TW
AGR
022

Red

Regional Training

on

"Conservation Based Agriculture"

Organized by

CRDA and REST

Training Manual

CCRDA

Christian Relief & Development Association
LIBRA
P.O.Box 5674

Mekelle University College

August, 1996

TABLE OF CONTENT

PART I. **1**

1. PROBLEMS OF LAND DEGRADATION 1
1.1. FORMS OF LAND DEGRADATION *1*
1.2. EROSION AS ONE FORM OF LAND DEGRADATION *2*
1.2.1 Forms of erosion *2*
1.2.1.1 Relative effects of types of erosion *3*
2. MAGNITUDE OF THE PROBLEM 4
2.1. ORDERS OF MAGNITUDE: rates of soil erosion vis-à-vis soil formation *4*
2.2 THE CONCEPT OF ACCEPTABLE LIMITS OF SOIL EROSION *4*
3. CAUSATIVE AGENTS OF LAND DEGRADATION BY EROSION 6
3.1 WATER EROSION *6*
3.1.1 Factors influencing water erosion *6*
3.1.1.1 Erosivity *7*
3.1.1.2 Erodibility *7*
3.1.1.3 Slope (S) and length of slope (L) *7*
3.1.1.4 Crop management factor C *8*
3.1.1.5 Conservation Practice P *8*
3.1.1.6 Use and misuse of the equation *11*
3.2 WIND EROSION *11*
3.2.1 Factors affecting wind erosion *11*
3.2.2 Soil movement by wind *12*
3.2.2.1 Types of movement *12*
3.2.3 The effects of wind erosion *12*

PART II. **15**

4. SOCIO-ECONOMIC ISSUES OF LAND DEGRADATION 15
4.1. Land Degradation and its Economic Implication *15*
4.1.1 Land Degradation in Ethiopia/ Tigray *15*
4.1.2. Effects of Soil Erosion: theoretical and empirical evidences *15*
4.1.3. On-site effects *16*
4.1.4. Off-site effects *16*
4.1.5. Economic implications of land degradation *16*
4.1.6. On-site economic implications *20*
4.1.7. Off-site economic implications *20*
4.1.8. Economic implications of water shortage *20*
4.2 SOCIOECONOMIC CAUSES OF LAND DEGRADATION 21
4.2..1. Socio-economic variables *21*
4.2..1.1. Tenure patterns *21*
4.2.1.2 Poverty, marginalization and disempowerment *24*
4.2..1.3 Awareness, perceptions and indigenous interpretations of land degradation *25*
4.2.1.4 Demographic change *26*
4.2.1.5 Economic and development policies *28*
5. RESPONSES TO LAND DEGRADATION 30
5.1. Indigenous conservation systems - General outline *30*
5.2. Indigenous Conservation Practices in Ethiopia *33*
5.3 MODELS AND PREDICTION *38*
5.3.1 CLASSIFICATION OF EROSION AND LANDUSE PLANNING *39*
5.3.1.1. Erosion by Water *39*

CCRDA

5.3.1.2. Erosion by Wind 40
5.4. Soil and water conservation measures - promoted from" above" 41
5.4.1 Scale of rehabilitation measures 42
5.4.2 Approach and quality of work 42
5.4.3 Nature of the conservation measures 43
5.4.4 Socio-political environment 43
5.5 Towards a new Approach to Conservation 45
5.5.1 Emphasis to biological measures 45
5..5.1.1 Why land husbandry? 47
6. ECONOMICS OF SOIL CONSERVATION AND WATER HARVESTING: REVIEW OF ISSUES AND CONCEPTS 47
6.1. Economic concepts of soil conservation and water harvesting 47
6.2. Methods and approaches for economic assessment 48
6.2.1. Cost-benefit analysis 48
6.2.1.1. Determination of evaluation criteria 49
6.2.1.2. Identification of costs and benefits 49
6.2.1.3 Quantification of costs and benefits 50
6.2.1.4. Valuation of costs and benefits 51
6.2.1.5. Time horizon 51
6.2. 1.6. Discounting concept 52
6.2.1.7. Income distribution aspect 52
6.2.1.8. Sensitivity analysis 52
6.2.1.9. Cost of labour input 53
6.2.2. Farm management analysis techniques 54
6.2.3. Mathematical and bioeconomic simulation models 54
6.3. Economic data collection 55
6.4. Conclusion 55

PART III 55

SUSTAINABLE AGRICULTURAL DEVELOPMENT: TECHNICAL ISSUES 55

7. SOIL AND WATER CONSERVATION 55
7.1 FUNDAMENTAL PRINCIPLES OF SOIL AND WATER CONSERVATION 55
7.2 SOIL AND WATER CONSERVATION ON CULTIVATED LAND 56
7.2.1 Land use aspects 56
7.2.2 Agronomic measures for soil and water conservation on cultivated land 56
7.2.2.1 Crop management for optimum cover 57
7.2.2.2 Timelines/early planting for timely/early cover 57
7.2.2.3 Intercropping 57
7.2.2.4 Crop rotation 57
7.2.2.5 Strip Cropping 58
7.2.2.6 Improved (planted) fallows 61
7.2.2.7 Green manures 62
7.2.2.8 Kraal manure 62
7.2.2.9 Mulching 63
7.2.2.10 Crop reside management (as a mulch, etc.) 64
7.2.2.11 Soil Management (for fertility and structure) 65
7.2.2.12 Tillage 66
7.2.2.13 Winter ploughing 66
7.2.2.14 Soil and water conservation through "good farming" 66
7.3 MECHANICAL METHODS OF EROSION CONTROL 66
7.3.1 Contouring 66
7.3.2 Contour bunds 66
7.3.3 Terraces 70
7.3.4 Waterways 70

CCRDA

7.4 WIND EROSION CONTROL 70
7.4.1 Wind breaks 70
8. AGROFORESTRY 71
8.1. WHAT IS AGROFORESTRY? 71
8.2. CLASSIFICATION OF AGROFORESTRY SYSTEMS 72
8.3. AGROFORESTRY SYSTEMS, PRATICES AND TECHNOLOGY 73
8.4. ECOLOGICAL INTERACTIONS IN AGROFORESTRY 74
8.5. MULTIPLE USES OF TREES (MPTs) 75
8.6. SOIL CONSERVATION FOR AGRICULTURAL SUSTAINABILITY 79
8.7. CASE STUDIES: 82
9. FOREST DEVELOPMENT 83
9.1 FORESTS AND PLANTATION DEVELOPMENT 83
9.2. NURSERY ESTABLISHMENT AND MANAGEMENT 84
9.3. PLANTATION ESTABLISHMENT 88
9.4. TENDING OF PLANTATIONS 94
9.5. DISCUSION FORUM 100
10.CULTIVATING DIVERSITY: CONSERVATION, ENHANCEMENT AND MANAGEMENT OF CROP GENETIC RESOURCES 102
INTRODUCTION 102
10.1. Africa and Climate Change 102
10. 2. Origin of cultivated plants 105
THE FIVE FACES OF GERMPLASM 106
10.3. Biodiversity/Genetic erosion 108
10.3..1 . What is biodiversity? 108
10.3..2. Genetic diversity 108
10.3.3. Genetic erosion 108
10.4. Crop genetic resources of Ethiopia 110
10.4.1. Management of genetic resources 111
10.4.2 CONSERVATION STRATEGIES 112
10.4.2.1. Ex Situ Conservation 112
10.4.2..2. In Situ Conservation 116
10.4.2..3. Conservation at local farmer/community level 116
10.5. TRADITIONAL FARMING SYSTEMS AND GENETIC DIVERSITY 117
10.6. Farmers contribution to maintaining genetic diversity in crops, and its role within the total genetic resources system 117
10.6.1. Support for traditional farming systems and the maintenance of genetic diversity 119
10.6.2. Bringing farmers into the genetic resources conservation systems 119
10.7. THE DILEMMA OF "GLOBAL 2000" AND LANDRACE CONSERVATION 121
10.7.1. The contours and costs of erosion: the Indian case 121
10.7.2. The Sasakawa Global 2000 (SG-2000) extension model in Ethiopia 122
10.8. Participatory research 122
10.8.1. Impact of farmers participatory research on Biodiversity 124
10.8.2. Farmers participation and its role in plant breeding 126
10.8.2.1. EXPERIMENTATION 129
10.8.2.2. RESEARCH METHODS AND FARMERS PARTICIPATION 133
REFERENCES **138**
11. IPM (INTEGRATED PEST MANAGEMENT) IN CONSERVATION BASED AGRICULTURE 139
11.1 Major constraints of food production in agriculture 140
11.1.1 Biotic factors 140
11.1.2 Abiotic factors 141
11.2 Definition of IPM 141
11.3 Factors which favour IPM in the tropics 142
11.4 Components of IPM 142

CCRDA

11.4.1 preventive control procedures 143
11.4.2 Cultural control 144
11.4.3 Host - plant resistance 146
11.4.4 Biological control 146
11.5 Chemical control 151
11.5.1 Pesticide use in relation to IPM 151
11.6 Rationale for IPM implementation 152
12. FARMING TECHNIQUES FOR MOISTURE STRESS AREAS 153
12.1 Parameters of moisture stress 153
12.1.1 Climatic variability 153
12.1.2 Crop varieties rainfall 153
12.1.3 Soil characteristics 153
12.2 Approved practices for crop production in moisture stress areas 153
12.2.1 Choice of crop varieties 153
12.2.2 Land preparation 153
12.2.3 Seeding 154
12.2.4 Moisture conservation techniques 154
13. Information Base for Sustainable Agricultural Development 155
13. 1 On Sustainability 155
13.2 On Information 160
PART IV **179**
14. CONSERVATION BASED AGRICULTURAL DEVELOPMENT: A SYNTHESIS 179
14.1 Agricultural Development Strategy 179
14.2 Development and Natural Resource Conservation: Policies and strategies 183
14.2.1. Community Participation and empowerment 185
14.2.2. The role of the public sector 188
14.2.3. Incentive policy instruments 189
14.2.4. Economic considerations 190
14.2.5. Integrated agriculture 191

CCRDA

.... 143
.... 144
.... 146
.... 146
.... 151
.... 151
.... 152
.... 153
.... 153
.... 153
.... 153
.... 153
.... 153
.... 153
... 153
... 154
... 154
... 155
... 155
... 160
... 179
... 179
... 179
... 183
... 185
... 188
... 189
... 190
... 191

Part I

1. PROBLEMS OF LAND DEGRADATION

1.1. FORMS OF LAND DEGRADATION

Land degradation involves the degradation of the land/soil and is commonly associated with the degradation of the natural vegetation and water resources. The main causes of such invariable environmental degradation are classified as physical, chemical and biological degradation types.

The three forms of degradation can be schematically represented as follows.

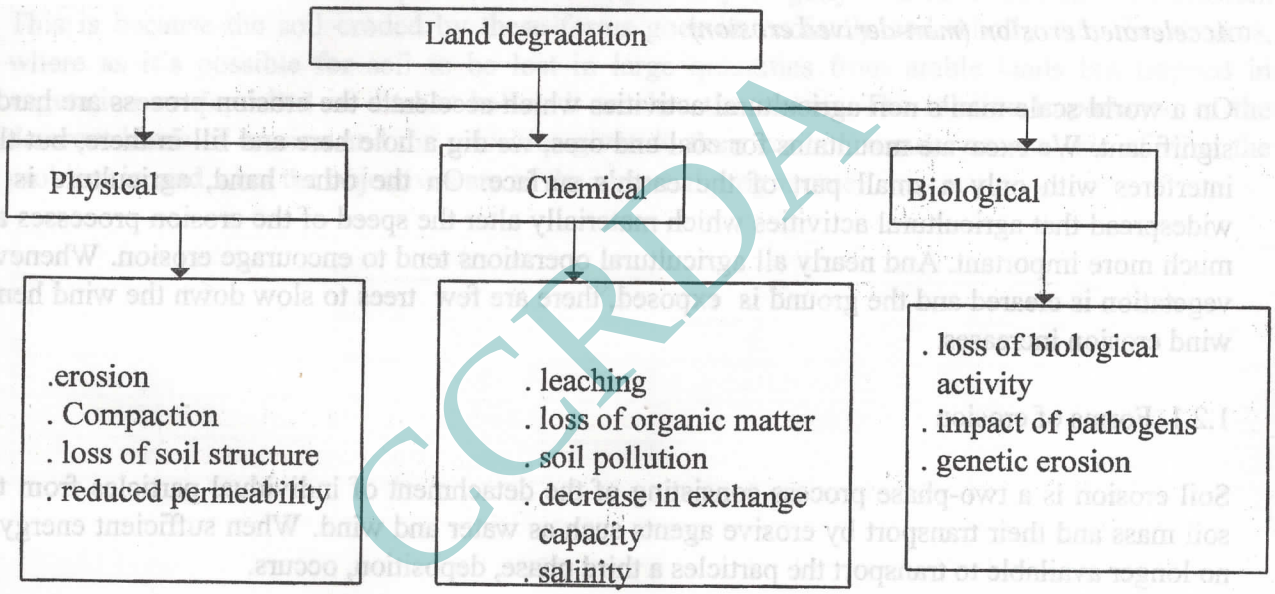


Fig. 1. Forms of land degradation

Over global scale the severity of each degradation form is equitable. However, in the semi-arid and arid Ethiopia soil erosion predominates over the other forms of degradation. Hence in the next section a detailed analysis will be given regarding the mechanics of soil erosion as one form of land degradation.

1.2. EROSION AS ONE FORM OF LAND DEGRADATION.

Soil erosion is generally defined as the removal of soil mainly by agents of water and wind . However it is also important to distinguish two types of erosion Geological and Accelerated.

CCRDA

Geological erosion

Geological erosion is generally very slow due to the protection of the natural vegetation. In many cases the loss of soil by this type of erosion is balanced by the equally slow process of soil formation.

Erosion has taken place and always will. The surface of the earth is constantly changing with maintains rising, valleys being cut deeper and wider, the coast line receding here and advancing there. The physical pattern of the earth surface we see today is not the result of some single cataclysmic sculpturing but the result of changes so infinitely slow that only after centuries is the effect noticeable. Erosion is simply one of the aspects of this constant process of change. We usually refer to geological erosion when erosion results from the forces of nature. Man's activity seldom slow down or halt the process but frequently speed it up.

Accelerated erosion (man-derived erosion)

On a world scale man's non-agricultural activities which accelerate the erosion process are hardly significant. We excavate mountains for coal and ores, we dig a hole here and fill in there, but this interferes with only a small part of the earth's surface. On the other hand, agriculture is so widespread that agricultural activities which materially alter the speed of the erosion processes are much more important. And nearly all agricultural operations tend to encourage erosion. Whenever vegetation is cleared and the ground is exposed, there are few trees to slow down the wind hence wind erosion increases.

CCRDA

1.2.1 Forms of erosion

Soil erosion is a two-phase process consisting of the detachment of individual particles from the soil mass and their transport by erosive agents such as water and wind. When sufficient energy is no longer available to transport the particles a third phase, deposition, occurs.

Rain splash is the most important detaching agent. As a result of rain drops striking a bare soil surface, soil particles may be thrown through the air over distances of several centimetres. Continuous exposure to intense rainstorms considerably weakens the soil. The soil is also broken up by weathering processes, both mechanical, by alternate wetting and drying, freezing and thawing and frost action, and biochemical. Soil is disturbed by tillage operations and by the trampling of people and livestock. Running water and wind are further contributors to the detachment of soil particles. All these processes loosen the soil so that it's easily removed by the agents of transport.

The transporting agents comprise those which act arealy and contribute to the removal of a relatively uniform thickness of soil and those which concentrate their actions in channels. The first group consists of rain splash, surface runoff in the form of shallow flows of infinite width, some times termed as sheet flow but more correctly called overland flow and wind. The second group covers water flow in small channels known as rills, which can be obliterated by ploughing and weathering, or in the larger, more permanent features of gullies and rivers. To these agents which act externally, picking up material from and carrying it over the ground surface, should be added

transport by mass movements such as soil flows, slides and creep in which water affects the soil internally, altering its strength.

1.2.1.1 *Relative effects of types of erosion*

The question is often debated as to which from of erosion is the most serious, and this is important if a conservation programme has limited resources which are insufficient to tackle the whole erosion problem and must therefore be used against selected part. However, there's no single answer, for it depends upon the reasons why the erosion needs to be controlled.

It the problem is that the production of food crops is jeopardised by erosion then splash erosion and rill erosion on a arable lands are the most important. If however the problem is that a high sediment load in streams and rivers threatens to silt up the storage dams required for an irrigation, then the most important source of this silt will probably be gully erosion or stream bank erosion. This is because the soil eroded by these forms goes immediately and wholly into the streams, where as it's possible for soil to be lost in large quantities from arable lands but trapped in vegetation or deposited in ditches before it reaches the stream. The relative importance of the deferent kinds of erosion and the priorities given to their control, require an analysis of what the problem is, and what the objectives are of the remedial programme.

CCRDA

2. MAGNITUDE OF THE PROBLEM

2.1. ORDERS OF MAGNITUDE: rates of soil erosion vis-à-vis soil formation

Theoretically, whether or not a rate of soil loss is severe is judged relative to the rate of soil formation. If soil properties such as nutrient status, texture and thickness remain unchanged through time it is assumed that the rate of erosion balances the rate of soil formation.

The rate of soil loss is normally expressed in units of mass or volume per unit of time. In a review of erosion under natural conditions Young (1969) quotes rates of the order of 0.0045 kg m^{-2} y^{-1} for areas of moderate relief and 0. 045 $kgm^{-2}y^{-1}$ for steep relief. For comparison, rates from agricultural land ranges between 4.5 to 45 kg m^{-2} yr^{-1}.

On a world scale, there's considerable variation in erosion rates; but if the rates are grouped in to those related to natural vegetation, cultivated land and bare soil, each group follows a broadly similar pattern of global variation (table 1).

Table 1 Rates of erosion for selected countries (kg m^{-2} y^{-1})

	Natural	Cultivated	Bare soil
China	0.02	15-20	28-36
USA	0.003-0.3	0.5-17	0.4-9
Ivory Coast	0.003-0.02	0.01-9	1-75
Nigeria	0.05-0.1	0.01-3.5	0.3-15
India	0.05-0.1	0.03-2	1-2
Belgium	0.01-0.05	0.3-3	0.7-8.2

ECRDA

In Ethiopia, about 76% of the land area is exposed to severe erosion, out of which 4% is of no more use to agriculture. Large parts of Tigray, Wello, northern Shoa, eastern Gonder, parts of Hararghe and Bale have suffered from serious ecological degradation and the carrying capacity of people and animals has been seriously undermined. In Wello about 50% of the cultivable land depict a soil depth of 10 cm, which means the land can be used neither for agriculture nor for grazing. In general, the scope for further expansion of the crop land on the highlands is negligible; the land frontier is closed.

2.2 THE CONCEPT OF ACCEPTABLE LIMITS OF SOIL EROSION

The concept can be para-phrased as:

Where is the line between natural and man-made erosion?
Is it possible to specify limits of erosion which can be accepted as reasonable?
What is the level of erosion at which we change from accepting it to doing something?

The usual answer to these questions is that the primary objective of soil conservationists is to ensure that the land is only used in such a way that the deterioration is minimized. This will be achieved when the rate of soil loss is no progressive than the rate of soil formation.

The rate of soil formation is that under undisturbed conditions it will take of the order of 300 to 1000 years to form 25 mm of soil but that when the disturbances (and aeration), leaching action are speeded up by tilling the land, this will be reduced to something like 100 years.

The level of erosion which has for many years been taken place (in the USA) as the upper limit of tolerable soil loss is 11.2 t/ha/yr equivalent to a formation rate of 25 mm in 30 years. Naturally the acceptable loss will depend upon the soil condition- if the profile consists of a deep soil whose fertility is the same at all depths, then to loose 25 mm of soil in 30 years is much less serious than if the profile consists of few cm of soil overlying hard rock. Target figures are therefore seldom higher than 11.2 t/ha/yr, but frequently higher. For drylands typical rate of soil loss is 5-100 t/ha/yr (0.37-7 mm/yr) and soil formation rate is < 0.36 cu m/yr (0.01-0.04 mm/yr).

CCRDA
Christian Relief & Development Association
LIBRARY
P.O.Box 5574

3. CAUSATIVE AGENTS OF LAND DEGRADATION BY EROSION

3.1 WATER EROSION

The severity of soil erosion depends upon the quantity of materials supplied by detachment and the capacity of the eroding agents to transport it. Where the agents have the capacity to transport more material than is supplied by detachment, the erosion is described as detachment-limited. Where more material is supplied than can be transported, the erosion is transport-limited. The recognition of which factor, detachment or transport, is limiting is important because the success or failure of conservation work relies upon applying remedies to the correct one.

The energy available for erosion takes two forms: Potential and kinetic. Potential energy (PE) results from the difference in height of one body with respect to another. It is the product of mass (m), height (h) and gravitational acceleration (g), so that;

$$PE=mgh$$

The potential energy for erosion is converted into kinetic energy (KE), the energy of motion.

$$KE=1/2mv^2$$

Most of this energy is dissipated in friction with surface over which the agent moves so that only 3 to 4 percent of the energy of running water and 0.2 percent of that of falling raindrops is expended in erosion.

3.1.1 Factors influencing water erosion

The factor controlling the working of the soil erosion system are the erosivity of the eroding agent, the erodibility of the soil, the slope of the land and the nature of the plant cover. In order to understand when and how much erosion is likely to occur, these factor must be examined in detail and the relevant aspects of them identified more precisely. Much of our understanding stems from empirical studies in which a wide range of data on Soil loss and presumed controlling variables is collected and the best relationships are sought using statistical techniques, particularly correlation and regression analyses. Since this approach is adopted by numerous researches working in many different areas of the world , it is not too surprising that the result is a multiplicity of variables being recognised as important but some disagreement as to which are the most significant. In a review of the relationship between erosion and climate, Douglas (1976) lists seven precipitation variables which have been used to explain spatial variations in erosion and a further seven for precipitation and eight describing antecedent conditions used to study temporal variations in erosion at single sites. In trying to simplify such lists, there is the problem of determining which variables merely express the same relationship and which identify truly separate relationships with Soil loss.

CCRDA

3.1.1.1 *Erosivity*

Rainfall erosion is the interaction of two items - the rain and the soil. The amount of erosion which occurs in any given circumstances will be influenced by both. We know from observation that one storm can cause more erosion than the other on the same land, and we also know that the same storm will cause more erosion on one field than on another. The effect of the rain is called erosivity and the effect of the soil is called erodibility. Formal definition of erosivity can be forwarded as; the potential ability of rain to cause erosion. It is a function of the physical characteristics of rainfall.

The most suitable expression of the erosivity of rainfall is an index based on the kinetic energy of the rain. Thus the erosivity of a rainstorm is a function of its intensity and duration and of the mass, diameter and velocity of the raindrops.

3.1.1.2 *Erodibility*

Erodibility defines the resistance of the soil to both detachment and transport. Although soil resistance to erosion depends in part on topographic positions, slope steepness and the amount of disturbances created by man (tillage), the properties of the soil are the most important determinants. Erodibilty varies with soil texture, aggregate stability, shear strength, infiltration capacity and organic and chemical content.

The role of texture can be shown by the fact that large particles are resistant to transport because of the greater force required to entrain them and that fine particles are resistant to detachment because of fine cohesiveness. The least resistant particles are silts and fine sands. Thus soils with high silt content are erodible.

The use of the clay content as an indicator of erodibility is theoretically more satisfying because the clay particles combine with organic matter to form soil aggregates or clods and it is the stability of these which determines the resistance of the soil. Soil with a high content of base minerals are generally more stable as these contribute to the chemical bonding of the aggregates. Wetting of the soil weakens the aggregates because it lowers their cohesiveness, softens the cements and causes swelling as the water is adsorbed on the clay particles. Rapid wetting can also cause collapse of the aggregates through slaking. In general, aggregate stability depends on the type of clay mineral present. Illite and smectite more readily form aggregates but more open lattice structure of these minerals and the greater swelling and shrinkage which occurs on wetting and drying render the aggregates less stable than those formed from kaolinite.

3.1.1.3 *Slope (S) and length of slope (L)*

Both of these two variables can be evaluated separately and so there could be separate numerial values for each. However when land has mechanical protection works the effective length of slope is the distance between channel terraces. This distance is designed as a function of the between channel terraces. This distance is designed as a function of the therefore convenient to have a single factor LS to represent the effectof both in the equation, but to explain this combined factor it is easier to first consider each component separately.

CCRDA

Obviously the steeper the slope, the greater the erosion for a number of reasons. There is more splash downhill, there will be more run-off, and it will flow faster. Not surprisingly then the amount of erosion is not just proportional to the steepness of the slope, but rises rapidly as the slope increases.

3.1.1.4 *Crop management factor* C

This factor is at the same time the most complicated, because there is an almost infinite number of different ways of managing the growing of crops, and also the factor which is evaluated in most detail, because there is a wealth of experimental evidence available about the effects of crop management on soil loss. In the early systems, such as the Slope- Practice Equation, a single value for the crop factor was used to give the average effect over the whole season. All the common crops and rotations were tabulated against values for C, and tables were produced for local regions so that the cropping practices important in the region could be specified in detail.

However there are clearly major interactions between crop management and climate. For example a period in spring when the soil is newly ploughed and without any plant cover is going to be dangerous if the spring rains are highly erosive, but less important if the spring rains are gentle. Similarly the effect on erosion of the state of the ground after harvest in the autumn will depend on whether or not the autumn rains are severe.

In the Universal Soil- Loss Equation a procedure is adopted to allow for such effect. Ordinarily an annual value of the C factor is multiplied by an annual value of the rainfall factor R, that is each is averaged for the whole year before they are combined. However it is equally possible to divide the growing season into periods and multiply C and R values for each period, averaging the products to get the annual combined effect. Mathematically the effect is the same, i.e.

$$CR = c_1 r_1 + C_2 r_2 + c_3 r_3 \ldots$$

In the US the wealth of data allows this calculation to be carried out with great mathematical precision, and detailed charts and tables are provided in Agricultural Handbook 537. However, the crop rotations and cropping practices and rainfall distribution patterns are specific to the United States , and in most other countries it will be more appropriate to use annual values of C are R.

3.1.1.5 *Conservation Practice* P

The standard conditions assumed in the basic question are that bare fallow is cultivated straight up and down the steepest slope. This is of course the worst possible erosion situation and so the P factor consists of a ratio by which the erosion will be reduced from the theoretical loss in this worst case.

