex slope
Landuse/vegetation: Maize yield
Previous fallow period (year): > 20
Previous cropping years: 5
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth: > 30 cms



Ap Dark reddish brown (2.5YR3/4) moist and reddish brown (5YR4/3) dry; loam; moderate, medium to fine and sub-angular blocky; slightly plastic and slightly sticky wet, slightly hard dry; common fine roots; gradual, smooth boundary.

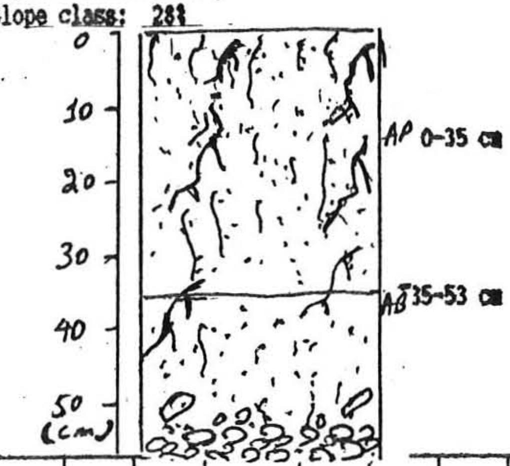
BA Dark reddish brown (2.5YR3/4) moist and reddish brown (2.5YR4/4) moist and reddish brown (2.5YR4/4) dry; sndy clay loam, weak to moderate, medium and sub-angular blocky; slightly plastic and slightly sticky, wet, hard dry; common, fine roots; gradual, smooth boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-22	Ap	5.6	5.520	0.238	49.7	89.2	54.1	69.5	59	0.9	4.9	5.0	18.4
22-53	BA	5.4	1.6	-	13	89	22	5	-	0.5	2.8	2.1	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-22	Ap	28	46	26	1.26	-	59	81	96	104	129.5

rofile No.: P-25
ocation: Dizi, about 300m northeast of Yember PA Office
ate of Description: 4/4/90
levation: 1630m
spect: South facing
lope class: 28%

Slope position: Middle part of a convex slope
Landuse/vegetation: Maize field
Previous fallow period: 12 years
Previous cropping years: 3
Surface stoniness: Class 0, no stones
Drainage class: 0, well drained
Soil depth:



Ap Dark reddish brown (5YR3/3) moist and reddish yello (7.5YR6/4) dry; clay loam; moderate, medium to fine and sub-angular blocky to granular; slightly plastic and slightly sticky wet, slightly hard dry; common fine roots; gradual smooth boundary.

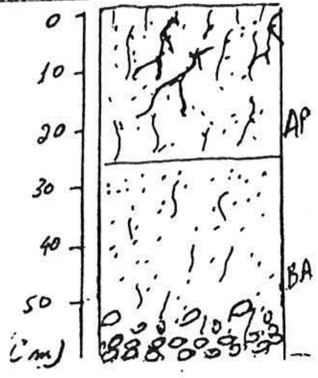
AB Dark red (2.5YR3/6) moist and reddish brown (5YR4/4) dry; sandy clay loam; moderate, medium and sub-angular blocky; slightly plastic and slightly sticky wet, hard dry; few fine roots; clear wavy boundary.

Depth (cm)	Horizon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-35	Ap	6.4	5.899	0.266	29.9	90.9	54.1	14.7	82	0.9	8.6	3.6	15.9
35-53	AB	5.6	2	-	16	83	31	3	-	1.2	2.75	3.65	-

Depth (cm)	Horizon	Texture=mm Sand 2-0.02	Silt 0.02-0.002	Clay <0.002	Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after 30min.	60min.	90min.	120min.	180min.
0-35	Ap	46	32	22	1.11	-	55	72.5	91.5	106	70.5

rofile No.: P-26
ocation: Dizi, about 350m northeast of the station
ate of Description: 5/4/90
levation: 1680 m
spect: Northeast facing
lope class: 29%

Slope position: Middle part of convex slope
Landuse/vegetation: Maize field
Previous fallow period: 3 years
Previous cropping years: 2
Surface stoniness: Class 0, no stones
Drainage class: 4, well drained
Soil depth: > 62 cms



0-24 cm

24-58 cm

Ap Reddish brown (5YR4/3) moist and reddish brown (5YR3/4)) dry; sandy clay loam; weak to moderate, medium to fine and sub-angular blocky; slightly plastic and slightly sticky wet, slightly hard dry; common, fine roots; gradual, smooth boundary.

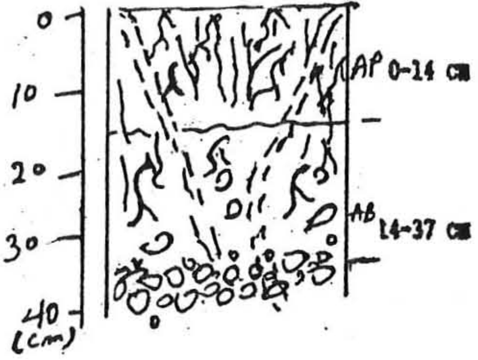
BA Dark red (2,5YR3/6) moist and red (2.5YR4/6) dry; sandy clay loam; and weak, medium and sub-angular blocky, plastic and sticky wet, hard dry; fine roots, clear wavy boundary.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil)			
										K+	Ca++	Mg++	CEC
0-24	Ap	5.8	4.175	0.175	21.1	94.9	95.5	17.4	64	1.0	6.9	3.3	17.6
24-58	BA	5.6	1.6	-	13	88	27	-	-	0.5	2.4	3.5	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180min.
0-24	Ap	24	46	26	1.12	-	18.5	29	35	41	55.5

ofile No.: P-27
ocation: Dizi, about 200m north of Tegrian settlement area
ate of Description: 25/6/90
levation: 1660
spect: Sout facing slope
lope class: 25%

Slope position: Middle part of concave slope
Landuse/vegetation: Maize field
Previous fallow period: > 20 years
Previous cropping years: 1
Surface stoniness: Class 0, no stones
Drainage class: Class 4, well drained
Soil depth: > 37 cms



Ap Very dark brown (10YR2/2) moist and dark brown (10YR3/3) dry; silty clay; strong, medium fine and crumb; slightly sticky, slightly plastic, wet, soft dry; common coarse roots and abound and fine and very fine roots; gradual smooth boundary.

AB Dark brown (5YR3/2) moist and reddish brown (5YR4/3) dry; moderate, medium and sub-angular to crumb; slightly sticky and slightly plastic wet, soft dry; coarse and abound at fine and very fine roots; wavy boundary; slightly gravelly.

Depth (cm)	Hori-zon	PH H20 1:2.5	Organic matter (%)	Total N (%)	NO3- (ppm)	NH4+ (ppm)	P-Bray (ppm)	P-Olsen (ppm)	BS (%)	Exchangeable Cations (me/100g soil) K+	Ca++	Mg++	CEC
0-14	Ap	6.4	6.383	0.308	22	113	36	13	82	0.39	7.4	5.0	15.6
14-37	AB	5.6	3.1	-	17	118	51	10	-	0.2	4.2	2.3	-

Depth (cm)	Hori-zon	Texture=mm			Bulk Density g/cm^3	Total Pore Vol.	Accumulated water intake (cm) after				
		Sand 2-0.02	Silt 0.02-0.002	Clay <0.002			30min.	60min.	90min.	120min.	180mi
0-14	Ap	-	-	-	0.8	-	64	92	113	137	166