CORDA

The Universal Soil - Loss Equation is designed for use in sophisticated agriculture where proper conservation practices can be expected as the normal order of things. The practice of ploughing, planting, and tilling on the contour is widespread, but the effectiveness of this alone varies according to slope. Observation and experiment indicate that contouring is most effective on middle range slopes from 2 to 7 per cent and less effective on flatter slopes, and on steeper slopes. The P values adopted for contour cultivation without other mechanical protection works are given in table 2.

Table 2 Values of conservation practice factor P

Slope	P value
1 to 2	0.60
2-7	0.50
7-12	0.60
12-18	0.80
18-24	0.90

Contour listing, that is throwing up small ridges while cultivating on the contour, is even more effective, but the effect only lasts, until the ridges are flattened by subsequent cultivation. If listing is practised the P value may therefore be reduced by 5000 but only for the crop stage periods when the ridges will be effective.

Terracing or contour ridging is normal practice when erosion is serious and the land slope more than about 2 % so this must be reflected in the P factor. However, the spacing of such works is dependent upon the steepness of the slope and so the effective length of slope is also reduced. The procedure is to use the same P value as for contour cultivation alone, and then use an LS factor appropriate to the spacing between the terraces.

Examples of using the equation

To Predict erosion

This is the simplest application of the soil-loss equation, and consists of calculating the predicted erosion when all conditions are known. Sample values might be:

Rainfall index R = 300
Soil erodibility K = 0.5
Slope 4 per cent LS factor = 1.0
Length of slope 300 m
Conservation practices 0.5
Cropping practice 0.2

Then E = RKLSCP

= 15 tonnes per hectare per year.

CCRDA

To select crop management practices

An example will illustrate this application . A farmer has asked for advice on management for a particular field. The fixed factors are

The rainfall index for this district is 300
The Soil erodidbility index is 0.5
The field slope is 6 per cent
The field length is 100 meters

Caribbean Relief & L I B R A R Y P.O.Box 3674

The soil-loss tolerance is 10 tonnes /hectar/year

the basic equation is E = R x K= 300x0.5 = 150

Which means that from a standard plot (22.6 m long and 9^0 slope) under bare fallow and no conservation practices, the erosion would be 150 tons/ acre/year. For this particular field S = 6, and L = 100 and hence the LS ration is 1.2 , so the erosion under the standard management is 180 tonnes/hectare/year. Substituting the soil-loss tolerance for E the equation now becomes

$$10 \times 180 \times C \times P$$

If the farmer is unwilling to put any conservation practices then p will remain 1, and C = $\frac{10}{180}$ = 0.55. This means the erosion will be excessive under any crop practice whose C value is more than 0.055 To achieve such a low C value would require almost continuos forage crops with hardly any cash crops so that solution is not very practicable.

CCRDA

If the farmer agrees to contour cultivation, P would become 0.5, and

$$C = \frac{10}{180 \times 0.5} = 0.11$$

Any rotation whose C value is less than this value is possible, and a large range of possible rotations could be used.

If the farmer agrees to contour cultivation and channel terraces the P value remains 0.5 but the value of LS is reduced. If the spacing between terraces were 30 meters, the LS value becomes 0.66, and so the equation becomes

$$10 + 300 \times 0.5 \times 0.66 \times 0.5 \times C$$

Hence C= 0.02.

At this value an even wider choice of rotations is available to the farmer > In this example the conservation Officer would encourage the farmer to adopt channel terraces and then check that the C value of the chosen rotations does not exceed 0.02.

3.1.1.6 *Use and misuse of the equation*

The simplicity and usefulness of the equation have undoubtedly led to it being used in situations for which it was never intended and for which it is not suitable. The originator W.H. Wischmetier has re-affirmed the original purposed and strongly urged caution in trying to extend the use of the equation (WISCHMEIER 1976). For example it should not be used to try to estimate the soil loss from drainage basins because it does not include the right factors- such as gully and stream bank erosion and. It is based on long term average results and is not suitable for predicting the soil movement in an individual storm.

3.2 WIND EROSION

3.2.1 Factors affecting wind erosion

On a world scale the erosion caused by rainfall is more serious than that caused by wind, and that is one reason why much more emphasis is given on water erosion. But this does not mean that wind erosion is less serious everywhere, and there are areas where wind erosion is just as calamitous as the worst water erosion.

The point was also made that on a continental scale wind erosion is mainly confined to the arid and semi-arid climates. But this does not alter the fact that very serious local wind erosion can occur in humid areas. When a moderate total of annual rainfall is concentrated into part of the year, the remainder may be completely dry and so vulnerable to wind erosion. This situation may also result in water erosion and wind erosion both being major problems in the same area, although the more usual situation is of either one or the other occurring, but not both together.

Another reason for localised high rates of wind erosion in climates and regions where it is not widespread is the particular vulnerability to wind erosion of some soil types. One example is dry structureless sands in coastal areas which are subject to stronger winds than inland areas, and also have little cohesion to resist movement. Ignoring localized cases, the factors which in general govern the likelihood of wind erosion are soil conditions, the rainfall and vegetation.

The physical nature of the soil will affect the ease withwhich particles are dislodged, but far more important than these is the fact that the only dry soil blows, and any soil will be unmoved by wind while its surface is moist. Climate therefore has a big influence on wind erosion, particularly the extent the soil is dried up by hot winds and low humidity and also the rainfall.

Wind erosion is more frequent when the mean annual rainfall is low and a rough guide areas most affected are those with less than about 300 mm and those with higher rainfall but longer dry periods. The third factor is the vegetation, for soil is almost immune to wind erosion when covered with a carpet of vegetation. This physically prevents the wind coming into direct contact with the soil in the same way that a good cover of vegetation reduces splash erosion.

CCRDA

For any given soil condition, the amount of soil which will be blown depends on two factors: the wind velocity and the roughness of the soil surface. Naturally a high wind velocity can move particles than a slower wind, in the same way the sediment carrying capacity of flowing water increases with velocity. An empirical formula suggested by Schwab et al (1981) is:

$$S \propto (v-v_O)^3 d^{0.5}$$

where

S - quantity of soil moved
v - wind velocity
v_o - minimum wind velocity which can move particles of this size
d - diameter of the particles

The roughness of the soil surface determines the frictional effect which it exerts on the wind, and so affects the wind gradient, that is the variation of velocity with height above the surface.

3.2.2 Soil movement by wind

3.2.2.1 *Types of movement*

Three distinct kinds of movement occur, depending upon the size of the soil particles.

Suspension is the movement of very fine particles, mainly less than 0.1 mm diameter. Stokes' law relates the speed of a body falling through a fluid to the square of the particle diameter, and the falling speed of such small particles is so low that once lifted they can remain suspended for long periods of time by the turbulence and eddy currents of the air. Dust storms are fine particles in suspension and can result in large amounts of soil being moved long distances.

Creep is the movement of particles at the other end of the size scale and which are rolled along the surface of the ground, pushed by the force of the wind and other particles moving with the wind. Theoretically there is no upper limit to the size of particle which could be rolled, but in practice most rolling particles are found to be in the size range 0.5 mm to 1 or 2 mm diameter.

Saltation is by far the most important of the three forms of movement. For one thing more soil is moved in this way than either of the other two, and also neither creep nor suspension occur without there being saltation. The movement is by a series of low bounces over the surface, and it occurs among the middle size of particles, light enough to be sometimes lifted off the surface, but too large to go into suspension. The size range of particles which may move in saltation is from 0.05 mm to 0.5 mm diameter, with most movement among particles 0.1 to 0.15 mm diameter. The kind of movement of a soil particle is thus determined by its size, as shown in figure 14.2. The dividing lines are naturally not very precise, with some overlap. The form of this bouncing movement is shown in figure 14.3 and starts with a particle rising into the airstream under the action of forces discussed shortly. The vertical speed falls off under the action of gravity, and at the same time the particle picks up lateral velocity from the wind. After rising to a peak which is only a few centimetres high it starts to fall, but continues to accelerate laterally under the force of the wind, and so returns to the soil in a long flat glide path, striking the soil with high energy.

CCRDA

Sometimes rotating particles have a very rapid spinning motion in flight, but it is not clear how often this happens. CHEPIL and WOODRUFF (1963) show high speed photographs of wind tunnel experiments in which the majority of the particles are clearly seen to be spinning rapidly. From the exposure time, the speed of rotation can be calculated as between 1200 and 60000 revolutions per minute. On the other hand, photographs of other wind tunnel experiments by BAGNOLD (1965) show only isolated particles spinning, and Bagnold's comment is that 'rotation does not seem to be the rule'.

There are several possible causes which separately or in combination may cause the initial upward movement of a particle going into saltation. In the collisions between grains rolling and bumping over the surface one may easily be bounced up into the air. A factor which helps this upward movement, although it is not strong enough to start it, is the pressure effect of wind flowing over the sand grains. An increase in the velocity of a fluid results in a decrease in pressure, known as the Venturi effect, which is used in the carburettor of a petrol engine to assist the flow of petrol into the airstream going to the combustion chamber. A closer example is the flow of air over the wing of an aircraft (figure 14.4). We may loosely think in terms of the thrust of the sir against the lower surface of the wing, but what really happens is that the air flows over the curved upper surface faster than over the lower surface. The downward pressure of the air on the top surface is less than the upward lift which keeps the aircraft up. Similarly there is a net upward force as the wind blows over sand particles.

A third factor which can help start the saltation process is the vibration energy which a moving fluid can impart to bodies in its path. Examples are the low-frequency oscillation of water weeds in a fast-flowing stream, and the higher frequency vibration of a kite string or a telephone wire in a high wind. Dry sand grains can also pick up a very high frequency vibration energy from the wind, and cases are known of this reaching such a point that the sand emits a sound. The connection with saltation is that when two rapidly vibrating particles touch, one may be flipped up into the air. Finally, once any particle has gone into saltation for any of the reasons discussed, it returns to the ground with sufficient energy picked up from the wind to bounce many more particles into the air. This high energy impact of saltating particles is also a powerful force on the large grains rolling along the surface as part of the creep process.

CCRDA

3.2.3 The effects of wind erosion

Wind erosion, like gully erosion, is very much a case of prevention being better than cure, for like gully erosion the process is self-generating and once started becomes progressively more difficult to stop. This trend starts right at the initiation of soil movement. Just as starting friction is greater than sliding friction, so the velocity necessary to start the first particle moving is greater than the velocity required to sustain the movement.

Wind erosivity

The kinetic energy of wind can be calculated from

$$KE = \frac{\gamma_a v^2}{2g}$$

where v is the wind velocity and γ_a is the specific weight of air defined interms of temperature and barometric pressure:

$$\gamma_a = \frac{1.293P}{1+0.00367T\ 101.3}$$

For T=15 ^{0}C and P=101.3, kinetic energy= 0.0625 v^2 Jm^2S^{-1}. Energy values for wind storms can be obtained by summing the energies for the different wind speeds weighted by their duration.

Estimating soil loss by wind

Attempts have been made to quantify the factors which influence wind erosion in order to combine them into a numerical equation which will allow the prediction of the amount of wind erosion in given conditions. This method successfully produced the University Soil-Loss Equation for rain erosion, but in that case there was a vast amount of experimental data field plots which allowed the calculation of the values of the empirical constants.

The empirical equation to calculate the soil loss by wind is given as;

$$E= f(I,C,K,L,V)$$

where E is the soil loss by wind erosion
I is the erodibility factor
C is a factor representing the local wind conditions
K is the soil surface roughness
L is the width of the field in the direction of the prevailing wind
V is a measure of the vegetative cover

CCRDA

Part II

4. Socio-economic Issues of Land Degradation

4.1. Land Degradation and its Economic Implication

4.1.1 Land Degradation in Ethiopia/ Tigray

Land degradation specifically soil erosion is generally considered as the major problem of the agricultural production systems of the developing countries such as Ethiopia. In Ethiopia detailed and comprehensive studies about the soil resources and the magnitude of erosion damage on them due to different causative factors are not available. However, looking at the topographic, climatic and land-use features of the country, one can imagine that the extent of erosion to be serious. Though they are very narrow in terms of their coverage and very shallow in the depth of their investigation, the most commonly quoted studies also support this hypothesis.

According to Hurni (1988), quoted in Belay (1992), the extent of erosion in the highlands of Ethiopia is estimated to be on average 42 t/ha/year. Stahl (1989:3) also predicted that about 17 per cent of the agricultural lands in the highlands of Ethiopia will be incapable enough to support production in the years between 1985 to 2010. There are also some area specific estimations of soil erosion rates. For instance one study in Central highlands of Tigray in the early 1970s reported an average rate of 17 t/ha/year (Hunting, 1975). Virgo and Munro (1978) have also suggested similar rate of soil loss. However, agricultural experts based on studies in other areas of Ethiopia and subjective judgement, estimated erosion rate in Tigray to be higher than 80 t/ha/year (REST, 1989). According to Hurni and Perich (1992) Tigray's soils are believed to be have lost 30-50 percent of their productive potential as compared to their original state some 500 years ago. These quoted figures are concrete examples of the paucity of the available data about soil erosion in Ethiopia.

Therefore, in order to estimate the economic impact of soil erosion, generally land degradation, scientific investigations of the extent and magnitude of the problem should be given priority.

4.1.2. Effects of Soil Erosion: theoretical and empirical evidences

Soil is the most important input to agricultural production. It is the most basic of all resources and the primary medium for food production. Soil provides all the necessary requirements for plant growth except sun light. Soil, as a resource, is non-renewable over the short to medium term. Non-sustainable use of soil resources that needs centuries to replace is an economic, as well as environmental, cost to society as a whole. In literature the effects of soil erosion are mostly classified into two broad categories: the 'on-site' and 'off-site' effects.

CCRDA

4.1.3. On-site effects

Soil erosion has at least the following major on-site effects:

i reduces the topsoil depth
ii organic matter loss
iii breakdown of soil structure and compacting
iv deterioration of soil texture
v loss of plant nutrients
vi reduction in availability of water
vii damage from uncontrolled runoff and flooding if it is water erosion

4.1.4. Off-site effects

Among the off-site effects of soil erosion the following can be mentioned:

i siltation of reservoirs and channels particularly irrigation and hydroelectric dams
ii increase in flooding hazard outside the farm
iii pollution

4.1.5. Economic implications of land degradation

Generally, the economic implications of soil erosion can be categorised into two in similar way as its effects: on-site and off-site economic implications.

4.1.6. On-site economic implications

Among the on-site economic implications of soil erosion, its effect on productivity of agricultural land is the major one. The impact of soil erosion on productivity is critical in the analysis of soil erosion and conservation. Though there is little agreement on the exact and direct effect of soil erosion on productivity, it is believed that soil erosion lowers crop yield.

We have seen that erosion affects the most important yield determining physical and chemical properties of soil. So, it ultimately leads to decreased productivity and farm income. Researchers employ two general techniques to estimate the effect of soil erosion on productivity. The first and relatively simple method involves estimation of the effect on yield of certain revealed erosion processes. The second method is a modelling approach.

Technically, the first method can be applied in two ways: by continuous monitoring of soil erosion and yield trends on an area over time or by creating artificial erosion such as desurfacing the topsoil. The former tries to establish a form of relationship between rates of erosion and crop yield losses. The relationship between loss of soil and crop yield has been extensively plotted in the United States and, to a lesser extent, in other temperate countries. In Africa, Lal (1983), quoted in Stocking and Peake (1986), has developed several exponential regression equations relating cumulative soil loss and yield for maize and cowpea growing on Alfisols in Nigeria. The crops were grown on different slopes. For the purpose of illustrating this method his findings are presented here in figure 1 and table 1. A very generalised and systematic representation of the erosion-productivity relationship is presented in figure 2. In this figure three possible forms of erosion-productivity functions are depicted.

CCRDA

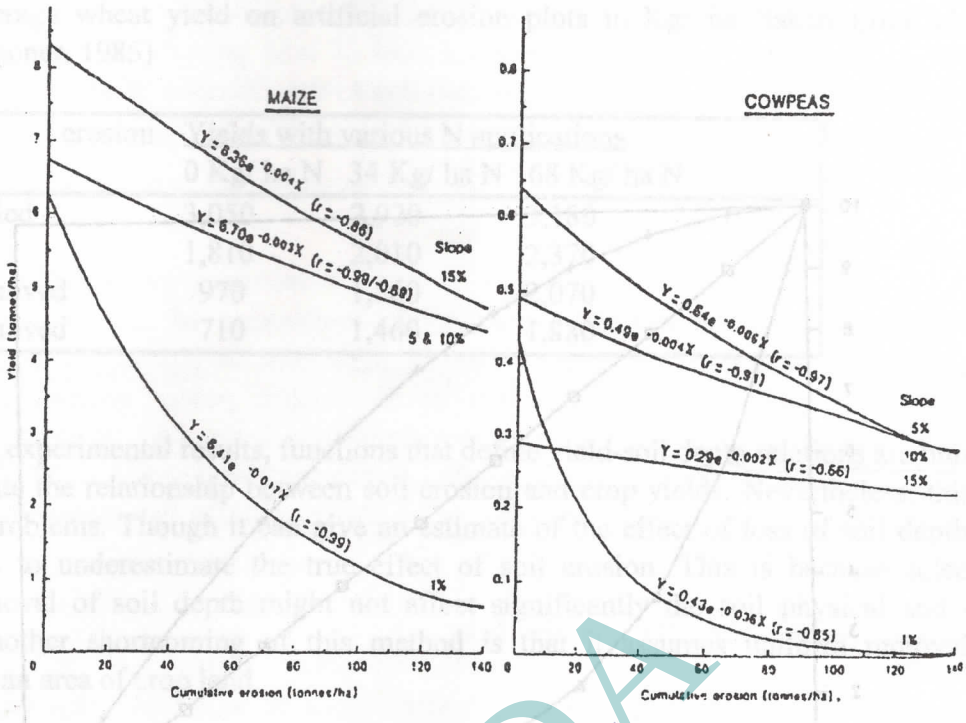


Fig.1. Relation between crop yield (Maize and Cowpeas) and cumulative erosion on an Alfisol in Southwest Nigeria, 1971-82 (data abstracted from Lal, 1983; quoted in Stocking and Peake, 1986).

Table1. Percentage decline in yield with cumulative soil loss on an Alfisol in Nigeria (R. Lal, quoted in Stocking and Peake, 1986).

soil loss (t/ha)	Equivalent depth of soil (mm)	yield decline on slopes of 1%	5%	10%	15%
Maize					
10	0.7	3	4	3	4
35	2.5	45	10	10	13
140	10	91	34	34	43
700	50	100	88	88	94
Cowpeas					
10	0.7	30	5	4	2
35	2.5	72	19	12	7
140	10	99	56	35	19
700	50	100	98	90	76

CCRDA

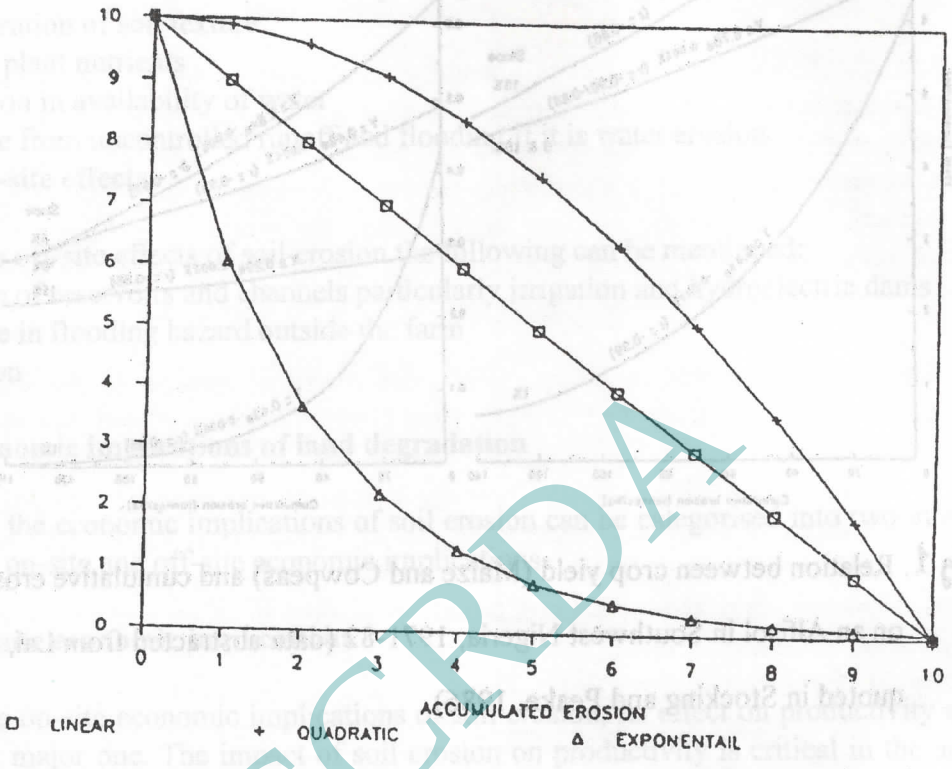


Fig 2. Three possible forms of Erosion-Productivity Functions (from Bojö, 1991)

CCRDA

The regression equations in figure 1 empirically confirm the relationship between yield loss and continuous soil erosion. This method has its own pros and cons. It is generally simpler, because it needs less detailed scientific knowledge on the part of the analyst. However, in addition to the difficulty of finding appropriate data and the shortcoming of estimation, the method is non-transferable and the results are site specific. This is because the relationship is highly dependent on specific conditions such as soil type, crop type, climate or agroecology, and topography. Other shortcomings are that it needs long period of time and only gives an aggregate impact of erosion.

As it has been pointed earlier, researchers also employ, in artificial studies, the yield-soil depth relationship to estimate the impact of topsoil erosion on productivity. This method involves removal or addition of a measured depth of topsoil and measuring its impact on yield. It assumes uniform distribution of topsoil before it is subjected to artificial erosion. This technique can be illustrated here by research done in Idaho by Massee and Waggoner (1985). The different treatments and their corresponding effects on wheat yield are presented in table 2. According to their findings, wheat grown on plots where the topsoil had been removed yielded less than the wheat grown on plots with untreated or thickened topsoil.

Table 2. Average wheat yield on artificial erosion plots in Kg/ ha (taken from Massee and Waggoner, 1985)

Artificial erosion treatment	Yields with various N applications		
	0 Kg/ ha N	34 Kg/ ha N	68 Kg/ ha N
15 cm soil added	3,050	2,920	3,180
Untreated	1,810	2,010	2,370
15 cm soil removed	970	1,560	2,070
30 cm soil removed	710	1,460	1,880

Based on such experimental results, functions that define yield-soil depth relations are built and are used to estimate the relationship between soil erosion and crop yields. Nevertheless, this method has inherent problems. Though it can give an estimate of the effect of loss of soil depth on crop yield, it tends to underestimate the true effect of soil erosion. This is because selective and purposive removal of soil depth might not affect significantly the soil physical and chemical properties. Another shortcoming of this method is that it assumes uniform removal of soil materials over an area of crop land.

The modelling approach to estimating the productivity impact of soil erosion is a relatively new concept. The basic principle underlying the mathematical models is the existence of biophysical interaction in the environment. That is, the model tries to simulate the interaction between the physical and biological parameters to predict yield effect of soil erosion. In general, the aim is to formulate separate models for the mechanics of the erosion process and the crop growth process and then to link the two by functions representing yield-erosion relationships. The mathematical models range from the relatively simple, such as those based on the universal soil loss equation (USLE), to the very sophisticated ones.

The USLE model starts by estimating the amount of soil loss and then, as an additional stage, assesses the effect of this loss on productivity. However, this model does not account for loss of productivity through degradation of the physical structures of soil and nutrient depletion by soil-mining, cropping systems.

Another comprehensive model is the erosion productivity impact calculator (EPIC) (Williams *et al.*, 1984; Jones *et al.*, 1991). It has better representation of the effect of various forms of soil degradation and of other biophysical variables on productivity. [**Note**: such models can be discussed in detail in collaboration with relevant staff members]. Generally, the modelling approach is more flexible and allows parameter values to be drawn from different data sources, but, such models are also data demanding and they are very difficult to apply in the absence of detailed knowledge of the biophysical environment and they still need to be tested against actual results in order to verify them. These drawbacks of the modelling approach limits it applicability in the developing countries.

CERDA

Other on-site economic implications are:

1. prevention cost: costs incurred by farmers or communities to control or prevent soil erosion
2. increase in production cost; like increase in cost of land preparation due to high power requirement to till the land which is compacted due to deterioration of soil structure; increase cost of fertilisation to compensate loss of nutrients;
3 opportunity cost of crop damage due to flooding

4.1.7. Off-site economic implications

For a comprehensive assessment of the economic implication of soil erosion the off-site implications should be taken into account. Among these cost of clearing or constructing new irrigation channels and reservoirs; reduction in an electric power generating potential of hydroelectric stations and an increase in their maintenance costs; cost of purifying water for domestic uses and alleviating other forms of pollution related to soil erosion; cost for the national economy due to transportation and deposition of sediments outside the national boundary, for instance the case of Abay River, etc.

4.1.8. Economic implications of water shortage

Water shortage during the growing season of crops causes stress which ultimately lowers crop growth and potentially achievable production. In extreme cases, when stress continues over the critical growing period of crops, it may lead to complete crop failure. The magnitude of the effect of water deficiency on the crop yield depends on when it occurs during the developmental stage of the crop. For example, in maize, stress at tasselling results in a greater reduction in yield than stress at other stages in the crop's growth.

The problems of water shortage are caused by low annual rainfall and unfavourable distribution of rainfall through the cropping season. Based on empirical studies, agronomists believe that crop yield can be expected to vary from year to year by about 10 to 15 percent as a result of changes in the distribution or the intensity of rain period or both. One study in India (Grewal *et al.*, 1989) specifically indicated that frequent crop failures were due to erratic rainfall distribution even though the mean annual rainfall was between 1000 and 1500 mm. On such occasions higher and stable yields can be obtained only by creating optimal soil moisture over the growing period of crops which ultimately requires some techniques of moisture conservation.

In sum, this section has briefly outlined the physical effects of soil erosion and their economic implications. Different ways of assessing and quantifying these physical effects which are used in the end for designing appropriate solutions, and economic and socio-economic appraisal of these remedies were discussed. The productivity impact of water shortage were also highlighted. Besides, the complexity of the problem and the need for a multidisciplinary approach is implicitly indicated.

CRDA

Other on-site economic implications are:

1. prevention cost: costs incurred by farmers or communities to control or prevent soil erosion
2. increase in production cost; like increase in cost of land preparation due to high power requirement to till the land which is compacted due to deterioration of soil structure; increase cost of fertilisation to compensate loss of nutrients;
3 opportunity cost of crop damage due to flooding

4.1.7. Off-site economic implications

For a comprehensive assessment of the economic implication of soil erosion the off-site implications should be taken into account. Among these cost of clearing or constructing new irrigation channels and reservoirs; reduction in an electric power generating potential of hydroelectric stations and an increase in their maintenance costs; cost of purifying water for domestic uses and alleviating other forms of pollution related to soil erosion; cost for the national economy due to transportation and deposition of sediments outside the national boundary, for instance the case of Abay River, etc.

4.1.8. Economic implications of water shortage

Water shortage during the growing season of crops causes stress which ultimately lowers crop growth and potentially achievable production. In extreme cases, when stress continues over the critical growing period of crops, it may lead to complete crop failure. The magnitude of the effect of water deficiency on the crop yield depends on when it occurs during the developmental stage of the crop. For example, in maize, stress at tasselling results in a greater reduction in yield than stress at other stages in the crop's growth.

The problems of water shortage are caused by low annual rainfall and unfavourable distribution of rainfall through the cropping season. Based on empirical studies, agronomists believe that crop yield can be expected to vary from year to year by about 10 to 15 percent as a result of changes in the distribution or the intensity of rain period or both. One study in India (Grewal *et al.*, 1989) specifically indicated that frequent crop failures were due to erratic rainfall distribution even though the mean annual rainfall was between 1000 and 1500 mm. On such occasions higher and stable yields can be obtained only by creating optimal soil moisture over the growing period of crops which ultimately requires some techniques of moisture conservation.

In sum, this section has briefly outlined the physical effects of soil erosion and their economic implications. Different ways of assessing and quantifying these physical effects which are used in the end for designing appropriate solutions, and economic and socio-economic appraisal of these remedies were discussed. The productivity impact of water shortage were also highlighted. Besides, the complexity of the problem and the need for a multidisciplinary approach is implicitly indicated.

CCRDA

4.2 Socioeconomic Causes of land degradation

What are the root causes of land degradation in Ethiopia ? We can categorize the causes into natural (physical and chemical) and socio-economic factors. We shall dwell here on the second category of factors.

4.2..1. Socio-economic variables

4.2..1.1. Tenure patterns

Tenure patterns bring into expression a complex relationship involving land use rights (arable, grazing or tree) and the with it related social and economic rights and obligations.

Tenure patterns could take three basic forms, namely, private, customary and community or state ownership patterns. It is argued that different tenure patterns do have different effects on land degradation.

A source of controversy in this respect concerns the relationship between common property and the generation of externalities in general and system sustainablility in particular. Here we do have what Harding (1968) described as the *'tragedy of commons'* in the sense that because no individual would have to pay the full costs of over exploitation, it would be in each individual's interest to extract as much as possible from the resource base, with the result that commonly held resources would inevitably be degraded, the so-called 'free-rider problem'.

In this respect indigenous communal tenure systems are a constraint to agricultural productivity and potentially promote land degradation. This has to do with the fact that such tenure systems discourage farmers to invest in land conservation measures. In other words, private property is more stable and adaptive than common property for the fact that the rights of exclusion for private property owners are generally upheld by the state: that is the customary ability of private owners to exclude other from utilizing their land has been formalized and codified in law. A key factor underlying the continued persuasive power of the tragedy of commons metaphor is the belief that private land ownership gives individuals increased incentives for managing their resource sustainabily. Only people who have secure tenure rights over their land holdings will have the motivation to invest in the long-term undertakings necessary & ensure the continued yields of fragile environment.

CGRDA

The other approach to this problem is that private property is not a solution to land degradation and resource depletion either. The individual in his interest to maximize utility may not give due regard to resource conservation. In fact, private property, secure land, and sustainable resource use are not inevitably or intrinsically linked. The short time preferences of the private owners to their ability to abandon degraded lands once maximum resources has been extracted, mean that they don't have the same incentives for environmental preservation that exist in communities whose families have inhabited a region for generation, and whose descendants will continue to inhabit for generations to come. In other words, even under communal forms of tenure pattern, if the community is the sole owner and beneficiary of the land, grazing, and forestry areas, they could actually maintain their environment and they can mobilize forces toward this end - so called the *dynamics of commons*.

In order to concretely see the relationship that exists between tenure rights and land degradation it is necessary to have a retrospective view of the history of tenure patterns in Ethiopia and their possible effect on land degradation.

In pre 1975 Ethiopia, though there were various and complex tenure system, it is advisable, for the sake of simplification, to concentrate on two of the basic tenure patterns, namely Rist and Gult.

The Rist system and its various forms was more prevalent in most parts of Tigray, Wollo, Shoa, Gondar and Gojam. Under this system an individual was said to have rights to land (Rist rights) in a given community if he/she was able to establish descent from one who was recognized as the original holder of the land in question or the founder of the community (Dessalegn 1984). The individual in this corporate system obtained usufruct right over his holdings, which, however, could not be transferred to others on sale, mortgage, etc., although he could lease them temporarily.

In this system, there prevailed less inequality and a higher degree of social security, it did generate land fragmentation and deterioration in the quality of land. That is, since a holder in this system (especially in Diessa) was entitled to use the land for only a short time (usually up to 7 years), it generated lack of incentive on the part of the individual member to invest in the improvement or even preservation of the land. In this sense, it is not perhaps more coincidence that much of the land degradation process have been taking place in these regions.

CCRDA

The Gult system of tenure emerged with the expansion (conquest) of the Abyssinian Empire to the south whereby land was expropriated from peasants and local chieftains and given to officials and loyal servants of the crown. Both land and peasants in the occupied territories were allotted to officials in proportion of their roles and rank. The local farmers were hence, turned to Gebars, that means tenants who work land for paying tribute to the land holding nobility. The new landowners held only Gult rights, i.e. not the right of ownership of land but the right of collecting tributes from tenants. Since in most cases, Gult rights were given for relatively longer periods (in some cases even for life) - irrespective of the effect that it had on the tenants - it created a sense of security of tenure. It was also characterized by less fragmentation and parcelization of plots. As a result we see lower degree of land degradation in the ex-Gult tenure areas.

After the overthrow of the Imperial regime, the Derg proclaimed the land reform legislation of March 1975 with the declared aim of changing the nature of agrarian relations in rural areas so as to prepare the necessary ground to agricultural transformation in the country. As a result it nationalized land (put it under 'public' ownership) and redistributed it to the tillers thereby doing away with landlordism and tenancy. There emerged men of free-holder subsistence producers having only user rights of land. From this reform, though tenants and the landless benefited, owner-cultivators were in most cases net-losers (Dessalegn 1984). In the attempt to promote equity of tenure, redistribution of plots within a short period of duration (in some cases even 1-2 years) was a common practice which means nothing other than the diminution of plots, the disruption of production activity, and the inculcation of feelings of insecurity and doubt in the farmers. Hence, by declaring the public ownership of the land the state replaced the landlord as the overlordship of the land and it also failed to guarantee tenure security to the rural producers. Rather than solving it, it made insecurity of tenure an enduring element. Consequently, land degradation continued unhindered to affect most parts of the country even during the Derg though, as we shall see, it introduced different conservation measures to tackle this problem.

So to come to the point, it is generally true that insecurity of tenure does facilitate and promote land degradation. And this may be connected with the type of tenure pattern which causes or rather promotes tenure insecurity - communal tenure pattern - and hence environmental degradation. Of course, it is important to make distinctions between common property regimes (in essence jointly held property) and

CCRDA

that of open access system (no restrictions on resource use) whereby the former does not as such encourage unrestricted resource consumption and depletion.

Moreover, lack of secure tenure may not be due to the absence of private ownership as such, but rather to the fact that existing social structures allow those who control usufruct rights - whether they be individual, or groups, corporations or governments - to grant or withdraw these rights at will. (Vivan: 9). This has been often the case in Ethiopia.

So, the point is not that of choosing between either private or communal, it is a point of guaranteeing tenure security so as to lay the necessary ground for environment preservation as well as regenerative measures.

4.2..1.2 Poverty, marginalization and disempowerment

Land degradation is a major cause of poverty. It is one of the physical manifestations of a complex of demographic, economic and social changes which causes rural population's poverty. Poverty is a symptom of one of the primary underlying cases of total level environmental decline in the third world today. (Vivan: 18). A combination of factors (climatic rise in human population and its associated demands on the environment) pave the way to the loss in land productivity (crops, livestock or fuelwood) which in turn leads to the marginalization of the rural poor from all development processes barely able to maintain themselves at the subsistence level. The process of degradation contributes to the worsening of poverty and further marginalization of the rural poor which is depicted in the further decline in rural standards of living.

In this case, their strategies to compensate for loss of productivity may in turn exacerbate the process of degradation. Poverty, hence, can cause environmental degradation.

Poverty reflected in the degree of destitution and hunger that people are subjected to, is a serious handicap on the side of the farmers to undertake conservation measures. Poor farmers lack the means (instruments, land, skill, etc.) and hence cannot undertake conservation measures. Hence, poverty limits the poor farmers' ecological handling competence.

CCRDA

However, it is not mere poverty as such which explains the farmers' poor ecological handling competence, but their state of disempowerment, a complex process centered around people's inadequate efforts to increase their participation and the lack control over physical and social resources in the development process. Disempowerment of rural households from the development process involves:

- the deprivation of access to the resources on which they depend;
- abrogation of their traditional tenure rights and rights to exclude outsiders (especially in communal tenure patterns, collectivization, etc.), and
- their ability to make their own decisions regarding resource management may be curtailed.

Marginalization and disempowerment is often accompanied by land degradation, and in turn can exacerbate such degradation because of deteriorating land management practices which typically accompany it. Therefore, the link between land degradation and poverty [in its broader sense] is direct and intimate (IFAD 1992).

On the other hand, though poverty causes and exacerbates environmental degradation, seen globally, the rich equally in their strive to enjoy higher standards of living, damage the earth's ecological health for their higher consumption of energy, raw materials and manufactured goods cause higher resource depletion and consumption of exhaustible resources.

4.2..1.3 Awareness, perceptions and indigenous interpretations of land degradation

These include the degree of cognitive understanding or ignorance, misjudgment, or not appreciating ecologically relevant data and interconnections on the one hand and the traditional, emotional or interest-oriented attitudes that hinder or explain the ecological competence action of farmers. (Jenssen 1986)

Soil degradation is a very slow process and almost invisible. Farmers seem not to observe the ongoing erosion problems is their environment. Or they do not perceive that as an immediate problem. Farmers usually attribute deterioration of crop yields to declining rains. But soil degradation may also have affected the water holding capacity and thereby reduced the soil's ability to overcome situations of water stress. Very likely, this process may also have contributed to the decline of yields. As long as farmers do not perceive soil degradation as a major determinants of decreasing yields this trend will certainly not be reversed.

CCRDA

It's also observed that farmers do not have the conviction that conservation measures can lead to a gradual increase in yields in agriculture. In this case, therefore, it is food for work which is the motivating force in people's participation. Without food-for-work farmers do not participate in (soil) regeneration measures. (Stahl 1989; Campbell 1991).

The peasant's adjustment to his environment, as one author wrote, is a straight forward practical one. He has no derive to conquer or to be master over nature; he has no inclination to fuse or lose himself in nature. (his) perception of natural objects is in terms of what will assist or hinder him aucting out a substance. The peasant's orientation toward nature is to get what one can out of what nature readily provides (Levine 1967). Consequently their attitude regarding resource use is shaped by their trust on God and their mentality of having the capability to overcome problems and misfortunes. Hence, their basic attitude toward ecology is characterized by indifference or virtual negligence.

Farmers do have a high individual time preference rates. i.e. they are inclined to value present economic benefits at the expense of future consumption. As individual discount rates are basically high, investment in land preservation tend to be very low (especially by small and poor farmers). Investment in soil conservation measures have, hence, to generate immediate and visible returns otherwise they will not be adopted by the local population. Moreover, the social rate of time preference based on intergenerational equity is significantly lower than individual rates.

Of course, there attitudes do not principally block action to introduce regenerative measures. But these together with the magnitude of poverty, land scarcity etc. do not allow to extraordinary initiatives by the farmers themselves as the situation indeed requires. Their action is characterized by inadequate commitment, a certain feeling of ambivalence, resignation and passivity.

4.2..1.4 Demographic change

The population of Ethiopia grew from about 23 million in 1967 to 42 million in 1984, and is at present estimated to be around 54 million. Within a quarter of a century has the population more than doubled. The average annual growth rate is at present 3.1 per cent. This trend is expected to continue for sometime to come given the persisting high fertility and declining mortality rates. In that case, the population will

CCRDA

more than double again within a quarter of a century and this is expected to have a serious impact on agricultural productivity and the supply of energy.

In other words, that rapidly intensifying pressure of population increase demands higher food production, arable land, energy source, etc. leading to overutilization of resources thereby aggravating land degradation in the process. Typically, a farming society under demographic pressure expands its production to marginal area without significantly modifying methods, except to shorten fallow periods, and begins to adopt more intensive cropping patterns and experiences severe stress between the crop and livestock sectors.

Seen on a face value though the country has a good agricultural potential - out of 79 million hectares of cultivable land only 18 per cent is currently under cultivation; a good possibility to expand to those yet unexploited. But the situation is quite different when one looks at the uneven spatial distribution of the population by agro-ecological zones. The highlands are the most densely populated area is the country, and it this region which is more affected by land degradation. The highlands of Wollo, Tigray, northern Shoa, eastern Gondar, parts of Hararghe and Bale regions have suffered from serious ecological degradation and their carrying capacity of people and animals have been severely undermined. Due to the high population densities average land per capital in northern Ethiopia amounts to 0.42 ha than the national average of 0.60 (Markos 1990). And this may further deteriorate in the coming future exposing the country more to low food production and famine.

It is, however, premature to conclude that food production declines because of the fact that peasants operate small plots, a phenomenon caused by high population growth. There are countries is Africa where agricultural production has not been constrained despite high population growth and limited cultivable land. That is to say farming systems can be adjusted to meet the increased demands while also protecting the soil.

This raises the question of why conservation-oriented land management and farming practices have not developed in Ethiopia. The answer may lie is cultural preferences for small-seed crops such as teff, barely, wheat, etc., in the poor communication of agricultural innovations, lack of adequate extension services and in the lack of appropriate research findings for dissemination. However, a critical factor appears to be the socio-political environment for peasant farmers.

CCRDA

Therefore, to regard reducing population growth as the most effective means of arresting environmental decline is over-simplistic. Concentrating on slowing demographic growth rates in order to relieve particular environmental problems ... is at best ineffective and at worst misguided, diverting more attention from more fundamental causes and more productive solutions (Vivan 1991).

4.2..1.5 Economic and development policies

Recently, the existing policy environment is increasingly being drawn into explaining land degradation issues in Ethiopia. In fact, the policy environment, policies regarding security of land use, pricing policies of agricultural products, development (economic) policies that emphasized sectors other than agriculture, neglect of small holder agriculture in particular, lack of agricultural supporting services - such as input supply, credit services, extension, education and training services, etc. - discourage farmers from investing in agriculture and thereby in preserving the quality of their land, and from adopting conservation measures introduced by the government.

If we have a look into the development policies of the last half century, policy gave emphasis generally to the so-called modern sector. During the Imperial governments first and second Five Year Development Plan (between 1957-62 and 1963-1968) it was the manufacturing, mining and infrastructure development that was given great importance. It was is the last phase of the Imperial government's development plan, during the Third Five Year Development Plan (1968-1973) that the important role of agriculture in development was recognized. But, even then it was private modern commercial farms that were supposed to be the motor of development in the country. Therefore, small holder agriculture received little policy attention.

During the Derg, though agriculture in general was said to be given policy emphasis, the development of co-operative agriculture and expansion of state farms got the highest attention in implementation. Policy gave once again little emphasis to peasant agriculture. This involves in terms of resource allocation - share in government expenditure to agriculture and human resources and land, supply of inputs, etc. ... not only agricultural productivity but also land degradation in the small holder agriculture.

At the same time the policy environment, as we have seen, guaranteed little security of access to land. Since the medium to long-term return typical for most conservation initiatives are discounted by farmers because they are uncertain about

CCRDA

their access to land. We do see little on-farm conservation measures undertaken by peasants themselves.

Major determinants with respect to the pattern of land use are relative prices of agricultural commodities. The policy of lower prices of agricultural products, with the aim of supplying lower consumer prices to urban centers, and the extractionist policy of the government (with the declared aim of fostering development in other sectors) affected the income of farmers, thereby constraining their capability and propensity to invest in agriculture. Especially during the Derg, where attempts were undertaken to centralize agricultural marketing deprived farmers to procure their product in the free market thereby lowering the price they get for their products from the Agricultural Marketing Corporation (AMC). The pricing and marketing policies of the AMC - the delivery of quotas, the policy of fixed and lower producer prices, the limiting of private grain trade and the strategy of encouraging collective agriculture by giving preferential prices to agricultural products - caused farmers to receive little return from farming ...impoverishing and thereby lack of resource to undertake soil and water conservation measures. Therefore, the policy environment has exacerbated rural people's pressure on degraded land resources, by deepening poverty and narrowing their income generating opportunities.

This phenomenon does have also an international dimension: farming societies increasing being drawn into the monetary and international economy, the agricultural policies of industrial countries which are characterized by protectionism and subsidization of their own production, also seem to have negative impact on the third world's agricultural production directly and soil degradation indirectly.

CCRDA

5. Responses to Land Degradation

Soil conservation is a comprehensive approach which encompasses both control of erosion and maintenance of soil fertility. (Young 1989). The general aim of soil conservation is to obtain the maximum sustainable level of production from a given area of land while maintaining the dynamic balance of nutrient exploitation and regeneration and the physical soil characteristics in a good status (Graaff, 1993).

5.1 Indigenous conservation systems - General outline

Owing to the changes in their environment, their needs, and the relative availability of resources in their surroundings, farmers have developed different adjustment (conservation) methods, as part of their farming systems, through the years. It's these vast wealth of knowledge that farmers developed in interacting with their ecosystem that we call indigenous knowledge.

Traditional land use systems are a reflection of the historical population density and the ecological potentials of settlement areas. In periods where there was excess arable land, productivity declines due to increased population pressure, soil exploitation, unreliable rainfall, etc. were encountered not by intensifying cultivation methods to increase yield per unit of area but rather by shifting to and clearing new lands. This pattern known as shifting cultivation is based on a mechanism where few years of cultivation is followed by several years (depending on the availability of land) of fallowing to allow the regeneration of soil fertility. However, with growing population pressure it led to the reduction of fallow periods.

In Ethiopia, as in many sub-Saharan African countries, there are various indigenously developed management techniques developed to combat specific environmental constraints or at best to minimize risk under the permanent and semi-permanent cropping systems. These include:

- choice of crops and the (adoption) of new varieties (fast growing, drought resistant varieties);
- seasonal and spatial arrangements in cultivation (multiple cropping, alley cropping, agro-forestry, crop rotation, intercropping, etc.);
- field techniques (reduced tillage);
- soil conservation and maintenance of fertility (terracing, crop rotation, intercropping with legumes, composting, manuring, vegetation burning); and
- water and moisture conservation (mulching, late cropping)

CRDA

The different soil and water conservation measures developed indigenously can be categorized in this manner.

Mechanical	Biological	Institutional
- Soil built terraces	- mulching	- herding
- contour drains and cultivation across the slope	- cover cropping - planted contourlines (e.g. grass strips)	strategies -irrigation management
- Earth or stone bunds	- agro-forestry	
- Contour raw of plant debris	- incorporation of organic matter	
- tie-ridging	- Green manure	
	- animal manure	
	- crop rotation	
	- increased share of legumes	

Source: Zegeye Hailu and Artur Runge-Metzger, 1993

Though there are a whole set of indigenously developed conservation measures their application by farmers and their effect in ensuring a sustainable environment is not as to be expected and has diminished through time. This has to do with the fact that the social and economic differentiation among farm households paves the way to variations in the application of these techniques among farmers within the same locality facing similar problems of land degradation. That is to say, all farmers may not have the options of maximizing the ecological potential of their lands. This is because adjustments are normally proceeded by indigenous experimentation, and experimentation is always associated with risks which only a minority of farmers, because of better resource endowment, is willing to take. Besides farmers experiment to a limited extent to refine their agronomic practices.

These measures, in most cases, only postpone the problem of land degradation and, hence, are no lasting solutions in their own right.

Last but not least there are other factors that hinder the farmers' efforts in adapting such measures and their effectiveness to combat land degradation.

CCRDA

These include such exogenous pressures as:

- policy decision,
- increased integration into the market economy, and
- population pressure

Population growth will force resource extraction to exceed the capacity of the environment to renew itself, and environmental degradation will be the unavoidable result. These factors threaten traditional resource management by farmers.

Though such indigenous measures, seen in their effectiveness in alleviating environmental illness was low, and have contributed only in adjustment process of the farmer to the changing environment, one should not arrive at conclusions that may advocate for replacing them with totally "modern" approaches. In fact, making generalized judgment about the future of traditional resource management systems in the context of development is inappropriate. It cannot be said that it is either possible or desirable to maintain them, and at the same time it is a mistake to dismiss them as obsolete or unable to remain adaptable in the face of exogenous pressures.

That indigenous knowledge can provide opportunities for achieving sustainable development should not be overlooked. In some cases existing systems can arguably be maintained, at least for the medium-term future. Traditions of community resource management will form the basis of community action which specifically addresses environmental issues. Hence, emphasis has to be placed on the necessity of participatory research approaches in order to tap this potential of indigenous innovations.

CCRDA

5.2 Indigenous Conservation Practices in Ethiopia

- What is really indigenous?

Indigenous means something originating, growing or living naturally.

Hence we can talk of indigenous knowledge, technology plants, land races and even "indigenous people".

People, particularly farmers, through their long tradition of experimentation (trial and error) have developed farming techniques considering their environmental conditions.

Farmers in Hararghe, Konso, Sheno, Shedeho Meket, and Bizet although all small holder farmers live in different agro-ecological zones in Ethiopia.

An Oromo farmer from Hararghe popularly known as "Kotu" (meaning farmer) through time has developed a farming system which is commensurate with the production of chat, sorghum and coffee.

The farm planning and allocation of resources is holistic in nature. Livestock are component parts of the system and the "Kotu" would manage livestock with care. An ox after plowing for two years is fattened and sold fetching good prices. The fattening process is unique in that, all vegetative material (weeds, leaves thinned from sorghum stalk etc.) are collected and brought to the feathered ox. The farmer deliberately leaves a standing tree in his farm land for feathering the ox and for use as a shelter. This practice also makes the droppings and the urine of the ox to increase the organic matter content of the soil.

CCRDA

Situational Analysis

1. The "Kotu" would keep a reasonable number of livestock. A pair of oxen in most cases for plowing his land (he also uses the "Dongora" manually to break clods of soil). To augment his sorghum based diet with protein source, he maintains two or three lactating cows. The lactation is synchronized so that he obtains a constant supply of milk. some farmers would have few goats, rarely sheep.
2. Keeping few number of livestock minimizes the burden on feed resources.
3. Fattening the ox (usually during the rainy season when feed is available) for eventual sell firstly enables the farmers not to keep unproductive animal in the farm (in actuality farmers keep oxen free of work for nine months, increasing the cost of feed). Secondly the type of breed (the Boran) responds by gaining weight to the available rainy season feed. After six months of fattening the farmer sells the ox with good price.
4. By deliberately leaving trees his farm lands for multipurpose use the farmer in Hararghe is actually experiencing agro-silv-pastral.

Conclusion: This small holder farming system is low input, sustainable and conservation based.

Questions: How would you improve this system to make it more productive?

CCRDA

soil conservation activities as an integral part of the cultural practices. Terraces, bunds and waterways that have been built by the earlier members of the community are maintained every year irrespective of sensitizing by extension agents (actually extension services in these areas were non-existent and if there was some it was weak in delivery and area coverage). To increase the rooting depth of the degraded lands, the people in Konso would travel to the lowlands, dig the soil and carry it long distance to spread the soil behind the terraced land.

Situational Analysis

Indigenous knowledge of conservation of soil. This knowledge developed and through time tested skill is now being popularized in other parts of the would.

Conclusion: Soil and Water Conservation activity should not be separated from the actual farming practice (cultural practice) exercised by the farmers. Current campaigns on mobilizing people for a certain period of time only to undertake soil and water conservation works should be scrutinized, evaluated and critically reviewed.

Question: Relate the situation above to the experience of indigenous soi and water conservation activities in your project area. Discuss with course participants.

CCRDA

Farmers in Sheno (North Shewa) in order to better utilize their highland soils have developed the "guie" (soil burning) system. In this system a land that has been left fallow for 10 years (5-15 years) is plowed. The sod (soil with plenty of grass roots) is collected into heaps with some dung and straw in the middle. The straw and dung is then burnt for se several days and thereafter the ash is spread on the land during first plowing. Barley the major crop of the area, then is planted. Yield of barley is relatively higher for the first three years and declines drastically. Farmers are then forced to fallow the land for yet several years repeating the cycle.

SITUATION ANALYSIS

The soils of Sheno are heavy clay soils, where internal drainage is restricted This shows the downwater movement of water creating water logge situation, thereby influencing the chemical, biological and physical propertie of the soils. If these characteristics are affected negatively then th relationship between the soil and the plant is also affected, because the soi is the medium for the successful cultivation of crops.

Since the farmer has to sustain his livelihood he has developed this uniqu soil management practice of soil burning. Through this process the textur of the soil is changed from fine to medium course, enabling the fre downward movement also releases potassium and phosphorus temporaril increasing the level of these nutrients making the soil higher in fertility. Thi results in higher yield of the barley. On the otherhand the level of nitroge decreases because of the burning of organic matter. Likewise the level o micro-organisms decreases.

CONCLUSION

The system is sustainable as far as the population pressure on land is low With increase in population, the fallow period of 5-15 years will decreas necessitating external inputs and technologies.

QUESTIONS

What is a broadbed maker? What is a broad bed and furrow? How was thi technology developed?

CCRDA

Farmers in Shedeho Meket (Amhara Region) have been isolated from rest of Ethiopia because of poor infrastructure. These people cultivate several types of landraces of wheat, barley, lentils, horse bean, peas and other crops. However, continued cultivation of the land without proper soil and water conservation practices has decreased the capacity of the land to sustain the different land races. Lack of proper cultivation, continued land degradation resulted in the decline of soil fertility. Farmers do not put manure because dung is used as source of fuel.

SITUATIONAL ANALYSIS

1. Rich land races originally
2. Poor soil fertility
3. No fuel wood, land is degraded
4. Dung is removed, low soil fertility
5. Population pressure

CONCLUSION

Diagnose the constraints, establish priorities and design intervention with active participation of the people.

Past Approaches

Soil and water conservation activities in Ethiopia were initiated in the late seventies as a response too the repeated drought and famine experienced in the northern, southern and eastern part of the country. Activities concentrated on the use of physical structures for soil and water conservation purposes. Research on soil and water conservation began at Suke (Hararghe) under the Soil Conservation Research Project (SCRP). Similar sites at Andit Tid (Shewa) Gunino, (Sidamo), Maiber (Wello) and in Eritrea conducted research. These sites represent different agro-ecological zones.

Research was carried mainly by graduate students based in foreign universities with objectives not clearly defined to reflect the technological needs of the constraints to soil and water conservation.

Inputs from research findings were not incorporated into the soil and water conservation activities of the different departments.

The following points can be drawn from past activities in research:

1. All research activities in soil and water conservation was not coordinated
   - SCRP conducted research in isolation without taking the farm as a unit of management for the farmer.
   - A.U.A. conducted on-farm research, but the methodology used was not based on cost-benefit analysis.

CCRDA

- I.A.R. altogether did not consider soil and water conservation as a strategy for increasing land productivity.

2. Soil and Water Conservation research requires policy instruments in landuse and land tenure. All research was mainly technical, without considering the political, social and legal implications.

Conservation of natural resources for sustainable agricultural development is based on the principle of watershed planning. In a given watershed there are different interacting factors that need serious consideration in research.

Biophysical parameters (climate, geology) soils, water sources, vegetation etc.) are considered to be non-boundary which span across different farming communities. On the other hand socio-economic parameters in a watershed study are bound to be limited mainly to a farm level.

A farmer like any planner will base his farming operations depending on his experiences and the information he obtains from his fellow farmers. If he is lucky he may also obtain support from extension agents. Hence, for conservation based agriculture to benefit from the outcome of research on soil and water conservation, the investigation has to be based on-farm. Research out-puts from research stations in most cases has proved to be a failure.

CCRDA

5.3 MODELS AND PREDICTION

There are several models and predictions to estimate land degradation. They are all based on bio-physical parameters. The Universal Soil Loss Equation (USLE) considers rainfall erosivity (R), soil erodibility (K), slope gradient (S), slope length (L), vegetation cover (C) and soil management (P). Theses are measurable and estimated values. The final value obtained is the amount of soil loss per hectare in a year (A). Those measurements are time consuming, expensive, and need manipulation of data. In the absence of a data base on soils, climate, vegetation cover, and management practices their usefulness for planning purposes is questionable.

Apparently the issue is not on the amount of soil being eroded. It has to be in quantifying in economic terms the amount of nutrients, organic matter, and soil depth being lost in relation with the reduction in yield the carrying capacity of the land.

Farmers are knowledgeable on how and when they have lost productivity of their land. they know on when big gullies are formed in farm lands and how. They associate formation of gullies in farm lands because of concentration of flow of water because of faculty farming and the building of roads.

For prediction purposes the need for information about the potential erosion triggering phenomenon is important. These include among others the topography (LS), surface erodibility (K) and main erosivity (R). Topographic and soil maps are equally as important as having a weather station.

In the absence of information on the rate of soil loss in a given area:

1. Survey the density of gullies in the farm land
2. Assess the rate of deposition on low-lying farms
3. Assess the sediment on the bench terraces
4. Assess the density of stones on farm land

CCRDA

5.3.1 CLASSIFICATION OF EROSION AND LANDUSE PLANNING

On the extent of soil loss from a given land erosion of land can be classified into:

5.3.1.1. Erosion by Water

5.3.1.1.1 Sheet erosion: This is the slow removal with water of fine sediments from farm lands. The loss of the soil is not easily describe, however the water coming out of the farm land is loaded with fine soil material. At site of deposition fine soil is deposited as small heaps. The soil is mainly fine in texture because of the removal of the clay and silt particles of the soil. Loss of nutrients (particularly if land is fertilized) becomes a special concern. Surface applied fertilizer (not well incorporated is solubilized and can be lost with running water.

5.3.1.1.2 Rill erosion: Finger like rills are formed on areas much affected by sheet erosion. Water is concentrated and with it the sediment load increases. Interms of soil loss this is an advanced stage.

5.3.1.1.3 Gulley erosion: The rills have now advanced in depth and breadth. The soil loss is extensive and if no measure is taken gullies reduce the size of cultivable land thereby diminishing the carrying capacity of the land.

5.3.1.2. Erosion by Wind

The loss of soil by wind is not well documented. Areas in the lowlands and solve highlands are exposed to strong wind for several months. This is assumed to also remove fine soil material. Particular mention should be made of the seasonal winds in large valley bottoms.

CCRDA

5.4. Soil and water conservation measures - promoted from" above"

Starting from the early 1970's, by recognizing the serious implications of environmental degradation and poor natural resource management, the past governments introduced a number of measures to alleviate or minimize the problem. Specially after 1974 institutional structures have been established to address the previously neglected environmental issues. Within the ministry of agriculture the Natural Resources Conservation and Development Main Department was established in 1985, having departments responsible for land use planning, wild life, state forests, community forestry and soil conservation. In the office of central planning a department of Natural Resources and Human Settlements evaluates the environmental implications of all government plans. It developed its staff working in the field activities in either soil conservation or forestry.

A package of conservation measures has been developed including terraces, bunds, tree planting and the closure of grazing areas, which were mainly introduced through food-work-programs. Between 1976 and 1988, food for work programs funded the construction of 600,000 kms of hillside terraces for afforestation of steep slopes, and 800,000 kms of soil and stone bunds for terrace formation on 350,000 ha of crop land. Some 500 million tree seedlings were planted covering some 180,000 hectares. Another 100,000 hectares have been closed for natural regeneration. (Hurni 1988, Belshaw 1988, Daniel Gemechu 1988, Wood 1990-93).

The government has made a number of public commitments to improve the country's natural resources, and their management. The land reform proclamation made the Peasant Associations responsible for the protection of natural resources in their localities.

However, since these were the first major conservation initiatives in Ethiopia, but mainly for lack of full commitment and other practical reasons that we will see below, a number of problems undermined their adoption and effectiveness. Analysis of these difficulties will be necessary so as to prepare the necessary grounds for reorientation of soil conservation and afforestration programs.

Experience over the last two decades has identified a number of problems in conservation initiatives and the circumstances under which they operate. These are:

CCRDA

5.4.1 Scale of rehabilitation measures

Most of the measures had a limited aerial extent. This has to do mainly with the fact that conservation measures were linked with food for work programs. For security as well lack of infrustructural facilities, most of the activities were concentrated in accessible areas along major roads. Until 1988, it was estimated that only 7 per cent of the highlands have been "treated" with conservation measures. In this case, it is estimated that it will take some 70 years to provide a 'first treatment' for the highlands (Hurni 1988; Wood 193). And this is hardly commensurate with the problem, especially since the area in need of treatment is growing rapidly as a result of agricultural expansion in the south-west (ibid.)

5.4.2 Approach and quality of work

Basically a food-for-work program, conservation has been introduced as a subsidiary activity to relief food distribution. People have built conservation measures primarily to obtain food. This together with the lack of education about environment degradation and conservation measures, has meant that there has been little understanding of the potential benefits from conservation and environmental rehabilitation; little preparedness to adopt such measures.

The conservation program was often planned in a top-down-manner. There was little opportunity for discussion and local participation in conservation planning. There was no any attempt to link the modern with traditional conservation measures, nor into the farming system. Conservation programs were regarded by farmers as imposition from the government and an additional task on top of their farming work. Moreover, farmers see the conservation works as belonging to government rather than to themselves. The revolutionary government has undertaken impressive campaign of hillside terracing and afforestation, but from a peasant view point, these often involved a high input of forced labour, removed land from cultivation, offered no immediate reward. (Calpham 1988: 164).

Consequently, the quality of construction was very poor, while the maintenance of the measures is not important to farmers. The low success rate in afforestation, around 7 per cent one year after planting (Daniel Gemechu 1988), is also attributed in part to lack of responsibility which results from top-down-planning.

5.4.3 Nature of the conservation measures

It was focused mainly on physical measures, such as bunds and terraces and trees planting; biological and agronomic conservation practices, which have a potential to create attractive conservation packages, have been overlooked.

CCRDA

The result of an evaluation indicates that the benefits of increased infiltration and reduced soil loss do not outweigh the loss of land to conservation works, and the reduced yields to vermin living in terraces, waterlogging and the disturbance of the soil profile. Yields improve little in the short-term, and may in fact decline, while these involve extra labour requirements and maintenance costs. This is hardly an attractive package. Rather it is a source of negative attitudes towards conservation, which is now expected to involve extra work but produce little immediate returns. (Yeraswork 1988; Wood 1990).

5.4.4 Socio-political environment

The adverse policy environment (tenure insecurity, neglect of small scale agriculture, pricing and marketing policies that have a disincentive affect on agricultural producers, etc.) has discouraged farmers from adopting conservation measures. As a result despite more than a decade of government initiatives in conservation there has been limited success. There has been little spontaneous adoption of conservation.

5.5 Towards a new Approach to Conservation

Soil and water conservation has the potential to contribute substantially to reversing the degradation of the productive capacity of land. So, while conservation initiatives must be the basis of agricultural development in Ethiopia, they need to be re-oriented in terms of their nature, approach, scale and quality if they are to contribute towards sustained agriculture.

Conservation measures should not be highly/totally dependent upon government or external funds which can fluctuate from day to day, nor should they require a range of tasks and measures which farmers must undertake in addition to their farming. Instead conservation must become part and parcel of the farming work cycle. Conservation oriented crop combinations and land management practices must involve few new inputs or extra risks. Above all they must provide farmers with short-term economic benefits, so that conservation based farming systems are adopted rapidly and spontaneously, with minimal external support (FAO 1986; Belshaw 1988; Wood 1990).

The biological characteristics which such farming systems or land conservation measures must introduce include a more vegetated landscape. Increased ground cover protects soil erosion, improves infiltration of rainfall and thereby reduces

CCRDA

runoff. It can help meet food, fodder and fuel need, of the farmer. Increased biological productivity must be sought not just to ensure rapid improvements in farmer's incomes, but also to provide flexibility in the land use system which will be necessary for the rehabilitation of degraded areas.

Farming practices which can help to conserve the natural resource base and raise productivity must receive some attention.

Intercroppng relay or sequential cropping improve soil stability with their diverse rooting systems; increase the density and period of leaf cover which protests the soil from direct rainfall and the sun's intense radiation. Crop rotation helps to maintain soil fertility and greater integration of livestock farming with arable cultivation to improve the use of manure or other techniques. Cut and carry method of using degraded pasture which has been closed to grazing can minimize land degradation.

- Crops for conservation - more widespread use of semi-permanent such as ensete, cassava or self-seeding and volunteering crops such as legumes and sweet potatoes could help stem erosion by reducing the need for cultivation.

- Agro-forestry - The most attractive shrub and tree species for agro-forestry are those which provide multiple purposes or benefits. Sesbania and Leucaena provide not only fodder, fuel and soil stabilization, but also improve soil fertility by fixing nitrogen.

- Cost-benefit analysis - It is important to ensure that conservation innovation not only do they meet environmental requirements, but that they are economically attractive, and fit into the existing farming systems with the ranges of resource constraints which farmers face.

Finally a more favorable policy environment will be required before those innovations will be attractive to farmers. Farmers need security of access to land and clear rights to trees, as well as agricultural prices that encourage investment in farming and the protection of the natural resource base. The different technical remedies, moreover, will only succeed if they can function within, and address, local socio-economic constraints (IFAD, 1992; 19) ... for while farmer's actions may be the immediate cause of the perceived problem of land degradation, the root cause lies in a range of economic to political parameters which lie practically outside farmers' control (Ibid.).

- **Prospect** - By African standards Ethiopia has a favorable natural resource base. Other countries with similar resources and levels of population density have managed

CCRDA

to achieve higher standards of living and restrict natural resources degradation to lower levels. More emphasis has to be given to *farming system development* and less reliance upon physical conservation works. Above all conservation practices must be attractive so that they will spread spontaneously through the country and need only a few demonstration plots and limited extension by way of *specific support.*

5.5.1 Emphasis to biological measures

5..5.1.1 Why land husbandry?

If we consider the farm as unit of planning and management, the land should be managed in a manner that will consider the interacting factors. The small holder farmer in Ethiopia does not specializen in a given production only. Livestock, crops and trees are managed in a way to achieve food security at household level. The livestock crops and trees are produced from the resources obtained from the land. With regard to management of soil and conservation measures, the farmer must be able to use his land to increase current productivity with a view of conserving for the future beneficiaries.

Hence the concept of land husbandry becomes imperative. In land husbandry the farmer manages his land not for particular use but holistically as a unit. The timing of activities need not be in a form of a compaign. The culture of intensive use of resources should be emphasised in land husbandry. The role of biological measures and related practices need integration in the land husbandry system. The problem is lack of suitable biological intervention for stabilizing bunds and terraces. However, if we observe keenly and make enquiries with farmers, there may indigenous shrubs, grasses and trees that may be beneficial for inclusion in land husbandry. Land husbandry is unique to the situation where the land is located. Land management practices developed for humid areas are not applicable to dryland farming. Similarly range management which takes the integration of livestock, vegetation and water resources is different from managing cropland and forest areas.

CCRDA

Current development is the expansion of urban areas. These areas need parks, green space and vegetable production areas. Urban dwellers use the small available space for intensive cultivation of vegetables. Use of wooden frames, old tyres, cans etc. to fill with soil for production of vegetables for home consumption needs to be seriously considered.

CCRDA

6. Economics of Soil Conservation and Water Harvesting: Review of Issues and Concepts

6.1. Economic concepts of soil conservation and water harvesting

Generally, from an economic point of view, soil conservation and water harvesting activities are investment works meant to maximise gains to society. Therefore, as in any investment activity, there is a need for economic appraisal. Information on the economics of these activities, at an individual and/or national level, is important for agricultural and land use policy decisions.

The economic appraisal of soil conservation and water harvesting activities needs to give due consideration to the spatial and temporal distribution of cost and benefits. This is because soil and water conservation activities generally have the function of redistributing the use rate of soil and water resources. Therefore, the evaluation techniques should ideally grasp these characteristics of conservation programmes.

Another point is that a clear distinction must be made between two levels of analysis namely financial and economic. Financial analysis is practically concerned with the pure return for an individual or organisation investing resources in some productive activity. Financial analysis can be used to examine the potential benefits that an individual farmer or any participating group can gain by adopting conservation measures. During financial analysis market prices or costs are directly employed without adjustment for market distortions such as transfer payment. The results of financial analysis are important for the following three reasons:

1. the government planner or analyst has to know whether or not the activities being proposed will be attractive to those private entities (farmers) which will have to put resources into the project to make it work;
2. the information from the cash flow analysis can be used to develop information needed to design appropriate incentives or tax packages to help ensure project implementation and continuity;
3. the same information is needed for budgeting purposes.

Economic analysis is concerned with the costs and benefits of conservation to society as a whole and so a wider view of the costs and benefits of conservation activity is adopted. We have seen that during financial analysis factor and product prices are simply taken without adjustment for distortions in the market. Estimates of net benefits in the case of financial analysis include the effect of inflation, subsidies, taxes and other transfer payments. However, such distortions are adjusted during economic analysis. The adjusted prices (economic prices) are assumed to reflect the 'willingness-to-pay' of society - the amount that society is willing and prepared to pay - to protect soil resources. Usually the concept of opportunity cost is employed during economic analysis.

6.2. Methods and approaches for economic assessment

Various methods and approaches are employed to evaluate the economics of soil conservation and water harvesting. In this section these different evaluation techniques will be reviewed under the following three subtitles: cost-benefit analysis, farm management analysis techniques, and mathematical and bioeconomic simulation models. The classification is purely arbitrary and it is only meant for the sake of discussion. The choice of the appropriate method depends on the nature

CGRDA

of the problem or objective of the analysis, the available resources including time and experts, the amount and nature of available data, and the need of the final users and interest groups.

6.2.1. Cost-benefit analysis

The most commonly used and relatively simple but comprehensive, method for the economic evaluation of soil conservation works is cost-benefit analysis(CBA). Cost-benefit analysis is also equally applicable to the economic evaluation of water harvesting technologies. The conceptual foundation and the procedures followed during cost-benefit analysis are briefly outlined as follows.

Cost-benefit analysis is a method of weighing the benefits and costs of a course of action. In practice cost-benefit analysis consists of impact analysis, followed by valuation and comparison. The rationale behind cost-benefit analysis is that any course of action is acceptable if its benefits are higher than its costs. In any cost-benefit analysis the major analytical steps can be summarised as:

- determination of evaluation criteria;
- identification of effects (cost and benefits) either from individual point of view or the society depending on the level of analysis;
- quantification of costs and benefits;
- valuation, including shadow pricing, of non-marketed inputs and outputs;
- determination of appropriate time horizon;
- discounting to determine present value of the stream of benefits and costs using true private or social discount rate depending on the level of analysis;
- consideration, where appropriate, of income distribution aspects;
- Identifying source of uncertainty and undertaking sensitivity analysis to show the likely impact of it; and
- policy implications or conclusion.

6.2.1.1. Determination of evaluation criteria

In cost-benefit analysis, selection of evaluation criteria is required in order to make proper comparison. The evaluation criteria can be broadly grouped into discounted and undiscounted measures. The basis for such classification is the concept of the 'time value of money'. The undiscounted measures ignore the time value of money, assuming equal dollar value regardless of when it is paid or received. An example of such measures is the pay-back period calculation. The pay-back period is the time interval by which the sum of the undiscounted net-benefits of a project equal the total undiscounted investment and running costs. It is the length of time from the beginning of the project until the net value of the incremental production (benefit) stream reaches the total amount of the capital investment.

Unlike the undiscounted criteria, the discounted evaluation criteria take into account the time value of money. They reduce or discount all cost and benefit flows into a single figure at a single point in time, which will then allow easy comparison. Cost-benefit analysis commonly uses discounted evaluation criteria such as net present value (NPV) and internal rate of return (IRR). Net present value is the present value of the discounted net benefits or net loss over the life time of the project.

CCRDA

Mathematically the formula for calculating NPV can be expressed as follows:

$$NPV = \sum_{t=1}^{n} B_t/(1+r)^t - \sum_{t=1}^{n} C_t/(1+r)^t$$

Where,
t = the time horizon form year 1 to year n
B_t = total benefits in year t
C_t = total costs in year t
Σ = a summation sign over the period of time
r = the interest rate or the discount rate, expressed as a decimal

Christian Relief & Development Association
L I B R A R Y
P.O.Box 5674

NPV - from financial analysis, is the present worth of the net income stream accruing to the individual or entity from whose point of view the analysis is being undertaken.
- from economic analysis, is the present worth of the incremental national income generated by the investment.

Internal rate of return is the rate of discount at which the net present value is equal to zero. Internal rate of return is the maximum interest rate that a project could pay for the resources used if the project is to recover its investment and operating cost and still break-even. They signify a worthwhile or profitable project if NPV >0 and IRR >r, where r is market interest rate (cost of capital).

6.2.1.2. Identification of costs and benefits

To undertake the cost-benefit analysis, listing of the cost and benefit items of the activity concerned is necessary. In soil conservation works costs are relatively easy to identify. However, identification of benefits is not so straightforward. Conceptually the benefits of soil conservation can be classified as on-site and off-site ones. The same conceptual classification can be applied to identify the costs and benefits of water harvesting practices. The most obvious on-site benefit of soil conservation is yield increase or stabilisation, whereas, among the off-site benefits are off-site productivity changes and reduced damage, such as reduction of reservoir siltation. In soil conservation, employment opportunities are mostly taken as a benefit by government. However, it is incorrect to list employment benefits as the sum of salaries. Labour is a cost to the project even though it has important distributional aspects. Generally, listing of all identifiable costs and benefits in a tabular form for a specific soil conservation or water harvesting practice is very much helpful during analysis.

6.2.1.3 Quantification of costs and benefits

Once the cost and benefits have been identified, they need to be quantified in order to be evaluated. For instance, the yield increased or loss minimised due to adoption of some conservation measures should be estimated based on comparison between the 'with' and 'without' situation, which is different from 'before' and 'after' change comparison. The latter does not account for changes which would have occurred without the conservation practice. The parameter values should be measured for the two scenarios (the 'with' and 'without') in a parallel way so that the net effect of introducing conservation techniques can be estimated. Generally, the methodologies cited under

CCRDA

section 4.1.6 of part II are used to quantify the impact of erosion and conservation. However, instead of directly estimating the effect on yield, agronomists also calculate nutrient loss reduced in order to quantify benefits of soil conservation practices . This method is based on the assumption that close correlation exists between nutrient losses and soil losses, such that nutrient loss can be predicted based on the knowledge of the level of erosion. The concept of 'enrichment ratio' is applied to correlate soil loss rate with the nutrient losses. But nutrient loss is one effect of soil erosion and reducing it is not the total benefit of conservation measures. Other possible cost components that need to be quantified are labour (in man-days) and area of land taken by conservation and water harvesting structures. Besides, other specific and overhead costs should be properly measured.

6.2.1.4. Valuation of costs and benefits

Cost benefit analysis involves comparison of cost and benefit items. But comparison is only possible if both costs and benefits are expressed in the same unit. It is only then that a meaningful picture of the analysis can be interpreted. Therefore, attaching monetary values to the costs and benefit items that enter the analysis gives a common ground for comparison. In this case proper prices must be used in order to reflect the true value either to the individual or the society depending on the level of analysis.

Generally, there are three approaches to the valuation of costs and benefits. These are:

1. Using market prices:
Market prices that result during the interaction of the supply and demand and where these are believed to reflect the willingness-to-pay are used to value costs and benefits of conservation work. This approach is also called a 'conventional market prices' approach.

2. Using surrogate market prices:

This approach assigns values to costs and benefits based on their substitutes which already have market values. For instance the value of land affected by erosion can be deducted from that of nearby fields which are not affected by erosion (some form of soil conservation measure practised). The difference in the price offered is assumed to be an approximate value for damage due to erosion. However, this only works where there is a competitive property or land market. The surrogate market approach is usually applied in the area of environmental economics to calculate (estimate) shadow prices for non-marketable environmental goods and services. The surrogate market approach is also called the 'implicit market prices' method.

3. Using hypothetical valuation:

Where there are no possibilities of estimating a reasonable market price measures of value, surveys or expert judgements are used to fix estimate values. Production costs are also used to estimate at least the minimum value. This method should be the last option. The hypothetical valuation methods is also referred as 'artificial market prices' approach.

Though the concept is embodied in the above three ways of valuation, the opportunity cost can be treated as a separate approach to valuation of costs. It considers the value of a resource in its best alternative use as a basis to valuation.

CCRDA

Soil and water conservation practices are highly labour demanding, especially in developing countries. Labour cost is the major cost component in soil and water conservation. In financial and economic analysis labour has to be properly valued. This will be treated later in a separate section.

6.2.1.5. Time horizon

The time horizon is the length of the future period that is adopted for decision-making purposes. It is very much dependent on the nature and objective of the project. There is no established rule for the choice of an appropriate physical and economic life time of a conservation project. A review by Bojö (1992) of 20 soil conservation projects in different countries shows that many of the authors do make arbitrary choice depending on the specific conditions they face. According to his review most projects adopt time horizons ranging from 10 to 20 years. But, there were some projects having 30 to 50 years time horizon. It is generally true that soil conservation projects require a longer period of time to generate a return on the investment.

6.2 1.6. Discounting concept

Discounting is defined as the process of adjusting the value of some benefits or costs received at some point in the future to a current value. This is done using a discount factor that can be calculated based on the following formula:

$DF = 1/(1+i)^n$, where

DF is discount factor

i is the discount rate expressed as a decimal

n is number of years

For instance, 100 Birr in 10 years time is only worth 38.5 Birr today when discounted at the discount rate of 10 percent. When using the net present value criterion in economic analysis to evaluate project worthiness, choice of appropriate discount rate is necessary. Theoretically the discount rate can be selected in three ways (Dixon *et al.*, 1989). These are:

1. The opportunity cost of capital. This is based on the theory of productivity of capital. It assumes the forgone benefit of capital invested in one project rather than in the next best alternative as a basis for the determination of discount rate. In other words, it takes the interest rate prevailing in the capital market as a discount rate.

2. The cost of borrowing money. This approach is a similar concept to the first approach. This may be a market rate, but in many developing countries the rate is fixed by a decision of a government or lender organisations; and

3. The social rate of time preference. It is suggested that the discount attached to future returns by the society as a whole is different from the discount individuals would use. Society has a longer time horizon, so that its discount rate would be lower.

For the purpose of economic evaluation of soil conservation and water harvesting projects the social discount rate (SDR), the rate that shows the real cost of a unit resources to society, is the most appropriate. A social discount rate should be selected properly in order to reflect the social time preferences. In other words, the social discount rate should be reflection of the weight that society attaches on future consumption. But, in practice, determining a single social discount rate is a very difficult task. For this reason a series of discount rates are usually used in soil

CERDA

conservation practices (Bojö, 1992). It is generally recommended to seek expert advice from responsible government bodies or use social discount rates applied by relevant sectors in the economy. In the case of financial cost-benefit analysis the prevailing market rate or the fixed rate given by relevant bodies is used.

6.2.1.7. Income distribution aspect

Besides the maximisation of the net benefits through project intervention, policy-makers are also interested in the distribution of these net benefits within the society. It is true, at least in principle, that any government is interested in achieving fair and equitable distribution of income within the society. But, such an objective is very difficult to incorporate easily into the framework of cost-benefit analysis.

Three approaches were applied by analysts so far. The first approach is to ignore the issue without further comment and omitting this step from the cost-benefit analysis though ,in principle, it is necessary to see the distributional aspect; the second approach is to limit the economic analysis to questions of efficiency rather than equity; and the third approach is to introduce distributional weights explicitly though its practicality is bounded by different problems.

A relatively simple but crude way of assessing such distributional aspects is done by estimating the proportion of the net benefit that goes to the different groups in the society assuming equal weight. The grouping can be based on region, size of holdings, and other attributes. Such information is important for formulating policies to improve equitability of income distribution within the society. For instance fiscal policies can be implemented by government to achieve this objective.

CCRDA

6.2.1.8. Sensitivity analysis

Cost-benefit analyses are mostly done under optimal ignorance. That is, information used during the analyses are not absolutely perfect. Besides, different assumptions and subjective judgements are mostly made in order to bridge the gap in information. However, these assumptions and judgements (even if they are done by experts) will have an element of uncertainty. Therefore, to handle the different uncertainties from different sources sensitivity analysis is necessary.

Sensitivity analysis is an analytical technique to test systematically what happens to the earning capacity of a conservation project, or any project for that matter, if events differ from the estimates made about them in planning. It is done by changing one assumption or combination of assumptions and checking their likely effect on the evaluation criteria. In soil conservation projects sensitivity analysis is mostly done by varying assumptions regarding prices, yield, discount rates and time horizon. Depending on the nature of the project other sources of uncertainties are also subjected to sensitivity analysis.

6.2.1.9. Cost of labour input

As has been highlighted earlier labour is a critical component of soil conservation and water harvesting works. Labour cost constitutes a large proportion of the cost of soil conservation and water harvesting works based on mass mobilisation. A large proportion of the labour is unskilled. This gives rise to valuation problem during economic analysis. Theoretically, valuation of labour can follow the principle of shadow pricing applied to other inputs, but, in developing countries

especially in the rural areas where there is excess labour, this principle is very difficult to apply practically. In areas with a high level of unemployment, labour demand can be met without creating a reduction in production in other sectors of the economy simply by reducing unemployment.

According to Stoking and Abel (1992), for the purpose of financial analysis, labour costs and its proportionate benefits vary enormously depending on circumstances:
- If soil conservation takes up leisure time and no other activity is reduced, the opportunity cost is zero. Financially, the labour is 'free';
- If another enterprise is curtailed in order to practise soil conservation, the cost is the income to labour which would have accrued from that enterprise;
- If off-farm work is abandoned, then similarly the cost is the amount of earning foregone;
- If workers are employed, the cost is their wage. However, the first circumstance, which leads to the assumption of zero opportunity cost of leisure time sacrificed, is unacceptable. This is because it ignores the status of labour as a resource and the value that leisure time has.

The private profitability of labour used in soil conservation is lower than its social profitability in most labour excess economies. This could be for two reasons. The first is labour, especially unskilled labour, employed during conservation work is paid usually at a lower rate than the shadow rate. This happens when people are involved in conservation works with a minimum payment which is enforced by government policy. Secondly, conservation works based on mass mobilisation are usually free of payment leading to the assumption of a zero opportunity cost of labour during the financial analysis. However, the result is wrong indicator of the profitability of conservation works because it excludes the major cost element.

During economic analysis, labour cost should be determined at least to reflect the minimum economic cost. According to Dixon *et al.*, (1989), for the workers involved in unpaid soil conservation or water harvesting works, the concept of 'reservation wage' can be applied. This concept reflects the worker's personal opportunity cost of lost leisure time or time for other non-wage activities. Practically, this indicates the minimum wage below which the worker is unwilling to work. Generally, the best approach is to employ a rate that appears reasonable depending on local conditions.

6.2.2. Farm management analysis techniques

Based on the scale and complexity of the analysis different farm management analysis techniques can be used to evaluate the farm level economics of soil conservation and water harvesting practices. They can be applied successfully in dealing with site specific evaluations were the effects are readily detectable. The most prominent analytical tools included in this category are gross margin calculations, partial budgeting, and so on. These tools are applied to measure changes in income to farmers within the framework of the 'with' and 'without' situations. The gross margin calculation gives due consideration to the total revenue and the total variable costs for both 'with' and 'without' conservation practices. In the case of 'with' situation, the cost of conservation is considered as variable cost.

Partial budget analysis is the most common method of assessing the effects of introducing some changes into an existing operation. It enables one to identify the costs and benefits that occur as a consequence of the introduction of change and weights their net effect. In this case the cost

CCRDA

category includes all extra costs incurred and revenues foregone due to the adoption of conservation techniques. Similarly, the benefit category includes all costs saved and extra revenues generated due to the adoption of conservation techniques.

The findings of these techniques are also important inputs to undertake a more comprehensive cost-benefit analysis. This is because the results can be organised in to flow of costs and benefits covering the project life time. Generally, these techniques are simple and flexible as compared to the cost-benefit analysis and mathematical and simulation models. However, they are only limited to comparison of pre-set alternatives and are weak to identify the optimal or highly profitable techniques.

6.2.3. Mathematical and bioeconomic simulation models

Mathematical and bioeconomic simulation models are popular in the USA for the economic evaluation of soil conservation and water harvesting practises. These models basically try to mimic the interrelationships among the biophysical, technical and economic environments. Based on these interrelationships, the impact of introduction of soil conservation and water harvesting techniques can be isolated and measured. Therefore, the existence of detailed and relevant data is the primary prerequisite for successful application of these techniques. These models are more often applied for the evaluation of the impact of soil conservation policies at higher levels- regional or national- rather than farm level activities.

6.3. Economic data collection

The importance of the final results of economic analysis is highly dependent on the quality and quantity of data used. That is, the availability of accurate, relevant and sufficient data is the basis for successful analysis. This in turn is dependent on the method of data collection. Researchers usually employ different data collection techniques depending on objective and subjective judgements. The most commonly used methods are farm surveys either formal or informal, experimental works, consulting records and expert guesses.

Using one or a combination of the economic data collection methods basic economic data are organised in the form of crop production budgets, yield trends, price trends, and other cost and benefit flows for the case of 'with' and 'without' condition.

6.4. Conclusion

In the foregoing review an attempt has been made to highlight the basic conceptual and methodological issues in the economic evaluation of soil conservation and water harvesting works. The major aim was to review alternative evaluation techniques which vary according to the level and objective of the analysis. The different data collection methods have also been enumerated. Generally, the basic constructs for economic evaluation have been lied.

CCRDA

Part III
Sustainable Agricultural Development: Technical Issues

7. SOIL AND WATER CONSERVATION

7.1 FUNDAMENTAL PRINCIPLES OF SOIL AND WATER CONSERVATION

Main themes of soil and water conservation deals with :
- erosion control: water and wind erosion.
- maintenance of soil fertility and structure (and therefore control of biological, physical and chemical degradation of the soil).
- water conservation and management.

Soil erosion control requires that detachment and/or transport of soil particles must be controlled. Strategies could be identified by considering the factors which influence the type and amount of erosion taking place as outlined above.
- Erosivity of rain: this cannot be changed directly although it is possible to control the effect on the soil:
- control rain splash.
- control runoff.
- Erosivity of wind: again, this cannot be changed directly although the effect on the soil can be controlled:
- control wind velocity.

- Erodibility of soil: the soil resistance to detachment and transport and its infiltration capacity can be improved or at least maintained through careful soil management, particularly the use of appropriate tillage practices and the maintenance of organic matter.

- Slope steepness and length can be modified through various forms of terracing (e.g. graded bunds, bench terraces, etc.) though this could be thought of as part of the strategy to control runoff.

- Cover of the soil controls rain splash, and to a certain extent, runoff.

The maintenance of soil fertility and structure is achieved largely through the addition of organic matter and careful tillage, and also helps reduce soil erodibility.

Water conservation and management can be built into the design of the strategy when considering how to control rain splash and particularly runoff.

The fundamental principles of soil and water conservation can therefore be summarised under four main headings:

1. CONTROL RAIN SPLASH: This is done by preventing the falling raindrops from hitting the soil directly. This reduces detachment, and controls crusting so that infiltration capacity is maintained. A good crop cover or surface mulch will do this.

CCRDA

2. CONTROL RUNOFF: The aim is to get as much of the rain as possible into the soil for use by the crop (water conservation), and control the remaining runoff. This is done by reducing:

- runoff velocity: e.g. by control farming, grass strips, surface mulch, etc.
- runoff quantity and/or concentration by:
- improved infiltration from improved soil structure and control of crusting.
- surface storage of runoff by tied crop ridges and level bunds.
- dispersal of runoff by grass strips or surface mulch
- removal of runoff by graded bunds and storm drains.

3. MAINTAIN/IMPROVE SOIL CONDITION: In particular its fertility and structure. Fertility improves crop growth and therefore productivity and cover, while a stable structure improves infiltration capacity and resistance to detachment and transport. Improved infiltration and rooting conditions also improve water conservation and use by the crop, and therefore productivity. Soil fertility and structure are not unrelated and are both achieved through the addition of organic matter and careful tillage.

4. CONTROL WIND VELOCITY: where this is a problem, through use of windbreaks, surface vegetation or mulches and increasing soil roughness.

The Essence of this soil and water conservation strategy is therefore

- Control rain splash and get as much water as possible into the soil.
- Control the remaining runoff.
- Maintain or improve the soil condition.

CCRDA

7.2 SOIL AND WATER CONSERVATION ON CULTIVATED LAND

7.2.1 Land use aspects

Cultivated lands is one of the main land use types found on self contained farms and scattered around villages. This consists of land actually under cultivation and any short fallows.

Extension workers are usually asked to give advice on land which is already being cultivated. The first think to consider in this case is that the land is actually suitable for cultivation: i.e. it is capable of sustaining conservation measures are used. In this respect slope is the most important factor and steep land of slopes greater than 12% should not be cultivated. Soil depth and texture are also important, and some other factors may also be taken into consideration.

The "Land Capability Classification" system has been developed to formally divide up land into different types according to its capability for productive and safe use.

7.2.2 Agronomic measures for soil and water conservation on cultivated land

These are also called "cultural" measure and are part of the group of "biological" measures: biological measure would also include agroforestry measures.

These are practices related to crop and soil management which are part of the normal farming operations. Almost all agronomic practices have some direct or indirect effect on protection as well as production. They are normally carried out for a variety of reasons, mostly production oriented, of which soil and water conservation is only one. Therefore, in developing sustainable farming systems, the agronomic practices should be manipulated to improve their protection effects as well as production.

Most of the recommendations are or should be included in the normal agronomic recommendations and are an integral part of good farming practice. In this presentation, however, the soil and water conservation aspects are emphasised so that adequate and appropriate soil and water conservation strategies can be devised and incorporated into the farming system.

These agronomic soil conservation measures derive their conservation effect mainly from the control of rain splash and the improvement of the soil.

7.2.2.1 *Crop management for optimum cover*

The cover which a crop provides to protect the soil from raindrop impact of the soil surface by rain splash. Therefore the aim is always to maximise cover. This can be done mainly through:

- correct plant spacing (i.e. row width and distance between planting stations).
- good seed for uniform germination.
- organic and inorganic fertiliser.

This should produce a healthy fast growing crop with a dense stand. This should also give high yields.

7.2.2.2 *Timelines/early planting for timely/early cover*

It is also important to have a crop cover to protect the soil as early as possible: the soil is at its most vulnerable when left bare and exposed, particularly soon after loosening it through cultivation and at the beginning of the rainy season when there are often heavy rainstorms.

With early season crops like maize this means early planting. Early planting also takes advantage of the early release of nitrogen produced by the first rains and warm soils, and so produces a faster growing healthier crop which has better cover and higher yields. Early planting needs early field preparation. Winter ploughing (i.e. as soon as possible after harvest) is particularly useful.

With late season crops like beans or sunflower, it is important to plant as soon as possible after land preparation and to use the minimum number of tillage operations.

7.2.2.3 *Intercropping*

Intercropping is the growing of two or more crops together (at the same time) on the same piece of land. This can help control erosion due to improved cover throughout the growing season. Many small farmers use Intercropping mainly to spread risk and demands on labour, and improve overall yields and diet, etc. The crops to be grown together must be compatible in terms of the timing of

CCRDA

labour and nutrient requirement, length of growing season, etc. it is usual to grow a legume together with a non legume. Typical combinations would be maize with groundnuts, maize with beans, maize with soya beans, maize with casava, maize with pigeon pea, etc.

7.2.2.4 *Crop rotation*

Crop rotation is the growing of different crops in succession on the same piece of land, with the inclusion of rest periods or fallows. Normally the land available is divided into a number of plots (ideally the same number as the number of different crop is grown on each plot which is at a different stage in the rotation sequence.

Because of differences in the characteristics of crops, there are a number of benefits of growing crops in rotation which relate to the control of soil erosion, making better use of soil nutrients reserves and the maintenance of soil fertility and structure, the control of pests, diseases and weeds, and reducing risk and the demand for labour.

a) Control of soil erosion

Crops differ in their effectiveness in protecting the soil against erosion, mainly through the effect of cover in controlling rain splash. Although much depends on crop management, widely spaced row crops and especially those which produce little cover in themselves and are clean weeded (e.g. tobacco, cotton, etc.), generally produce high levels of erosion. The season crops and those planted on the flat (as opposed to on ridges) also tend to have high erosion. Closely spaced crops receiving little or no cultivation after planting (e.g. groundnuts, finger millet, etc.) generally produce lower levels of erosion: and dense untilled crops (e.g. grass, pasture,/fodder legumes, etc.) produce very little erosion once established. Therefore, erosion prone crops and protection effective crops should be grown in rotation so that high soil losses under the protection effective crops: and the average soil loss over a number of years is acceptable.

b) Maintenance of soil fertility and structure

Crops also differ in their requirements for nutrients and their ability to extract what they require from different soil depths. Therefore different crops grown in a planned rotation can make better use of soil nutrient reserves. Deep rooted crops like cotton also help to break up the soil below hoe or plough depth.

Crops also differ in what they put back into the soil from their roots (e.g. nitrogen fixed by leguminous plants) and the crop residues if these are ploughed back into the. Some leguminous plants (e.g. sun hemp, velvet bean, etc.) are grown as green manure and can help maintain soil fertility, although this has its own problems.

After some years of cropping (usually around 4 to 5 years depending on management), it will be necessary to restore the fertility and structure of the soil. This can be achieved through fallow (rest) periods. Fallows may be unplanted (weedy regrowth) or planted (usually grass and/or legumes). A properly designed planted fallow (section 3.2.6) should restore soil fertility and structure faster and produce something useful e.g. fodder.

CCRDA

c) Control of pests, diseases and weeds

Crops differ in their susceptibility to different pests and diseases. Therefore rotation can help control the build up of pests and diseases. The inclusion of widely spaced row crops which are clean weeded (e.g. maize) helps to control the build up of weeds.

d) Reducing risk and the demand for labour

Different crops are planted, weeded, harvested, etc., at different times. Since several crops are grown at the same time, on different plots, each at a different stage in the rotation sequence, the farmer is dealing with a variety of crops at any one time. In this way, the demand for labour can be spread out over time, and he risk of crop failure and the effects of price fluctuations can be reduced.

The design of rotations should therefore take advantage of the differences and interactions between crops to optimise the benefits outlined above.

- Farmers generally require production of some food (for the family, workers and livestock), and some cash. The interest, means (labour, capital, etc.) and ability of the farmer are also important.
- Land characteristics - The amount of arable land available, soil type, slope, erosion risk, fertility, etc., are important factors.

- Marketing and economic - The crops grown must have a ready market if they are to be sold and must be profitable. The profitability will change from time to time as prices change.

Many factors must therefore be taken into consideration when designing rotations. Farmers, farms and the marketing and economic situation vary from place to place and over time. Rotations are not fixed and must be changed to suit the situation.

In designing rotations, decisions need to be made about:

- what crops to grow: production requirements, interest and ability of the farmer, etc.

- what order these crops should be grown in: to optimise positive and minimise negative effects.

- management practices of the different crops and how they fit together from season to season (different crops and how they fit together from season to season (different crop on the same plot), and during any one season (different crops on different plots); i.e. compatibility.

- frequency, type and length of fallow.

At present, many farmers want to grow mainly maize and only a very small amount of other crops. This severely restricts the possibilities for rotation. In addition, hardly any arable land is fenced, and in the dry season, all cattle are free to eat crop residues and of course any planted fallow grasses or legumes. This drastically reduces the farmer's interest in planted fallows. In such a situation, the following general recommendations could be made:

CCRDA

- Diversify crops: plant other crops, especially legumes (e.g. groundnuts, beans, etc.) in addition to maize.

- Develop live fencing of arable land: this will greatly improve the possibility for rotations, improved fallows, etc.

- Where possible, use frequent (say every 4 years) and short (2 years) planted fallows

In addition, it is important to develop and encourage the adoption of more complete rotations suitable for farmers in the different farming systems through out Zambia. Table 3.1 gives some examples of possible rotations to illustrate the kind of thing that some small-scale farmers, and many of more commercially oriented farmers, are doing in some areas.

Table 3. Examples of possible rotations.

	year 1	year 2	year 3	year 4	year 5
rotn A	Maize	G'nuts	Maize	G'nuts	
rotn B	Maize	G'nuts	Cotton		
rotn C	Maize	G'nuts	Tobacco		
rotn D	Maize	S/beans	Maize	S/beans	
rotn E	Tobacco	Maize	Pasture	Pasture	Pasture

CCRDA

Notes:

- Rotation A is a fairly common rotation for small-scale farmers.
- Rotations B and C could also be followed by small-scale farmers.
- Rotation D is fairly typical rotation for dryland commercial farmers.
- Rotation D is a very conservative rotation for commercial tobacco growers with livestock.

- The above rotations could be followed by a fallow, or continued and followed by a fallow later: this could be a weed fallow or preferably some kind of planted fallow or pasture.
- Maize may be substituted by any other cereal such as sorghum or millet.
- Groundnuts or soya beans can generally be substituted by other legumes such as field beans, cowpea, etc.

The following guidelines will also help in developing suitable rotations:
- Soils with a high erosion risk will need a higher proportion of protection effective (higher cover) crops in the rotation and more frequent fallows:

- Low cover crops include tobacco, cotton, all late planted crops and all crops planted at too low a plant population.

- Moderate cover crops include all crops other than cotton or tabacco, provided they are planted (with good management) at the correct high populations, they are adequately manured and/or fertilized, and they are early planted.

- High cover crops include grasses, pasture/fodder legumes, tea. coffee, etc., once established and under good management.

- If land is in short supply and planted fallows are used mainly for soil fertility restoration, it has been found preferable to have frequent (say every 4 years) and short (2 years) fallows, rather than fewer long ones: grass and/or legume pastures would normally be less frequent and left down for longer.

- It is nearly always preferable to grow maize as the first crop in the rotation.

- Tobacco is particularly susceptible to nematodes and should not be grown on the same piece of land for more than two years, and should be followed by crops which are not susceptible eelworm (such as maize, sorghum millet or grasses).

7.2.2.5 *Strip Cropping*

Strip cropping is the best way to carry out crop rotation.
The different crops and fallows are grown in strips along the control, ideally between control markers, grass strips or bunds: erosion prone crops and protective effective crops are then grown in alternate strips.

7.2.2.6 *Improved (planted) fallows*

As mentioned above, planted fallows help restore fertility and structure more quickly than weed fallows and provide some useful grazing. Even if there are no other crops in the main pat of the rotation (e.g. only maize), farmers can still use planted fallows to great advantage. The advantages will be greater if the field is fenced (e.g. live fence) so that the farmer's own cattle get full benefit from the grazing. It has been found preferable to have frequent (say every 4 years) and short (2 years) fallows rather than fewer long ones, where the main objective is to restore fertility for growing field crops. This is because the beneficial effects of these planted fallows are build up quickly (e.g. 80% in the first year and 15% in the second) and rarely last for more than one or two years of the following crop.

Where the provision of high quality pasture for grazing is an important objective, it would be better to design the fallow as a grass or grass/legume ley and leave it down for longer (say 3 to 5 years). In this case the grazing must be managed for the full benefit of the owner in order to justify establishment.

The best way for small farmers to establish fallows is by undersowing in the last crop before the intended fallow. This works well for maize. Seed can be broadcast or preferably drilled after the first weeding. Cuttings could also be planted in this way. This method of establishment has several advantages:

- no special land preparation is required.
- the weeding for the crop also weeds the fallow.
- fertilizer from the maize crop helps the establishment of the fallow.
- the maize crop protects the young fallow plants.

CCRDA

Crops grown in planted fallows are mainly grass and pasture/fodder legumes, grown in pure stands or as a mixture: some leguminous trees and shrubs are also now being tried.

Some possible species for planted fallows are listed below.
Appendix 8 gives summaries of relevant characteristics of these species. Further information can be obtained from relevant textbooks, and particularly "A Zambian handbook of pasture and fodder crops" (Thorp/EAO, 1979).

- Rhodes grass (Chloris guayana): a productive pasture grass which can be use in leys as a pure stand or mixed with pasture legume which mixes well with Rhodes grass.

- Style (Stylosanthes guyanensis): a hardy pasture legume which mixes well with Rhodes grass.

- Sitratro (Macroptilium atropurpureum): a hardy pasture legume which mixes well with Rhodes grass.

- Pigeon pea (Cajanus cajan): a shrubby legume which can be closely planted for food (the grain), fodder and soil improvement.

- Sesbania sesban: a fast growing leguminous shrub which provides fodder and improves the soil.

7.2.2.7 *Green manures*

Some annual leguminous plants (e.g. sun hemp, velvet bean, etc.) may be grown in rotation in order to plough them in as a green manure when the plants are still young and green at flowering stage. The best way for small farmers to establish the green manure crop would be by undersowing in the previous crop (e.g. maize) as for the establishment of planted fallows. There are still however a number of problems with green manures.

- Green manure crops are generally late season planted and unless undersown into the main crop, may give rise to high erosion levels before establishment.

- Farmers find it hard to see the value of planting a crop only to plough it all back into the soil.

- Ploughing the crop in is a physically demanding operation and really requires a tractor.

- It is reported from Zimbabwe that much of the potential improvements in organic matter may be lost through ploughing.

A properly planted and managed planted fallow (undersown into the last crop) is almost certainly preferable.

7.2.2.8 *Kraal manure*

In areas where there are sufficient cattle, the manure from the kraals (where cattle are kept at night) is one of the best sources of organic fertilizer a farmer has.

CCRDA

The recommended rate for application of kraal manure is approximately 40 ox carts per hectare (10 ox carts per lima) although this will depend on the quantity available. The ideal way to apply draal manure is to spread it over the field during ploughing so that it is ploughed in immediately in order to minimise the loss of nutrients. However, most farmers prefer to take it to the field before ploughing and so spread the demand for labour. In this case, the kraal manure should be tipped from the ox cart into small heaps spaced every few meters across the field, and ideally covered. The manure should then be spread out over the field just before ploughing.

there are three main problems with using draal manure:

- an adequate supply of manure must be available, fairly near to the field.

- transport (ox carts) to take the manure to the field sufficient quantities.
- the risk of introduction of weed seeds and insect pests from the manure.

In some areas, kraals could be cited nearer to the field to minimise the transport requirement. The use of well rotted manure from old kraals, or possibly composting the manure, can reduce weed seeds and pests. The practicability of these possible solutions needs to be studied. A lot could be learnt from farmers in southern and western provinces where kraal manure is widely used.

7.2.2.9 *Mulching*

A mulch is some kind of material, usually dead plant material, which is spread out over the soil surface. Mulching has many benefits:

- Mulching is very effective in controlling erosion through control of rain splash (through cover) and to some extent, runoff speed and concentration. A mulch acts in the same way as the plant cover and ground litter in a forest. while a heavy mulch can effectively stop erosion, even a fairly small amount of mulch has a beneficial effect. whereas the growing crop only provides cover once the crop is established (see section 3.2.1), a mulch can be in place and therefore effective before the start of the rains.

- The dead plant material also decomposes to provide organic matter which helps improve the soil organic matter status and structure.
- Mulching also controls wind velocity and creates a microclimate at the soil surface, which conserves soil moisture through a reduction of evaporation, and reduces soil temperatures and temperature fluctuations. This generally improves yields in semi-humid tropical areas.

- Mulching also helps control wind erosion through its effect on the wind velocity at the soil surface.

Mulching is therefore potentially very useful in soil and water conservation although there are a number of problems:

- There must be an adequate supply of mulching material which can easily be distributed over the field. For practical reasons, mulching material is usually obtained from the residue of the previous

CCRDA

crop, lopping from specially grown hedgerow intercropped in the field, or plant material cut and brought in from outside the field.

- There is often competition for the mulching material which may be needed as fodder for livestock. Where the arable land is not fenced and all cattle are free to eat the crop residues under free range grazing systems I operation after harvest, there will be no crop residues left for the coming rainy season. where the arable land is fenced but the owner needs the crop residues to feed his own cattle, the amount of crop residue available will be limited.

- Land preparation, planting, etc., present special problems with a mulch because the tillage tools become clogged. This is particularly difficult with ox ploughing because of the extra power required.

- There may be a risk of pest and disease build up, depending on the source and type of mulching material.

- Termites in particular, are thought by farmers in some areas to be a problem for the crop, which would be made worse by leaving a mulch on the surface. Mulches are potentially food fro, and may therefore attract, termites. However, this does not necessarily lead to a greater termite problem for the crop. Termites prefer dead plant material to a living healthy crop and should eat the mulch in preference to the crop. A good mulch will also conserve moisture and improve crop growth and so should also be realised that termites "process" the organic material and actually improve soil structure.

Hedgerow Intercropping (alley cropping) and some other agroforestry practices also produce a mulch which acts in the same way as crop residues and has some of the same problems. However, non-browse species could be used in areas with free range grazing, and the potential disease problems could be controlled through management. A mulch brought in from outside the field may be used to high value crops such as fruit or vegetables, although this is primarily for the conservation of moisture.

CCRDA

7.2.2.10 *Crop reside management (as a mulch, etc.)*

Unless it has to be destroyed to prevent some disease or pest problem (e.g. as with cotton), the crop residue remaining after harvest is a resource which has two main, often conflicting uses:

- a mulch for soil erosion control and water conservation, and/or a source of organic material for incorporation into the soil for soil improvement.

- fodder for livestock.

Crop residues are therefore a valuable resource which must be managed carefully according to the requirements of the farmer for fodder and/or mulch, whether the field is fenced or otherwise protected from free range grazing, the tillage implements and systems used by the farmer, and the soil type. A number of options are available:

If the field is not fenced and is therefore subject to free range grazing:

- The crop residue could simply be left for free range grazing though this would give little benefit to the owner of the field.

- It would be useful to winter plough (see section e.2.13) and try to bury as much of the residue as possible for soil improvement and allow the rest to be grazed.

If the field is fenced and grazing can therefore be controlled:

- The crop residue could be grazed by the farmer's own cattle.

- The field could be winter ploughed (see section 3.2.13) to bury some of the residue, leaving the rest left to be grazed by the farmer's own cattle.

- The crop residue could be left as mulch or, if there was sufficient residue, partly grazed with the remainder left for mulch.

Where fodder is required, this normally takes preference over grazing.

Appropriate tillage practices need to be developed to work effectively with the mulch.

Where it is not possible to keep crop residues on the field, other means must be found of controlling erosion and putting organic matter into the soil.

7.2.2.11 *Soil Management (for fertility and structure)*

The aim of soil management is to maintain the fertility and structure of the soil:

- fertility improves crop growth and therefore the cover as well as yields.

- a soil with a good stable structure has better infiltration of water and so reduces runoff: in addition, it would be inherently more stable and so less likely to break down under cultivation and better able to resist erosion.

The main ways to maintain soil fertility and structure are by:

- maintaining soil organic matter content by:
  - returning all crop residues to the soil
  - green manuring
  - application of kraal manure etc.
  - fallowing especially with a planted fallow
- use of appropriate tillage practices

Thus soil management is not a separate activity but is the concern, direct or indirect, of many of the normal agronomic practices in the same way as "soil and water conservation".

CCRDA

7.2.2.12 *Tillage*

A variety of tillage techniques and implements have been developed to do a number of things:

- seed bed preparation.
- control weeds
- make ridges.
- break up the soil surface to receive rains and increase surface roughness for increased surface storage.
- break up hard pans at depth.
- mix in/buty organic materials, fertilizer, etc.

All these tillage operations disturb the soil in some way and so tend to break up the soil structure and cause loss of organic matter through exposure to the air and oxidation. While such disturbances are not normally harmful on healthy soils with a reasonable organic matter content and a good stable structure, and may even be desirable on heavy clays, they tend to destroy structure and so harm non cohesive light sandy soils with low organic matter content. The amount of damage done depends not only on soil type but also and particularly on the operation (ploughing, ridging, weeding, etc.) and the means of carrying it out: i.e. hoe, oxen, or tractor. While tractors have a high potential to damage susceptible soils, oxen have much less and hoe cultivation very little.

In addition to the main objective for carrying out a particular tillage operation (e.g. seed bed preparation, etc.), from a soil and water conservation point of view there are several others. These soil and water conservative objectives and the principles of the methods for achieving them are summarised as follows:

a) to minimise the damage done to the soil structure and organic matter, and the formation of hard pans.

- tillage to be done at the optimum moisture content:
- if the soil is too wet, soil structure is destroyed by smearing and puddling
- if the soil is too dry, penetration to the optimum depth is difficult and the soil is ground to dust.
- use the minimum number of tillage operations.
- use of the chisel instead of the mouldboard plough.

b) to enhance the state and development of soil structure and so maximise infiltration and help reduce runoff.

- directly: through breaking up the surface and hard (sub-surface) pans.
- indirectly: through incorporation of organic materials.

c) to maximise surface roughness and therefore surface storage and resistance to surface flows, and so help control runoff:

- all operations to be carried out on the control.
- leave seed bed with maximum acceptable coldness.
- ridging along the control
- tied ridging

CCRDA

It can be seed that these soil conservation objectives may conflict with or complement the main objectives of a particular tillage operation. thus the preparation of a fine seed bed conflicts with minimising the damage done to soil structure. This will need some compromise.

Other objectives and factors need to be taken into account.

- cultural requirements and erosion risks of different soils.
- risks and possibilities with different means of tillage (hoe, ox, tractor).
- machinery available.
- farmer objectives and preferences.

Thus the design of appropriate optimum tillage systems is quite complex. As a guideline, consideration is given to the possibilities for farmers with the different types or means of tillage.

Hoe cultivation

Due to the versatility of the use of hoes, and differences in farmer preference, there are a great number of tillage techniques used by hoe farmers. For example:

- Minimum or no tillage: scrape off the weeds, plant directly and ridge later (where there are only a few weeds left after the dry season). Planting may be on the side of the old ridge, in the furrow or on the flat.

- Split the old ridges with some of (or without) the crop residues being buried in the old furrow.
- Hoe dig the whole surface and plant on the flat (no ridging).
- Most farmers make the distinction between the land preparation work done during the dry season and that done after the rains have started.

Because all cultivation, planting, weeding, etc., is done by hand, there is little danger of over pulverising the soil or working at non-optimum moisture content. In fact one of the major objectives of most farmers is to minimise the labour requirement. In addition, it should be fairly easy to work with crop residues on the surface, although most hoe farmers would not have the time or resources to fence their fields to prevent free range grazing. Nether would most hoe farmers have access to kraal manure or the necessary transport. Therefore while there is scope for development of techniques with better conservation benefits, the main general recommendations which can be made at present are:

- all tillage operations should be carried out on the contour.
- use the minimum number of tillage operations possible
- leave the seed bed with the maximum acceptable coldness.
- make and maintain well formed ridges along the control: this is a very effective practice which many farmers are using.
- use tied ridging, at least around depressions, anthills and other problem areas (section 3.4.3).
- early field preparation for early planting and cover (section 3.2.2).
- incorporate kraal manure, etc.
- change plough depth from year to year to minimise the risk of the formation of plough pans.
- leaves as much crop residue as possible on the surface (section 2.3.10).

Tractor cultivation

CCRDA

Tractors have enough power and weight to do a lot of damage to the soil and so much greater care is needed. Frequent ploughing of low organise matter sandy soils will destroy structure and cause a hard pan at plough depth.

While the same principles and objectives apply the number of implements and power available and therefore the number of options open to farmers are varied and a detailed discussion of this is beyond the scope of this manual.

7.2.2.13 *Winter ploughing*

Winter ploughing is that which is done as soon as possible after harvest, before the ground is too hard. Winter ploughing has many benefits including:

- allows rapid field preparation for early planting (section 3.2.2)
- gives improved infiltration of early rains for early planting and quick crop establishment.
- some of the crop residues may be incorporated and so protected form animals on free range grazing: however, where the field is fenced and there is good control against fire, it is probably better to leave crop residues on the surface.
- can help control pests and diseases.

However, winter ploughing may need stocking of some of the crop of make space, and may compete with harvesting for labour.

7.2.2.14 *Soil and water conservation through "good farming"*

It is clear from the above that for soil and water conservation, the two most important objectives are:

- maximum crop cover: to protect the soil from raindrop impact.
- strong stable soil structure: to increase the infiltration of water into the soil and so reduce runoff, and increase the inherent ability of the soil to resist erosion.

These both improve yields and sustainability which means that soil and water conservation is really just an integral part of "good farming".

7.3 MECHANICAL METHODS OF EROSION CONTROL

Mechanical field practices are used to control the movement of water and wind over the soil surface. A range of techniques is available and the decision on which to adopt depends on whether the objective is to reduce the velocity of runoff and wind, increase surface water storage capacity or safely dispose of excess water Mechanical measures are normally employed in conjunction with agronomic measures.

7.3.1 Contouring

Carrying out ploughing, planting and cultivation on the contour can reduce soil loss from sloping land by up to 50% compared with cultivation up-and-down the slope. The effectiveness of contour

Christian Relief and Development Association
LIBRARY
P.O.Box 5674

farming varies with slope steepness and slope length, for it is inadequate as the sole conservation measure for lengths greater than 180 m at 1^0 steepness.
On silty and fine sandy soils, erosion may be further reduced by storing water on the surface rather than

7.3.2 Contour bunds

Contour bunds are earth banks, 1.5 to 2 m wide, thrown across the slope to act as a barrier to runoff, to form a water storage area on their upslope side and to break up a slope into segments shorter in length than is required to generate overland flow. They are suitable for slopes o 1^0 to 7^0 and are frequently used on smallholdings in the tropics where they form permanent buffers in a strip-cropping system being planted with grasses or trees (Roose, 1966). The banks, spaced at 10 to 20 m intervals, are generally hand-constructed. There are no precise specifications for their design and deviations in their alignment of up to 10 percent from the contour are permissible. Hurni (1984) calculated the effectiveness of contour bunds to control erosion in Wello Province, Ethiopia, and showed that they would only reduce soil loss sufficiently on the lowest of the slopes examined (Table 10.1).

7.3.3 Terraces

Terraces are earth embankments constructed across the slope to intercept surface runoff and convey it to a stable outlet at a non-erosive velocity, and to shorten slope length. They thus perform similar functions to contour bunds. They differ from them by being larger and designed to more stringent specifications. Decisions are required on the spacing and length of the terraces, the location of terrace outlets, the gradient and dimensions of the terrace channel and the layout of the terrace system.

Terraces can be classified into three main types:
diversion, retention and bench.The primary aim of diversion terraces is to intercept overland flow and channel it across the slope to a suitable outlet. They therefore run at a slight gradient, usually 1:250, to the contour. There are several varieties of diversion terrace. The Magnum terrace, formed by taking soil from both sides of the embankment, and the Nichols terrace, constructed by moving soil from the upslope side only, are broad-based with the embankment and channel occupying a width of about 15 m. Narrow-based terraces are only 3 to 4 m wide and consequently have steeper banks which cannot be cultivated. For cultivation to be possible, the banks should not exceed 14^0 slope if small machinery is used or 8.5^0 if large reaping machines are operated. Diversion terraces are not suitable for ground slopes greater than 7^0 because of the expense of construction and the close spacing which would be required. Retention terraces are used where it is necessary to conserve water by storing it on the hillside. They are therefore ungraded or level and generally designed with the capacity to store runoff volume with a ten-year return period without over-topping. These terraces are normally recommended only for permeable soils on slopes of less than 4.5^0.

Bench terraces consist of a series of alternating shelves and risers and are employed where steep slopes, up to 30^0, need to be cultivated. The riser is vulnerable to erosion and stones or concrete. There is no channel as such but a storage area is created by sloping the shelf into the hillside. The basic bench terrace system can be modified according to the nature and value of the crops grown. Two kinds of system are used in Peninsular Malaysia (Williams and Joseph, 1970). Where tree crops are grown, the terraces are widely spaced, the shelves being wide enough for one row of

CCRDA

plants, usually rubber or oil palm, and the long, relatively gentle riser banks being planted with grass or a ground creeper. With more valuable crops such as temperate vegetable s grown in the highlands, the shelves are closely spaced and the steeply sloping risers frequently protected by masonry. Level bench terraces are used where water conservation is also a requirement, as in the loss area of China (Fang, Zhou, Liu, Liu, Ren and Zhang, 1981) and in parts of Kenya (Barber, Thomas and Moore, 1981).

7.3.4 Waterways

The purpose of waterways in a conservation system is to convey runoff at a non-erosive velocity to a suitable disposal point. A waterway must therefore be carefully designed. Normally its dimensions must provide sufficient capacity to confine the peak runoff from a storm with a ten-year return period. Three types of waterway can incorporated in a complete surface water disposal system: diversion channels, terrace channels and grass waterways. Diversions are placed upslope of areas of farmland to intercept water running off the slope above and divert it across the slope to a grass waterway. Terrace channels collect runoff from the inter-terraced areas and also convey it across the slope to a grass waterway. Grass waterways are therefore designed to transport downslope the runoff from these sources to empty into the natural river system ; they are located in natural depressions wherever possible but, occasionally, natural channels are reshaped to serve as grass waterways.

7.4 WIND EROSION CONTROL

7.4.1 Wind breaks

Shelterbelts are placed at right angles to erosive winds to reduce wind velocity and by spacing them at regular intervals, break up the length of open wind blow. Shelterbelts are strictly living windbreaks. Inert structures such as stone wall, slat and brush fences and cloth screens can be used to perform similar functions on a smaller scale.

A shelterbelt is designed so that it rises sharply on the windward side and provides both a barrier and a filter to wind movement. A complete belt consists of two tree rows and up to three shrub row, one of which is placed on the windward side. The density of the belt should not be so great as to form an impermeable barrier nor so sparse that the belt is transparent. A belt of the correct density is best described as translucent. It should be possible to see the presence of objects on the other side of the barrier without being able to identify them. This density is equivalent to a porosity of 40 to 50 percent. It gives the greatest overall reductions in wind speed over a distance 30 times the barrier height (skidmore and Hagen, 1977). More open barriers do not reduce wind velocity sufficiently. With denser barriers there is a much greater reduction in wind speed close to but, since the velocity increases more rapidly with distance downwind than is the case for more porous barriers, they are effective for shorter distances. Using wind tunnel studies, Woodruff and Zingg (1952) developed the following equation for determining shelterbelt spacing:

CCRDA

8. AGROFORESTRY

8.1. WHAT IS AGROFORESTRY?

Two charactersitics are common to all forms of agroforestry and separate them from other forms of land use, namely:

1. the deliberat growing of woody perrenials on the same unit of land as agricultural crop and/or animals, either in some form of spatial mixture or sequence;

2. there must be a significant intercation (positive and/or negtive) between the woody and non-woody components of the system, either ecological and/or economical.

It is quite wrong to define agroforestry as a successful form of land use which achieves increased production and ecological stability. It acn be aimed to ahive these, and in many ecological and socio-economic settings agroforestry approaches have higher potential to achieve these than most other approaches to land use. But with the wrong choice of species combinations, management practices, and lack of peoples' motivation and understanding, agroforestry may indeed fail just like any other form of land use may fail, and it will still be agroforestry in the objective sense of the word.

The following definition has been suggested:

Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) and/or livestock in a spatial arrangement, a rotation, or both and in whcih there are both ecological and economic interactions between the tree and non-tree components of the system (Young, 1989).

This definition implies that:

- Agroforestry normally involves two or more species of plants (or plants and animals), at least one of which is a woody perennial;
- An agroforestry system always has two or more outputs;
- The cycle of an agroforestry system is always more than one year; and
- Even the simplest agroforestry system is more complex, ecologically (structurally and functionally) and economically, than a monocroppping system.

Additionally, there are three attributes which, theoretically, all agroforestry system posses. These are:

1. Productivity: Most, if not all, agroforestry systems aim to maintain or increase production (of preferred commodities) as well as productivity (of the land). Agroforestry can improve productivity in many different ways. These include: increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, and increased labor effeciency.

CCRDA

2. Sustainability: By conserving the production potential of the resource base, mainly through the beneficial effects of woody materials on soils, agroforestry can achieve and indefinitely maintain conservation and fertility goals.

3. Adoptability: The fact that agroforestry is a relatively new word for an old set of practices means that, in some cases, agroforestry has already been accepted by the farming community. However, the implication here is that improved or new agroforestry technologies that are introdued into new areas should also conform to local farming practices.
(Slide 1 from ICRAF training manual).

8.2. CLASSIFICATION OF AGROFORESTRY SYSTEMS

The main poupose of classifcation is to provide a practical framework for the synthesis and analysis of information about existing systems and the development of new and promising ones.
Criteria for classifying agroforetry systems are the spatial and temporal arrangement of components, the importance and role of components, the production aims or outputs from the system, and the social and economic features. Accordingly, agroforestry systems can be catagorised:
1. Structural basis: refers to the composition of the components (include spatial arrangement of the woody component, vertical stratification of all the components, and temporal arrangement of the different components.

2. Functional basis: refers to the major function or role of the system.
3. Socio-economic basis: refers to the level of inputs of management (low input, high input) or intensity or scale of management and commercial goals (subsistence, commercial, intermediate).

4. Ecological basis: refers to the environmental condition and ecological suitability of systems.

The broad bases of classification of agroforestry are by no means independent or mutually exclusive. While the structural and functional bases often relate to the biological nature of woody components in the system, the socio-economic and ecological stratification refers to the organisation of the systems according to prevailing local condiitons (socioeconomic or ecological).

1. Structural classifcation of systems

This can be defined interms of its components and the xpected role or function of each, manifested by its ouputs. In fact, it is also important to consider the arrangements of components in addition to their type.
a. Based on the nature of components
b. Based on the arrangement of components

CCRDA

2. Classification based on function of systems

Productive and protection (which is the cornerstone of sustainability)

3. Ecological classifcation: based on agroecological zonation

4. Classification based on socioeconomic criteria

Socioeconomic criteria such as scale of production and level of technology input and management have been used as a basis for classifying agroforestry systems. Lundgren (1982), for example, grouped systems into commercial, intermediate and subsistence systems.

8.3. AGROFORESTRY SYSTEMS, PRATICES AND TECHNOLOGY

System: is a group of interacting components, operating for a common purpose, capable of reacting as a whole to external stimulii (Spedding, 1979). Often agroforestry systems and practices terms have been used synonymously in agroforestry literature.

An agroforestry system is a specific local example of a practice. charcterised by environment, plant species and their arrangement, management, and socioeconomic functioning.

An agroforestry practice denotes a distinctive arrangement of components in space and time.

Although hundreds of agroforestry systems have been recorded, they all consists of about 20 distinct agroforestry practices.

Agroforestry practices

Productive (wood, fruit, leaves etc)	Productive (wood, fruit, fodder)
Trees in intercropping (spatial)	Trees/ shrubs as fodder banks (spatial)
Multilayer tree garden (spatial)	Trees on rangelnd (spatial)
Taungya (temporal)	Live fences/ hedges (spatial)
Trees in homegardens (spatial)	
Trees on croplands (spatial)	

Predomintly protective (cropping or livestock systems)

Tree rotation in shifting cultivation (temporal)
Tree rotation in improved fallow (temporal)
Trees for animal and human shade (spatial)
Shelterbelts and windbreaks and windbreaks (spatial)
Trees for soil conservation

CCRDA

'other' agroforestry practices

Mixed multi-layer tree crop plantations (spatial)
Multipurpose trees and woodlots (spatial)
Apiculture (trees for bee fodder) (spatial)
Aquasilvicuture (trees with fish) (spatial)

Agroforestry technology refers to an innovation or improvement, usually through scientific intervention, to either modify an existing system or practice, or develop a new one. Such technologies are often distictly different from existing systems/prectices; so they can easily be distinguished and chracterised.

8.4. ECOLOGICAL INTERACTIONS IN AGROFORESTRY

In agroforestry, many different components need to interact in various ways. Interactions between species concerns the ways in whcih plants can influence their neighbours by changing thrie environemenet ; directly (competing for nutrients and other limited resources), or indirectly (encouraging certain insect species etc.)

If trees are added to cultivated land there are a number of possible interactions beteween tree (A) and cro (B). (A) may have a positive effect (+). negative effect (-) or no effect (0) and vice versa. Therefore threre are fivepossible outcomes; (--), (-0), (++), (+0), (+-).

Niche Theory

In ecology, a niche stand for the preise way in which a species fits into the environment. Not just where it is found (habit) but how the plant relates to its physical and biological environment. in other words, how does it compete?

Competition

'An interaction between two individual plants tat reduces the finess of one or both'

I) Exploitation - concerned with limiting shared resource. Plants occupy similar niches have similar demands for water, nutrients, light etc
II) Interference behavioural, e.g. production for toxic substances

Facilitation

'an interaction between two individual plants that increases the fitness of one or both' Plants whcih occupy different niches will have different requirement for resources so they will not be competing and their presence may in some way benefit one or both plants.
I) Mutualism- (++) - reciprocal increase in fitess e.g. N. Fixation
ii) Commensalism (+0)- - one individual benefits e.g. microclimatic benefit or trees.

CCRDA

Relative Yield Concept.

The aggressivness of one plant against another can be examined using the index of the'relative yield' concept.

The 'relative yield' of species A is the yield in a given mixture of species A and B compared with its yield in pure stand of A.. Likewise for species B.

The sum of the relative yield for A and B is called "Relative Total Yield" (RTY). If the RTY $=>2.0$ There is increase total productivity (niche differentation) If the RTY + 1.0 There is no change in yield (Same niche occupies, +ve and -ve interaction are cancelled out.

If the RTY $=<$ 1.0 there is a total fall in yield, species are mutually antagonistic, some sort of interference.

8.5. MULTIPLE USES OF TREES (MPTs)

Definition

'All woody perennials that are purposefully grown to provide more than one significant contribution to the production and/or service functions of a land-use system'

(Wood and Burley 1991)

Traditional silviculture

Wood; sawlogs, poles

Rural Development

Wood, sawlogs, poles, tools, building materials, fencing, utensils etc. firewood, charcoal

Leaves, Fodder, shade, mulch (soil improvement), medicine, dyes

Fruit, Human and animal food, oils, soil improvement

Flowers Bees for honey

Bark Medicine, dyes, gums

Roots Medicine, firewood, soil conservation/stabilisation, soil improvement

Other Functions;

Windbreak, boundary markers, habitat for other birds and animals/biodiversity, ornamental,

CCRDA

Design requirements of trees for agroforestry systems;

i) Are the trees to be productive or protective or both?
ii) No species can fulfil all our requirements so we have to select a combination of the most suitable species available to fulfil our objectives.
iii) We therefore have to evaluate the suitability of available species in terms of their productive and protective functions in addition to their compatibility with each other and other plant species which we also want to grow in our diverse agroforestry systems.

The Ideal Tree or 'Ideotype'

We can use the concept of an 'ideal tree' or 'ideotype' analysis to evaluate the suitability of available MPTs.
i) In terms of their productive and protective capabilities and the ease of managing them for these purposes.
ii) In terms of their compatibility with other species.
ii) It can also help us to identify characteristics of individuals within species which we can select to improve their productive, protective and compatibility characteristics.

Ideotypes

Model trees based on morphological and physiological characteristics.
4 general categories;

1) Isolation; Wide branches, broad leaves,- grow best as free standing trees e.g. Ficus
2) Competition; Grow well in a community of their kind but will dominate less aggressive species e.g. Eucalyptus.
3) Crop Have the ability to share environmental resources with crops with competing for resources e.g. Ziziphus spina-christi
4) Associative Have the ability to positively interact with crops and actually increase crop yields while sharing resources e.g. Faidherbia albida.

The table below can be used to characterise MPT characteristics for particular purposes, whether for production of particular products or for ecological interaction purposes. You will be able to get a general idea of competitiveness of the species and the practicalities for managing the trees in an agroforestry system from looking at these factors. However, in order to ascertain 'associative' species you may need to carry out further research.

CCRDA

Attributes in relation to Production and Service Function

Attributes	Effects
Dioeciuos or monoecious	Distribution of sexes between plants, has important implications for fruit and seed production, tree density and pollen flow.
Method of pollination/ breeding	Inbreeding/ outcrossing- variations in seedling populations of the same origin.
Tree height	Ease of harvesting leaves, fruit, seeds, wood, shade
Stem form (tree architecture)	Suitability of wood for poles, timber, shading area, rainfall interception, leaf drip
Multi or single stemmed habit	Fuelwood production, shading
Wood quality	Suitability for fuelwood, charcoal, and other wood products (strength, workability etc.)
Crown size and form	Quantity of leaves, quantity of fruit and flowers, shading area, rainfall interception, windbreak
Leaf size, shape, and nutritional value	Shade quality, leaf drip, rainfall interception, nutritional value of browse
Rooting pattern (deep/shallow, tap or spreading)	Below ground competitiveness, suitability for soil conservation
Thorniness	Problems of product collection, suitability as a live or dry fence.
Phenology: leaf flush, leaf fall, flowering and fruiting calendar	Timing of products to meet seasonal shortages, demands for labour, drought resistance.
Deciduousness	Seasonal or permanent leaf fodder availability, windbreak, live fence
Pest resistance/ vigour	Major requirement for all functions
Site adaptability and ecological range	Altitude, rainfall, suitability for alkaline, saline, acid, waterlogged or degraded soils
Response to pruning or cutting	Pollarding, coppicing, suitability for intercropping, wood and fodder production and windbreak regeneration.
Ability to fix nitrogen	Improve soil fertility, provide good browse, suitable in rotation or intercropping.

CCRDA

Genetic Aspects (Selection)

There is much variation within species in terms of the above characteristics. Considerable variation in many species can be found at provenance or variety level. This variation is an under-utilised resource for future genetic selection and improvement, provided that we have clearly identified these valued characteristics for agroforestry systems.

Phenotypic variability is related to the breeding pattern of the species. High variability is common in outcrossing (cross-pollinating) species, such as many forest trees like Acacia and Prosopis. Species which are self-pollinating or grow from root suckers are less likely to show such great variations within populations.

It is important to recognise which MPT traits can be improved and which cannot. For example, a species will either be able to coppice or not. However some individuals within a species will nodulate more than others and some individuals will have a more convenient branching habit than others so these characteristics can be selected for.

However, plant breeding for improvement of species for agroforestry is a long way from being a common practice, especially with indigenous species. However, it can start every time seeds are collected. If the characteristics we have described are clearly understood, appropriate mother trees can be selected on a much more sophisticated level than is currently the practice in most countries.

CCRDA

Exercise

Describe a suitable ideotype to fulfil the following objectives;
1) Fodder production,
2) Fuelwood production
3) Shade
4) Soil improvement
5) Soil conservation
6) Be compatible with crops (not competitive, ideally associative)

What is exotic?

It is important in a country such as Ethiopia, to note that there is great potential for trying indigenous species in wider areas than their existing ecological range, e.g. Dryland species from S. Ethiopia can be tried in the north. In this case, from an ecological and cultural point of view, introducing a southern Ethiopian tree to northern Ethiopia will be the equivalent of introducing an exotic from another country.

The size of a country may determine the suitability of relying just in indigenous species. Ethiopia is a large country with a broad indigenous biodiversity and therefore there are more opportunities here for concentrating on indigenous species.

Exotic Species

1) Advantages
i) Choice of species
ii) Disease
iii) Research knowledge and experience
iv) Genetic choice

Indigenous Species

1) Advantages
i) Availability of seed;
ii) Indigenous/ local knowledge;
iii) Adaptability;
iii) Opportunities for selection
iv) Growth indicators
v) Ecology/ Biodiversity

Summary

Indigenous species offer the potential for the best suitability in terms of ecology, economy and cultural suitability. With suitable breeding programmes we should be able to produce suitable ideotypes to meet the needs of Ethiopian people. It is a lack of documented research information on these species is the main limiting factor. Exotic species are well described, easily accessible and can be selected for suitability for site and function like items on a menu, without further research being necessary. This however, is a dangerous trend and one which agroforestry research is trying to address. Further efforts should be made to disseminate information on indigenous species, and only when there is no suitable indigenous species should we resort to exotics.

CCRDA

3.6. SOIL CONSERVATION FOR AGRICULTURAL SUSTAINABILITY

Soil conservation is the maintenance of soil fertility which requires:

1) Control of erosion
2) Maintenance of organic matter
3) Maintenance of soil physical properties
4) Maintenance of nutrients
5) Avoidance of toxicities

(Young 1989)

Physical processes of erosion

Soil erosion is a two stage process consisting of detachment of soil particles from the soil mass and their transport by erosive agents downslope.

Primary factors determining soil erosion

i) Erosivity of the eroding agent, rain or wind which are very high in Ethiopia
ii) Erodibility of the soil
iii) Slope angle and length
iv) Vegetation cover

Main types of erosion in Dryland Ethiopia

1 Rainsplash action, pedestal erosion etc.
2 Overland flow and rill erosion
3. Sub-surface flow and tunnel erosion
3 Leaching
4 Gully erosion
5 Mass movements
6. Wind erosion

Vegetation for soil conservation

Trees aid soil stability by a combination of rainfall interception, regulation of runoff and infiltration, binding and anchoring the soil by deep root penetration, provision of ground cover and soil organic matter through litter production, and by capturing and recycling leached nutrients carried by subsurface flow and reduce windspeeds to reduce wind erosion. The hydrological effects have been discussed before but it is impossible to separate the role of trees for erosion control with the role of trees for other aspects of soil conservation such as nutrient cycling and the contribution of organic matter.

Techniques for trees for soil conservation

A) The role of woody perennials in the cover approach

Vegetation can reduce the effects of rainsplash action in the detachment phase of soil erosion by interception of raindrops and the dissipation of their erosive energy.

i) Canopy cover
ii) Ground Cover;
iii) Mulching

CCRDA

B) The role of woody perennials in the barrier approach

Trees and agroforestry can also be incorporated into soil erosion control measures which deal with the transport phase of soil erosion. These are called the barrier approach methods. We can distinguish between supplementary uses of woody perennials in stabilising conservation structures such as terraces and direct use of trees and shrubs as the major method of reducing erosion.

1. Direct

i) Contour hedgerows
ii) Boundary planting and live fences

2. Supplementary

i) Trees on grass barrier strips
ii) Trees on ditch-and-bank structures
iii) Trees on terraces

C) Afforestation and watershed management for multiple purposes

It is important to acknowledge the soil erosion control contribution of afforestation sites. Here in Tigray we are referring to;

i) Area enclosures
ii) Community plantations
iii) Enrichment planting in enclosed areas.

By establishing whole forests, not just individual trees or hedgerows we are conserving soil through both the detachment and transport phases of soil erosion. Protected watersheds do not become degraded and cause siltation of reservoirs, and they provide a source of timber and non-timber forest products.

D) Bio-engineering

Supportive research on the role of woody vegetation for erosion control can be found in the engineering and bio-engineering literature, concerned primarily with road-related soil conservation issues. Both the detachment and transport phases are considered with particular reference to the function of trees and other vegetation in stabilising mass movements and increasing slope mechanical stability through the penetration of deep-rooted plants. In countries such as Ethiopia where road

CCRDA

construction is taking place on steep slopes, the use of vegetation as a low-cost, low-maintenance form of engineering is an attractive area of research.

8.7. CASE STUDIES:

1. Discussion on Breed (1995), Kindeya (1995) and Poschen (1986)
2. A report to JICA (1996) Green Promotion Project of Tembien

CCRDA

9. FOREST DEVELOPMENT

9.1 FORESTS AND PLANTATION DEVELOPMENT

IMPORTANCE OF FORESTS

The importance of forests can be appreciated from three angles. i.e. economic, ecological, and recreational.

A. ECONOMIC IMPORTANCE:

1. Timber
2. Non-timber products: A forest can provide
3. Creation of jobs: projects.

B.ECOLOGICAL IMPORTANCE.

1. forests control erosion and stabilize the soil.
2. regulation of water shade.
3. improve microclimate.
4. protection of agricultural field and farm animals from harmful weeds, rays of sun, disease and so on.
5. forests maintain and conservethe bio-diversity.
6. Forest stabilize man made structures like dams. i.e. integrated physical and biological conservation.

C.RECREATIONAL IMPORTANCE

REASONS FOR PLANTATION DEVELOPMENT

Plantation is an area covered with trees artificially. Mostly it is of monoculture in species composition. Though not adequate, the area coverage of plantations is increasing from time to time. Countries of the world, especially developing nations had made massive afforestation programs. This is mainly because of destruction of natural forests. Increase in population and technological advancement had aggravated devastation of forests in extent and complexity.

According to World Bank estimates 15-20 million trees are removed every year. At this level of destruction, after 60-80 years the whole tropical forests would possibly be destroyed. Open wooded formations and savannas are severely exploited because of their proximity to the people. Removal of forests had greater repercussion especially in ecologically unstable areas like arid lands and mountains. Any change in the existing forest of that area will result at least a great damage in that particular habitat. To rectify this hazard, plantation establishment had become indispensable.

CCRDA

- MAJOR REASONS FOR DESTRUCTION OF FORESTS WHICH COULD AROUSE THE NEED FOR PLANTATION ESTABLISHMENT ARE:

1. agriculture:
2. fuel wood, charcoal and poles:
3. shifting cultivation:
4. intensive forest logging
5. urban and industrial expansion
6. over grazing and fodder gathering
7. forest fire (accidental or deliberate); wars.
8. continued increase in demand for forest products (for quality hard woods) by developed nations.
9. increase in technological capacity
10. settlement: eg. indonesia, ethiopia.
11. development projects usually done with out considering their impact on the environment.

POSITIVE FACTORS FOR PLANTATION DEVELOPMENT

1. Land Availability:
2. High Productivity:
3. As a tool for development in developing countries.
4. Environmental Protection; environmental forestry for soil and water stabilization will encourage forestry development both at small scale and large scale levels.

9.2. NURSERY ESTABLISHMENT AND MANAGEMENT

Planning a nursery

Two types of nursery;

1) Temporary Nursery;

Established for a short period (5 years or less), to meet specific needs of a specific project; afforestation of a particular area etc. These tend to produce only limited numbers of seedlings.

2) Permanent Nursery;

Established to provide a permanent supply of seedlings.

Farm nurseries/ Family nurseries; producing up to 10,000 seedlings a year for sale and home use.

Community nurseries or school nurseries; producing 10-30,000 seedlings a year.

Centralised nurseries e.g. Ilala; produce up to 500,000 seedlings a year.

CCRDA

Selecting a site for the nursery;

Technical Factors

1) Find an area of gently sloping land (1-3%).
   Slopes over 5% should be terraced.
   This allows drainage without erosion.
2) Find an area which is big enough to produce the number of seedlings you want.
3) Provide a continuous water supply
   Access to a pipeline or a perennial river.
4) Vehicle access is necessary for all but the smallest nurseries.
   Choose a site accessible by road.
5) Access to labour supply.
   Depending on the size of your nursery you will have to employ permanent workers. You therefore must site the nursery close to a labour supply. Most nurseries are usually therefore close to towns.
6) Supply of electricity and telephone.
   This is only important for the larger nurseries.

Environmental Factors

1) Extremes of climate should be avoided
   Avoid frost-prone areas or particularly low hot areas.
2) Avoid exposed sites
   Avoid hail-prone areas, persistent gusty winds, flooding risks, areas of excessive erosion.
3) Find a site with good workable soil.
   Free draining sandy loam. Avoid very clay soils.
   Avoid very acid or alkaline soils.
   Organic matter is not so important, don't have too many weed seeds and pathogens.
4) Ideal sites have a few mature trees
   Provides a windbreak.
   Some shading from the sun.

Nursery Design

1) Ideally nurseries are square
   minimise pathways
   centralise buildings and water supply, soil preparation areas
   minimise fencing.
2) Provide enough area for buildings; seed store, tool shed, office etc.
3) Provide enough room for soil preparation areas
4) Provide a water supply to enough strategic points around the nursery.
5) If protective hedges are planned leave enough room.
6) Avoid areas of waste ground in the nursery where weeds will grow.
7) Decide on bed width; normally 1-1.2m to allow tending operations.
8) Paths between beds should be wide enough to walk along with tools and equipment. (min 60cm).

CCRDA

9) Provide enough room for vehicle manoeuvring
10) If expansion of the nursery or broadening of activities is planned find a site with room for expansion, e.g. seed orchards, bee keeping, vegetable production etc.

Raising seedlings

There are two methods
i) Containerised (potted)
ii) Bare-rooted
Most seedlings in Dryland countries are containerised.

Advantage of containerised;

Higher survival rate (trees are planted on-site with their own root ball)
Disadvantages of containerised;
Higher costs; i) Costs of mixing soil and filling pots
ii) Need for high quality seed
iii) Higher cost of transport (heavier)
Containers must be removed at time of planting to allow root development
If seedlings are left in the container too long they become root-bound

For cost reasons there has been a growing interest in returning to bare rooted.

Container filling/
Soil Preparation for container-grown seedlings

i) Soil must be of a pH of 5.5-7.0
ii) Sandy loam texture (not >20% clay)
iii) Mixture; Sand 40%, Forest Soil 40% and Manure/organic matter 20%
Ratios will vary according to availability of each component
Beware that manure is not too fresh-damping off (fungal attack)
iv) It is assumed in many nurseries that by mixing the seedlings with forest soil the necessary nitrogen fixing mychorrzae will be introduced. But for some species further inoculation with crushed root nodules may be necessary.
v) In some nurseries in Tigray there are organic matter facilities; pits-usually 1m×1m or larger (e.g. llala), where you put in organic matter, cover with a layer of soil, water, and then cover with another layer of organic matter etc. (using weeds, straw, branches from N fixing trees-avoid Eucalyptus or Cupressus branches).
vi) The soil mixture is sieved to remove lumps and stones and mixed.
vii) The polytubes are filled by hand in Ethiopia because labour is cheap. It is possible to mechanise this process but hand filling will provide the best bulk density and women in particular are very good at filling pots.
viii) Filled polytubes are placed side by side in the sunken nursery beds and are self-supporting.
ix) Soil is then raised up against the side of the beds to stop the outer pots drying out.

CCRDA

Soil Preparation for bare-rooted

i) You sow directly into the nursery soil so there is no need for soil mixing.

ii) If you are not mixing with forest soil you may need to inoculate for N fixing trees.

iii) Because you are not mixing, the quality of the nursery soil is therefore very important.

iv) The soil must be easily worked and be in good physical condition with plenty of organic matter.

v) Soil preparation must begin long before sowing the seeds to bring it to a suitable condition. It may need to be cultivated up to 8 times. In some nurseries the stock may be rotated and beds are left fallow with leguminous crops to improve fertility (although this is not common in Ethiopia).

vi) Beds are raised above the ground by about 10cm to improve drainage.

vii) In other countries it is common to put fertiliser on the beds as they get used year after year but I understand that this is exceptional in Tigray, due to cost and the fact that as yet it has not been seen as necessary.

viii) An alternative to fertiliser use is mixing in organic matter.

Seed sowing

Timing

i) After seedling pre-treatment

ii) At the right time of year e.g..

Most Acacias and Eucalyptus Jan/Feb

Many other species Sep-Nov (Casuarina, Citrus, Cupressus).

For each nursery you should have a tree sowing calendar.

a) Containerised

Two methods;

1) Sowing directly into the into the pots.

This is the most straightforward but the problem is that you may get no seeds or several seeds germinating in the same pot. This is the reason you want high quality seed.

2) Sowing into germination trays. Good for;

i) Very small seed species (can get blown away, or difficult to count into each pot)

ii) Very expensive seeds (minimise waste)

iii) Seeds with very low viability

iv) Species susceptible to fungal/insect damage-more intensive care.

CCRDA

Transplanting
Reject low size seedlings
Don't handle by the stem-use the leaves
Don't bend the taproot, be gentle and careful
Water well after transplanting to avoid drying out

b) Bare rooted
Broadcast sowing by hand is the best way.
Thin to about 4 or 6 cm spacing (approx. 40 seedlings /m2 is ideal)
Very light seed may be mixed with soil before broadcasting
Try to get an even distribution- not patchy

Watering/Irrigation

1) Water Supply;
2) Quality of water;
i) pH < 7
ii) Low salt content
iii) Not too cloudy
3) Irrigation Design
4) Watering Techniques (Hand watering, surface irrigation and Pipe irrigation)

5) Watering Requirement

Other important considerations in nursery management also include: shading, shelter, weed control, protection from fungal attack, protection from birds and animals and preparation for planting out (hardening Off and Conditioning).

9.3. PLANTATION ESTABLISHMENT

Plantations are established to fulfil one of four objectives;

1) Domestic/Commercial uses
2. Environmental Protection
3) Industrial uses
4) Integrated rural development (Agroforestry)

Procedure for Selecting Objectives

Identify the Interested Parties
i) Who owns the land?
ii) Who will own the trees?.
iii) Who will manage the plantation?
iii) Look at policy; national, regional, zonal, woreda, kebele, village.
iv) Who is paying for the afforestation?
v) What are the markets for timber and non-timber forest products?

CCRDA

Factors to consider in species selection

Christian Relief & Development Association
LIBRARY
P.O.Box 3674

1) Climate of the Site

a) Rainfall/Moisture (annual rainfall, Distribution of rainfall, Variation between years and Water balance)
b) Temperature
c) Altitude
d) Soil (depth, physical structure, chemical
e) Other factors (sites subject to prolonged flooding, fire resistance, resistance to browsing/ grazing and human pressure, and Resistance to termites and other pests or diseases).

Procedure for Species Selection

i) Review of literature (General compilations, monographs/ bibliographies of particular species, species reports for particular areas, national books about species and their uses, local reports about species and uses, electronic sources; CD Roms and world-wide research networks; e.g.. Nitrogen Fixing Tree Association
ii) Interview people
iii) Personal Observation
iv) Species Trials

Methods of site preparation and tree planting techniques for Dryland areas.

1) Planning and Organisation

i) Planting site should be ready well before the first rains.
ii) Trees must be transplanted from the nursery as soon as sufficient rain has fallen to moisten top 20cm soil. You cannot plant into dry soil.
iii) Do not delay planting unnecessarily as this will increase seedling mortality- each seedling needs an entire rainy season to get established.
iv) Timing of planting is therefore limited, so preparation and organisation are required.

a) Have transport organised in advance and have a contingency plan in case of break down.

b) Have good relations with workers; community members in most cases. They must be informed of planting times and arrangements of where to be and when.

c) Plan realistically. It is better to plant a small area well than a big area badly. Poor quality, rushed planting can cause very high mortality rates.

2) Site Preparation

i) Site delineation

Clearly identify the planting site. Make sure that all members of the community are well aware of plans. Make sure nobody grazes their livestock two days or so after you have planted your seedlings.

CCRDA

ii) Access

Identify suitable access for the vehicles and workers. Vehicles may not be able to get onto the planting site so identify a suitable drop-off point for the seedlings and identify a convenient (minimum distance) route for people to carry seedlings on foot. Seedlings are heavy (especially potted) and can be damaged during transport so aim to make transportation as less stressful as possible for the seedlings.

iii) Site clearing

The area around each tree, should in theory, be cleared of all vegetation and roots to at least 1m2, so minimising competition for water and avoid shade from existing trees.

iv) Spacing

In theory, most dryland areas should aim for a spacing of about 3-4m, according to species, however, this is often not achieved in reality.

v) Digging

a) Timing

In areas of <1,200mm rainfall (most of Tigray), holes should not be dug too long in advance of the use. Normally you would do this to save time when it comes to planting but;

Rains may be intermittent and the sun and wind may dry out the hole and the excavated soil leaving it harder and less manageable than it was before

b) Size

Each hole should be 40cm x 40cm (deep). This easily provides enough space for bare-rooted or potted root balls. Reality is often that smaller holes are dug because people are paid according to the number of holes. This can cause damage to roots at time of planting and root balling.

The excavated soil should be placed carefully beside each hole as it will be needed later for re-planting.

vi) Transplanting

a) Container stock

Transplanting container stock from the nursery is easier but harder work because they are heavier. Container stock can just be lifted one by one from the beds. If the roots have grown out of the containers they may need trimming with a sharp knife.

Potted seedlings are then loaded into crates and then onto vehicles which should have a protective tarpaulin. Potted seedlings require much more room in transportation as each must be transported upright and not damaged.

Often, if the planting site is far from the nursery, seedlings may be transported one day and planted the next. In which case, a temporary or satellite nursery should be established. This is simply sunken beds with a water supply. The seedlings must be watered and sunk into the ground for moisture conservation. If the pots dry out during transport and planting many seedlings will die.

CCRDA

i) Bare-rooted stock

Young seedlings must be dug up slowly and carefully using shovels or other strong, sharp tools to dig very carefully around the roots. The roots will however, always be damaged so in order to minimise the damage the wounded area (through which moisture is lost and infection enters), the damaged roots must be trimmed neatly (especially the long ones), so area of damage is minimised. This should be done as soon as the seedling is lifted. If you have been root pruning you should have less of a problem.

After roots are pruned they are bunched into groups of about 25 and packed in wet mud. Efforts should be made to retain the root ball. Then wet grass, leaves, old sacking or polythene is placed over the bundles, making sure they are as wet as possible to minimise desiccation on their way to the planting site. These bundles of seedlings are then loaded onto transport to be taken to the planting site.

If they need to be stored on-site overnight or even for part of the day they should be healed in.

vii) Leaf Stripping

Some species e.g. Azadirachta indica (neem) should have most of their leaves removed before transportation. This minimises evapotranspiration loss.

Other species can be transported as stump cuttings. You remove the whole shoot except for a small stump and some roots as we talked about before, so this makes transportation much easier.

viii) Re-planting

a) Plant the seedling so the collar is even with the ground surface. If the collar is misplaced this can cause increased mortality. The collar is the point on the seedling where it emerged from the ground.

b) Clearly identify where the collar is, this will not be so obvious with barerooted. Obviously with container stock you will plant the whole root ball so the collar will remain at the soil surface.

c) Carefully backfill by hand. Put soil from the top of excavated soil around the bottom of the root structure. Should tamp in the soil with your heel to remove air pockets, tamping is done diagonally- see diagram.

d) After the hole is filled the remaining soil should then be shaped into a shallow depression = basin (mini micro-catchment).

Micro-Catchments

i) Specialist technique for very harsh, dry sites, where survival of a few trees is the priority.

ii) Re-shaping the terrain around trees to maximise their moisture availability.

iii) May even enable trees to establish where they could not grow naturally.

iv) Over excavation is necessary with rocky sub-surface- to allow root and moisture penetration.

CCRDA

v) All surface runoff is collected and concentrated into the root zone around trees.
vi) It can even work on relatively flat land with only a slight gradient.

Shape
''Half-moon'' or ''fish scale''.
2-4m around each plant is reshaped (see p106 Weber and Stoney). This provides a large enough catchment volume so runoff from 7mm rain can be stored w/o overflowing- therefore depends on slope angle, catchment size, rainfall pattern = Trial and error.
Building of micro-catchments requires skill and care.

Contour ridges

Similar to micro-catchments but on a larger scale. Construct contour ridges as earth walls along the contour. The ridges help prevent soil erosion as well as increase infiltration of moisture into the soil.

The distance between the ridges depends on slope angle. This is a similar principle to deciding on terracing design which you will be covering next year.

Enrichment planting of area closures and post-planting survival count and beating up operations.

1) When to enrichment plant
Enrichment planting is the planting of seedlings in gaps within the natural vegetation cover.

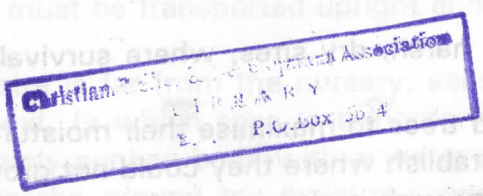
Here in Tigray, the extent of enrichment planting depends upon existing vegetation cover in any afforestation site. Generally speaking;

>70% shrub ground cover- The area is enclosed without enrichment.
40-70% shrub ground cover- The area is enclosed and will have enrichment planting.
<30% shrub ground cover- The area will be considered as an afforestation site.

Vegetation cover will vary greatly from one site to another, but on most afforestation sites there will be some existing vegetation which we will want to keep for soil and water conservation, which we will have to be planting around.

Additionally, on most enclosure sites there will be large gaps in the vegetation cover which will need filling, so we enrich the planting site with some seedlings.

CCRDA



2) When to blank-up

Blanking-up is the replacement of dead seedlings on a plantation site.

Post-planting survival count

A few weeks to a few months after planting, depending on growth rates, (but certainly within the first growing season) an assessment is made of how many plants have died, which will be due to planting shock, poor rainfall etc. A second survival count may be taken towards the end of the dry season for planning purposes for seedling requirements. Seedlings mortality which has occurred over a longer period may be due to prolonged drought, insect damage, grazing, etc. I cannot give a recommended timing for Tigray as I understand post-planting survival counts have not yet become a standard practice in plantations. A plantation where one seedling in five has died is said to have 20% mortality, 80% survival.

As a general guideline, at less than 3m spacing (1,100 trees/Ha or more), then a 20% mortality is considered acceptable and you would not bother blanking-up. The reason is that you still have enough trees on the site. However, if most of the mortalities are in particular areas rather than evenly distributed, then you may consider blanking up in those particularly bad areas.

If you have wider spacings than 3m then you have fewer trees planted on the site, which would be normal in Tigray. You therefore consider only a 10% mortality figure as acceptable. Any higher figure and you will have to blank up. Unfortunately, from a workshop I attended recently, there are some very high mortality rates in Tigrayan plantations, even up to 100%.

Blanking should only be done once; if plantation failure continues then a closer examination of species suitability, planting techniques, transportation, community participation etc. must be made. Plantation failures arise more from a failure to apply known techniques than from any technical impossibility.

2) How to Blank up

i) Planning and organisation;

Same as before, though obviously there may be fewer seedlings involved, fewer labourers etc., (although not necessarily) but still the need for good organisations and planning remains. For enrichment planting there is still only a short period of time when it is best to plant to maximise the benefit of the rainy season.

Blanking-up in dryland areas should usually be done in the following growing season after planting. You should not leave it longer as replacement seedlings will be at too great a competitive disadvantage.

Factors affecting seedling mortality

i) Planting skill (especially firmness of soil around roots and planting depth). More training, care and supervision will be required.
ii) Immediate post-planting weather- a long dry spell or very heavy, erosive rains)

CCRDA

iii) Condition of seedling- good root to shoot ratio, stressed during planting and transport. More training and care.
iv) Poor soils- waterlogging. Look at species suitability.
v) Insects- termites etc. Look at possible controls or species suitability
vi) Weed competition. See later
vii) Animal damage. Protection or improved community co-operation

ii) Site preparation;
a) Identification (delineation) of planting areas (they will tend to be scattered amongst existing vegetation), must be clarified and good supervision made during the planting to ensure that all the gaps are being filled.

b) Site clearance and digging will be the same as before, although greater emphasis may be in conserving the existing vegetation so care must be taken to avoid damage to existing trees. For blanking-up you will be able to re-excavate the same holes.

c) Spacing will entirely depend on the proximity to existing vegetation. A spacing of about 3-4m would be appropriate between the newly planted seedlings and between them and the existing vegetation. There will therefore be reliance on the digging team to use their common sense in plant spacing.

iii) Seedling selection;
There will be greater competitive stress upon seedlings used in blanking up or enrichment planting. They will be required to compete with established vegetation. Seedlings should therefore be healthy, robust and a little larger than average. You cannot use those seedlings left in the nursery which were rejected in the first planting. If fertiliser is available it would be best to use it on those seedlings used in enrichment or blanking up.

9.4. TENDING OF PLANTATIONS

PRUNING

In tropical countries there are two basic reasons for pruning;
1) To improve stem and wood quality in industrial crops.
2) In community/agroforestry plantations, for the harvesting of fodder, fuelwood, and possibly snag-free poles

1) Pruning for wood quality
The importance of pruning in industrial plantations is all related to timber quality. The principle is that stem timber with many branches will be laid down with knots. Knots are points of weakness in the wood and reduce its quality and value. Additionally they can cause problems with sawmilling equipment. Therefore by removing lower branches which are not needed for photosynthesis you can encourage the tree to lay down good quality wood over the knots to provide clean, high quality saw timber.

Species used for industrial timber plantations tend not to be branchy and the trees are spaced close together. Therefore when branches are removed by clean cutting

CCRDA

close to the stem the trees will tend to heal over rather than reshoot from the wound. As this practice is not really relevant to dryland forestry I will say no more about it.

2) Pruning for harvesting fodder and fuelwood

i) Which species

It is important to make sure that the species you are using responds well to pruning. If we are interested in producing fodder and fuelwood we want the tree to respond to pruning by putting out lots of new shoots from the stem in contrast to industrial plantations. This will depend partly on the species but also on the spacing of trees and the amount of light getting to the plant.

It is better to select species which are naturally branchy and possibly multi-stemmed rather than those which grow as single-stemmed, straight trees. Most common dryland species including Acacias, Balanites, Ziziphus and Albizzias fall into this category. Most of the exotics introduced here also respond well to pruning, especially those such as Leaceana and Sesbania which are grown for fodder production.

ii) Timing of pruning

Although I have not found much in the literature on this there are some general principles that can be applied. However, it would be interesting to discuss the timing of pruning with local people in this area. In general, if we wish to encourage bushy growth we should prune just before or at the beginning of the rainy season so that the trees have a whole growing season to put on new growth. However, if there is ground water available to the trees it may be possible to prune all year round. The fact is though, that if you prune in the dry season there will not be vigorous regrowth until the rains and you therefore lose some of the other benefits of trees such as shade, and wind-breaking during the dry season.

But I am sure you would get some interesting management tips from local farmers with regard to pruning all the different species, for different purposes in this area.

iii) The extent of pruning

If species are pruned too much, too often inevitably this will suppress growth and may kill the tree regardless of species. Each individual tree should be managed responsibly so that good health and vigour are maintained as well as the production of tree products.

iv) Techniques for pruning

If branches are pulled and snapped off rather than cut, they can leave large scars which allow in disease to infect the tree and also discourage re-shooting. Obviously people are limited by the availability of sharp tools for cutting branches cleanly however, within their limitations people should attempt to minimise tree damage, particularly bark stripping, during fuelwood harvesting. Ideally branches should be cut close to the stem but just laving enough collar to encourage the tree to heal the wound and resprout.

CCRDA

v) Community management

As most forestry here is social forestry and agroforestry the operation of pruning will be the responsibility of the communities. It is therefore essential to ensure that the community understand that they are responsible for the good maintenance and management of trees and that the long, healthy survival of trees will be to their advantage. Careless pruning will unnecessarily damage the tree and in some cases whole trees are unnecessarily harvested for their fuelwood. Research is required into the existing level of indigenous knowledge on tree harvesting and if people are not aware, training should be provided by extension staff.

THINNING

This is the operation that naturally reduces the number of trees growing in a stand. In a plantation (either for soil conservation or for industrial purposes such as timber production or pulpwood production), you may plant more trees than you eventually want or that the site can support when the trees are grown. You plant extras in case of seedling mortality, and to establish ground cover quickly etc. It is therefore commonly necessary to thin out some trees after a certain period so you do not have too many mature trees for the site to support.

Reasons for thinning;

1) To reduce the number of trees in a stand so that the remaining ones have more space for crown and root development.
2) For stand hygiene, to remove dead, dying diseased and other trees which could be a source of infection for other trees, and which encourage pests and diseases.
3) To remove trees of poor, crooked form (industrial plantations) so that all the growth resources are put into the best trees.
4) To provide an intermediate income from the financial sale of the thinnings.
5) To allow light through the canopy to encourage understorey growth for animal grazing.
6) To encourage natural regeneration and multi-aged stands.

No-thinning option

1) Thinning is expensive
2) When growing trees for pulpwood, fuelwood, poles and soil conservation, tree form is not so important so thinning is less important.
3) The site can be damaged during thinning so for soil conservation sites this may not be desirable.
4) Seedling mortality may have already been high and so you may not want to reduce stocking density any further

Thinning is not a common practice at this time in dryland Ethiopia but it is useful if you understand the basic principles.

Effects of thinning;

Thinning reduces the number of trees which are competing with each other for light, soil moisture and nutrients. This has a similar effect to widening the spacing of original planting operation. Lessening of competition has three main effects;

CCRDA

1) Lowers natural mortality. In an unthinned stand, trees may eventually start to die if competition is too great. This may be especially true in a drought year. It may be better to remove the less healthy, smaller, crooked or diseased trees to reduce competition so that more healthy trees will not die in extreme drought years.

2) Thinned stands let in more light so individual trees develop wider, deeper crowns rather than tall thin crowns and this may be better for fuelwood and fodder production.

3) Bigger canopies of individual trees mean that growth is faster because they have a bigger photosynthetic area, therefore a few faster growing trees are more likely to become well established than many, slower growing trees.

4) The most important effect of thinning in industrial plantations is greater diameter growth of the stem. This is the most important, valuable part of the tree in such plantations and there has been a lot of research on the effect on diameter increase of different frequencies and extents of thinning. But this is not so important in dryland forestry but if you want to read about it more see Evans Chapter 15.

Thinning techniques intensity and frequency

Techniques

i) Systematic; trees are thinned in lines, regardless of individual tree quality.
ii) Selective thinning; trees are selected for poor form, disease, size etc.

Intensity

A; Light thin (just dead, depressed, small trees)
B; Moderate thin (all the above plus some sub-dominants)
C; Heavy thin (all the above and all the sub-dominants)
D; Very heavy thin (all the above and even some of the dominants in order to get evenly spaced distribution of dominants)

Frequency

Thinning may be done once or may be done several times over the life of the plantation. Frequency and intensity are related. The decision for timing thinning is complex and again applies more to industrial plantations so if you want to read more about it see Chapter 15.

POLLARDING

Pollarding is a variation on coppicing and is probably the most common system used in dryland areas for the production of fuelwood and fodder and to avoid damage to new growth by browsing animals. Pollarding is not a different system from a selection system but is rather a technique suitable for dryland selection systems but also for dispersed trees on cropland or rangeland. Pollarding is a variation of coppicing, whereby the tree is cut well above ground level to harvest the branches and leaves and to stimulate the production of new shoots.

CCRDA

Rapid re-growth

Due to the fact that the trees have established root systems they can produce far more volume of wood in this way than could be produced by a rotation of growing trees, felling them and re-planting.

In addition to producing multiple stems for firewood the tree will produce one large central stem which can eventually be harvested for construction purposes or making tools. However, this will have to be replaced, usually this is done by protecting natural seedlings and allowing them to grow (most Acacias) or by selecting one or two coppice stems which regrow (such as Ziziphus spina-christi).

Advantages and disadvantages

Advantages

i) This is the most suitable system for fuelwood production in agrosylvopastoral systems. By cutting the trees well above ground level, the new shoots are out of reach of browsing animals. It is therefore a suitable system on areas where there is free grazing of animals which is most cropland, rangeland and even some area enclosures here in dryland Ethiopia.

ii) Unless the whole tree is harvested there is no cost involved after each cutting, the tree naturally regenerates.

iii) It is suitable for small scale production where individual farmers can manage the harvesting on a substance basis of providing fuelwood and fodder as and when it is needed.

iv) The system is compatible for growing crops and grasses as certain species interact and the crops can benefit from the soil conservation, shading and windbreak effects of trees, without competing with crops at ground level for space, water, nutrients.

Disadvantages

i) It is not a suitable method for commercial-scale timber production.

ii) It is not a suitable system for producing large diameter trees of high quality for timber.

iii) Certain species (Eucalyptus) are not suitable for planting in fields and on rangeland as they discourage the growth of an understorey crop.

COPPICING SYSTEM

Coppice system involves reproduction by stool shoots or suckers. When felled near the ground most deciduous species (up to a certain age) will send up shoots from the old stump (stool). Suckering involves putting up shoots from the root system surrounding the original tree rather than the stump. There is much variation between species as to how easily they coppice and whether they coppice indefinitely or whether they will stop coppicing after a certain age.

CORDA

Conifers

Generally, conifer species are less able to coppice, but there are exception, including Casuarina sp to some extent. But this is the reason that there is no widespread conifer production under the coppice system.

Stool age

With most species large stools tend not to coppice vigorously, so after a certain period of time (40 years or so-varies according to species) the stools are replaced

Cut Low

Coppice stems are cut low to the ground to encourage the new shoots to develop their own root systems, rather than relying on the original roots. It is also important that cutting is carried out with sharp tools to avoid tearing the bark from the wood as this will cause death and decay.

Products

Poles/ posts, fuelwood; medium sized roundwood, (suitable for pulp or chipboard) but not large timber.

Advantages and Disadvantages

Advantages

i) Reproduction from coppicing is easier and cheaper than re-production by seed, especially in dryland areas where seedling mortality is often high.

ii) In the early stages coppice re-growth is much quicker and poles produced may be much cleaner and straighter than those produced by seed.

iii) There is a short rotation length when compared with clear felling for timber production so returns on an investment are made sooner.

iv) You can produce large volumes of wood on a commercial basis from an area under coppice management which can justify the costs of investment in equipment and can generate employment locally.

v) The products produced are roundwood of various sizes which is valuable in Ethiopia for construction (poles and posts), and the side branches can be used for firewood.

Disadvantages

i) It is not a suitable system for producing large diameter trees for timber production.

ii) Coppice places a high demand on the site for moisture and nutrients due to its large number of vigorous young shoots.

iii) Coppice systems may not be suitable for many species in area enclosures. Coppicing may leave large gaps in the canopy which is bad for soil conservation and many indigenous dryland species do not coppice well. Further research should be recommended for those indigenous species which do coppice well.

iv) Coppicing is not compatible with animal grazing as the new young shoots will be browsed.

CCRDA

9.5. DISCUSION FORUM

Having the technical knowledge from the training

Discussion issues:

1. How will forest development contribute to food self-sufficiency

2. Forestry Development issues in Ethiopia in general and Tigray in particular
A report to JICA

3. The eucalyptus debate.

CCRDA

10. Cultivating Diversity: Conservation, Enhancement and Management of Crop Genetic Resources

INTRODUCTION

10.1. Africa and Climate Change

The climate of any place is the result of interactions between local, regional and much larger scale factors. Thus the climate of Africa can not be considered in isolation, and, some more general aspects of the mechanisms of climatic change will be considered in this case.

In many regions of the world agricultural production is currently limited by climate, most of these limitations being in developing countries. Insufficient rainfall is the main climatic limit in these areas which curtails the growing period available for crops. Africa has been described as a continent on the brink of disaster. The region has only 50% of the land area which is suited to rain-fed agriculture (Timberlake, 1985). It is characterized by the marginal agriculture and marginal farmer and the region may be most vulnerable both to short-term variations of weather and long-term changes of climate.

Desertification: is a world- wide phenomenon and does affect most ecosystems. However, the areas or ecosystems most susceptible to its threats are the arid, semi-arid and sub- humid climatic zones which lie along the fringes of the great deserts of the world, where the annual rainfall is between 200-600 mm and the ecology is largely based on crop and livestock farming activities. Ethiopia, as part of Africa, has a larger expanse of dryland, than Asia and Australia (Darkoh, 1989).

According to the executive director of UNEP (1984:12, quoted in Darkoh, 1989) "desertification is generally associated with impoverishment and reduction in vegetation coverage, involving an initial loss of biological productivity and exposing the soil surface to accelerated water and wind erosion.". This leads to a reduction in soil organic matter, deterioration in soil structure and soil hydrological properties, with crusting and compaction causing further loss in fertility and resulted in land degradation.

CCRDA

In this case, Africa is the continent most at risk. Some 6.9 million sq. km of sub-Saharan Africa - an area more than twice as big as India are under direct threat of desertification. Half of the world's people most menaced by desertification live in the Sahel. UNESCO (1977) mapped areas of Africa considered to be a particular risk. It is likely that around 6,000,000 ha y- becomes irrevocably unproductive and a further 21 million ha y-of potentially productive land of Africa becomes economically useless. (Temberlake, 1985).

Also, roughly 70% of Malagasy's forest has been cleared and replaced by Savannah grass land, 65% of which are at risk of desertification (Derbeg quoted in Barrow, 1991).

Soil Erosion: The immediate effect of clearing the forest accelerates soil erosion, which ravages the surface in a network of gullies and also greatly increase the sediment load of local streams, often choking them with bar formations. Soil erosion from land clearing and improper management in the developing world and in particular those of sub-tropics and tropics- reached massive proportions and is the subject of world wide attention.

In Africa the problem is very severe. It is a serious problem in several ecologically sensitive regions, the Caribbean, eastern Africa and other densely populated regions with severe land shortage. Brown (1981 quoted in Lal and stewart, 1992) observed that as much as a billion top soils are lost from the Ethiopian highlands each year and a total of 87% of the near east of Africa; north of the equator are subjected to accelerated erosion.

Drought: Drought is a recurrent feature of African climate. It is a water deficit that exists for a long enough period to cause hardship. It is defined differently under different circumstances. Almost by definition drought tends to be a recurring phenomenon. continual drought would cause a region to become arid.

A number of researchers have examined the recurrence of droughts for example for Africa. Much attention had focused on claims that the Sahalian sudanic zone of Africa has suffered more drought in the last 30 years because the pattern of precipitation has changed, becoming higher over the Mediterranean, and scarce south

CCRDA

of Sahara (Barrow, 1991) However precise estimates of the crop losses caused by droughts are impossible because of the difficulties in separating the impact of components such as management technology and climate. In spite of these difficulties, Africa, apart from the Sahelian countries, faces chronic food problems and wide fluctuations in production arising largely from the vagaries of the weather in recent years.

Impact on Land-use and Yield Potential: In Africa, reduced moisture availability results in decreased productive potential, marginal agriculture and decline in acreage under-use. Low crop yields and animal deaths are an indication of agricultural drought. In October 1984, based on FAO reports, five countries in Africa (Niger, Sudan, Ethiopia, Kenya and Mozambique) were experiencing severe food shortages, harvest failures in the early 1970s in the Sahel, caused innumerable deaths of livestock and people. The drought conditions in northern Ethiopia, notably Wollo region have caused crop failures and famines in that area.

According to Parry (1990) preliminary work has been completed in South Africa, indicating that an increase an annual mean of temperature of 2°C to 40°C in Natal province would increase rates of evapotranspiration by 5% to 15% and reduce biomass productivity by about the same amount.

Impacts on Plants and Animals: A shift in the geographic distribution of terrestrial biota is a long term response to climate change. Predictions of migration rates are very uncertain. It is impossible that many tree species will not be able to change their geographical distribution as fast as the projected shifts in suitable climate and extinction may occur.

There is no doubt that the Africa (Sahara) is biologically impoverished and expanding the impact on vegetation could be considerable if climate change is sudden. It is inevitable that **some wild species and crop varieties will be unable to withstand the** change. Most of the 20 species of large mammals fairly common at the beginning of this century have become rare or extinct in the past five decades. A number of rare tree and shrub species are also endangered. If the trend that has prevailed over the

CCRDA

past 50 years continues, all large mammals become extinct, not only in the Sahara, but also in the arid zones bordering it-Africa. (Lehouerou, 1992).

Besides, uncontrolled and excessive grazing is also responsible for depleting vegetation and denuding the landscape, causing shift climax vegetation, soil compaction and accelerated run off and erosion. " No where else are the adverse effects of uncontrolled and excessive grazing more severe and obvious than in the Sahel ." (Timberlake, 1985)

Pest Attack: World wide pre harvest losses to pests are currently estimated to be about 35% with about 12% lost to insects 12% to diseases, and 11% to weeds Drought and temperature increase may extend the geographic range of some insect pests, diseases and weeds allowing their expansion to new regions as they warm and become suitable habitats. Hence the average crop loss to pests for Africa corn, potato, rice and wheat 45% ranging from 37% for rice to 55% for potato (Pimental *et al.*, 1992).

Locust invasion has been recorded in Africa and the presence of tsetse fly has effectively denied large areas of sub-Saharan Africa in livestock production. In these areas, swarms of quela birds descend on crops from desert fringes and the parasitic witch weed, striga, with its pretty purple flowers, blooms among the millet and sorghum stems and sucks nutrients from their roots. Moreover, drought may debilitate a crop so that weeds become a problem, being more robust they better withstand drought. Such a 'down ward spiral' leading to desertification has been associated with striga - which in Africa and India can reduce grain crops by 90% especially, for millet or so on

10. 2. Origin of cultivated plants

Crop growing was based on extensive production in large fields and intensive production in small gardens. The practice of planting extensive areas in grains and forages gave rise to the specialized discipline of crop agriculture now called **agronomy. Horticulture** developed from the practice of cultivating intensively gardens that provided fruits, herbs and etc. **Forestry** developed from the protection of wild lands that produce timber. For agricultural research, especially plant breeding,

CCRDA

It is very valuable to know their place of origin, their centers of genetic diversity and their wild relatives. A number of regions especially rich in concentrations of different plants have been characterized as centers of diversity and are thought to coincide with the primary and secondary centers of origin of present day cultivated plants. Vavilov, a Russian geneticist, (1920) reported the following centre of origin:

1. China, 2 south Asia, 3. Central Asia, 4. Asia minor, 5. Mediterranean, 6, Abyssinica (Ethiopia), 7. Central America, 8. South America

The introduction of new species into new habitat has been one of the most important features in world agricultural development.

Table 1. The centers of world production and centre of production for selected world crops

	Production	origin
Cacao	Africa	Brazil
Coffee	Brazil	Ethiopia
Maize	Mid west US	Tropical America
Wheat	North America	Central Asia
Potato	Eastern Europe	Peru

Effective selection is dependent on the existence of genetic variability. Collections of Germplasm are available for most crop species and this can be used to increase the available genetic variability either by crossing them with the currently used Germplasm or by selecting within them for local conditions. It is clear that a much wider range of Germplasm is needed by breeders today, including not only standard cultivars and breeding lines related to them but also wild species and the primitive cultivars/Landraces that still exist under cultivation.

The five faces of Germplasm

Plant Germplasm important to agriculture fits into one of the following five categories.

a) wild relatives:

These plants are strictly the product of nature and can provide important genes to modern crop plants. Because they have stood exposed in nature, they usually

CCRDA

provide genes for hardiness, such as tolerance to heat, drought or flooding, saline or sandy soils, diseases and pests and so on. For example resistance for 25 diseases in modern tomato have been found in wild relatives and 15 of them have been breed into commercial varieties.

b) weedy relatives

This plants prosper in habitats disturbed by man. Weeds provide botanical bridges between wild relatives and crop plants across which important genes can pass. Weeds are hardy plant pioneers - **colonizers** that move into and adjust to human altered environments- **genetic opportunists**, we might say.

c) Primitive cultivars/Landraces:

Cultivar is short for "cultivated variety" so primitive cultivars are crop plants developed in primitive agricultural systems. Landraces are plants that have evolved over long periods of time, through both human and natural selection. Wherever they were planted, over time Landraces adapted to whatever environmental and human influences confronted to them. As a result, primitive cultivars-while not as diverse as wild relatives- contain tremendous genetic diversity that, because they are more closely related to highly inbred modern cultivars, can be more easily tapped by plant breeders and bio-technologist.

d) Advanced or modern cultivars

These cultivated varieties do not or cannot be produced strictly by natural selection; they are the products of modern plant breeding and /or molecular techniques.

e) Advanced breeding lines

Plant breeders have developed these plants under controlled conditions and use them to create the modern cultivars and hybrids grown by farmers world wide. this Germplasm has been so manipulated that even nature probably wouldn't recognize it. Increasingly, advanced breeding lines will contain genes and sets of genes that molecular biologists have altered in place or transferred in from another source. Germplasm from advanced breeding lines is often called elite, which means it is what everybody's after and is costly to produce. Conserving these sources is therefore crucial to the future of crops. Our existing system of genetic resource conservation and use, however, may need to be redirected inorder to maintain their diversity

CCRDA

10.3. *Biodiversity/Genetic erosion*

What is biodiversity?

10.3.1 . **Biodiversity** can be broadly defined as the full range of variety and variability within and among living organisms and the ecological complexes in which they exist. Biodiversity as a resource is an essential raw material for the welfare of man and the environment. This is because society is dependent upon biological resources for food, medicine, energy, shelter, recreation and other useful products. Biological resources, however, need proper conservation, sustainable development and rational use to avoid loss of biodiversity through genetic erosion and environmental degradation.

10.3.2. **Genetic diversity** refers to the variation of genes within species or allele frequency differences within and between population. Each species in an environment has a characteristic genetic diversity. The pool of genetic diversity within a species forms an adaptation to its present environment and a store of adaptive options for possible changes in the environment. The loss of genetic diversity results in the reduction of variability and contributes to the extinction of species by reducing its ability to adapt to changing environmental conditions thus depriving society useful non-renewable resources. Conceptually, species is regarded as a population or series of populations within which free gene flow occurs under natural conditions.

10.3.3. **Genetic erosion:** is loss of genetic diversity. At present the loss of biodiversity is both Global and National concern. The formal system for plant improvement and conservation of genetic resources can undertake actions to support traditional agriculture in marginal areas and thus arrest the genetic erosion. The continued and successful use of Landraces will limit genetic erosion, but this can only be an ethical and viable strategy if it is linked to the social and economic development of the poor farming communities that continue to use them. Improving the social and economic value of traditional cultivars through Germplasm enhancement and improvement is a promising development that decentralized

CCRDA

breeding approaches provide. Decentralized here refers to the efforts of formal breeders to work with farmers in the improvement of their genetic resources within their diverse environments and social conditions.

The change in food habits also has its ow contribution for the extinction of some traditional crops. In Uganda is now a net importer of rice due to food habit change to rice.The food habit of Egypt is also changed from sorghu and maize to wheat through subsidised food distribution and food aids.Therefore there is a need of keeping the diversity of food habits of any populatio, since each has its own advantages. In TanZania, an encouragin policy of subsidising millet is pursued as a means of self sufficiecy at village level (Seyfu, 1993).

The loss of genetic diversity under Ethiopian condition can be caused by several factors. Some of them are as follows:

Cause 1. High human or animal population and resource consumption: whenever the population growth and consumption exceed the sustainable ecological carrying capacity, the result is genetic erosion through shifting cultivation, forest fire and thus over-exploitation of resources.

Mechanism: The growth in human or animal population and increased consumption result in the loss of habitats and genetic erosion through fragmentation, forest fire and shifting cultivation expansion and thus over-exploitation of resources. The degraded condition of Ethiopian highlands can be a good example. Particularly the accelerated rates of deforestation, habitat destruction and land degradation in Ethiopia are alarming. As a result, several indigenous forest species and other plants are seriously threatened to become extinct.

Cause 2. Introduction and use of narrow spectrum of plant varieties: The introduction of exotic Germplasm and the displacement of the more heterogeneous indigenous Landraces by genetically uniform varieties cause the loss of useful local Landraces. In forest trees, aggressive exotic forest species, if given emphasis, could expand fast at the expense of indigenous species.

Mechanism: farmers shift to newly introduced more uniform and high yielding varieties abandoning their heterogeneous Landraces. Introduced species/varieties also

CCRDA

threaten the indigenous material through competition creating conducive conditions for new pests and diseases resulting in epidemics.

Cause 3. Economic system and resource ownership: an economic system leading to under evaluation and overuse of natural resources and inequity in resource ownership discourage conservation-oriented land other resource management practices resulting in loss of local plant genetic resources. This situation is aggravated by poverty.

Mechanism: over-exploitation of plan resources of immediate benefits without any management options for conservation and sustainable use is one of the mechanisms contributing toward the loss natural resources

Cause 4. Lack of proper resource conservation, research and development, and other conservation related policies and inadequate public awareness.

Mechanism: Lack of proper national development policy guidance or the implementation of counterproductive policies and approaches in agricultural research and development, and other sectors have serious negative impacts on resources conservation and sustainable management.

Cause 5. Drought and other natural calamities

Mechanism: recurring drought and other calamities resulting in famine and disruption of rural communities cause the loss of genetic resources. Severe drought conditions results in the destruction of genetic resources and farming systems. For example the consumption by farmers of their landrace seed stocks and the introduction of grain/seed through famine relief activities accelerate the process of genetic erosion.

Cause 6. War:

Mechanism: in Ethiopia there had been a number of historical events in which religious wars or regional conflicts had contributed to the destruction of forests, agricultural and social systems.

10.4. Crop genetic resources of Ethiopia

Plant germplasm is the base for productive agriculture. The loss of genetic diversity results in rduction of variability and contributes to the extinction of species by reducing its ability to adapt to chaging environmental conditions.The coutry has a wealth of morphogeic diversity in crop species probably due to: a) its highly dissected highlands ad b) the heterogeneous evironmental conditions which vary over

CCRDA

small distances ad, c) a very diverse cultural history of the people which provided thousands of years of artifical selection.

Vavilov's discovery made the world community of plant reeders awre of Ethiopia's genetic tresures. The significace of Ethiopia as a source of importat plant diversity is evideced by flow of germplasm in and out of the country since historical times. Earlier, Egyptians, the Arabs, and the Indians exchaged plant materials with Ethiopia. Later, since the early days of the European voyages of discovery, the Portuguese, Italians, Germans, Russians ad others greatly benefited from the Ethiopian diverse plant germplasm. Through germplasm exchange Ethiopian genetic resources are n ow included in most major gene banks of the world. The fact that Ethiopia is an important primary and secondary genetic center of several cultivted species makes it a useful source of germplasm of several traits in general and genes for resistace to diseases and pests in particular. A single Ethiopian barley plant happened to have the one gene that now protects California's $160 million annual barley crop from yellow dwarf virus (Witt, 1985).

CGRDA

10.4.1. Management of genetic resources

Management of genetic resources has achieved broad recognition since it is a crucial factor for all development and environmental protection. In this regard the 1992 Rio Earth Summit conference and the adoption of the global convention on bio-diversity can be seen as a landmark in the global struggle to conserve the biological feature of the earth. However the attention given to safeguard the genetic heritage of the world is very limited.

It is believed that a large part of the biological diversity has already been endagered mostly as the consequence of the introduction of genetically uniform varieties. The industrialised countries lost the largest proportion of their crop diversity before the second world war. What remains in developing countries is being eroded at a faster rate than what it was before. Many of the traditional crop varieties have been displaced and are still displaced by varieties developed from commercial breeding companies.

Ethiopian farmers have created and maintained local landraces of different crops which are adopted the agro-climatic conditions and meet the needs of their families and their farming system. Some of these land race have been eroded due to the high frequency of drought and war. Currently the introduction of genetically uniform improved varieties which are the most contributing factor towards genetic erosion in most countries are threatening the very existence of these landraces.

The loss of landrace undermine the very sense of sustainable development in the countryg as it limits the farmers option in selecting varieties and reduces the genetic variability that would be used for future crop improvement programme. Particularly at time where the country is dealing with climatic changes, loosing any more the existing bio-diversity is an erosion of option for development. Thus there should be an integrated effort to safeguard the existing crop genetic diversity.

Many of the improved crops that are currently grown commercially are the result of the genetic fusion from the land races. It is the farmers of the Southern regions who provide the genetic material for the breeding industries of the north whose capital are worth in billion dollars. For instance, the breeding industries of America, whose capitals are estimated to be 17 billion dollars, are dependent on the genetic sources that they have collected from countries, like Ethiopia.

CCRDA

10.4.2 CONSERVATION STRATEGIES

Conservation of plant diversity can be achieved in a number of complementary ways: conservation of whole plants in their native ecosystems or conservation of samples of a plant's genetic diversity of endangered species. Frequently one method acts as a back-up to another, and the degree of emphasis placed on a particular method depends on a specific strategy developed to fulfill conservation aims and uses.

10.4.2..1. Ex Situ Conservation

Farming communities everywhere in the world have adapted local crops and plants to their needs. But it has been in the tropical and subtropical belts of the planet where

Technical questions: Many samples in gene-banks are easy-to-access from-the road collections and do not represent the full spectrum of what farmers developed. The long-term security of gene banks for conservation is questioned. Problems with power supply and consequent temperature fluctuations, seed desiccation, and poor regeneration are frequent. NGO have suggested that genetic erosion in the gene banks may be as it is in the field.

High tech, high problems:

A lot of materials conserved in the gene banks is quickly losing its viability and there is a lot of uncoordinated duplication. Some countries have expensive excess storage space and find it hard to keep up with the growing maintenance costs, while other countries lack proper long term facilities. The FAO (1996) report points out with concern that one of the major gene banks in the world--- the Vavilov Institute (VIR) in Russia, which holds the world's third largest wheat collection and important collections of other crops (including barley, rice and corn, cotton, lentil and sugar beet)--- does not meet these criteria. The VIR has only medium term storage facilities. The need for frequent regeneration is a strong threat to the diversity in its accessions.

In their reports countries noted gene bank problems among them

- **Equipment problems,** particularly in cooling units (reported by a number of African countries, Vietnam and Romania), lack of seed cleaning and humidity control equipment.
- **Irregularities in the supply of electricity**)reported by a number of African countries, Cuba, Bangladesh, Iraq and turkey).
- **Difficulties in the seed drying,** especially in the humid regions of Africa Asia and Latin America.
- **The security of the system:**

One of the main problems gene banks around the world are facing is regeneration. In order to stay alive, seeds stored in gene banks need to be grown out and harvested, regenerated once in while. The frequency of these regeneration depends on the type of crop. If the gene bank had to regenerate its collection once every ten years, one would expect routine regeneration needs to be 10 % annually. However, according

CCRDA

to FAO conclusion, Almost half of all stored seeds world wide now need to be regenerated. Some of these "may already have lost their viability or genetic integrity, or they may be from populations where re-collecting may prove more cost-effective than regeneration. However for some of them re-collection may be impossible, because of extinction in the field.

What is being conserved:

Figure 1 shows the representation of cops in gene banks. The high proportion of cereals (48 %) reflects not only their key role in global food security, but also to Northern agriculture and international agricultural trade.

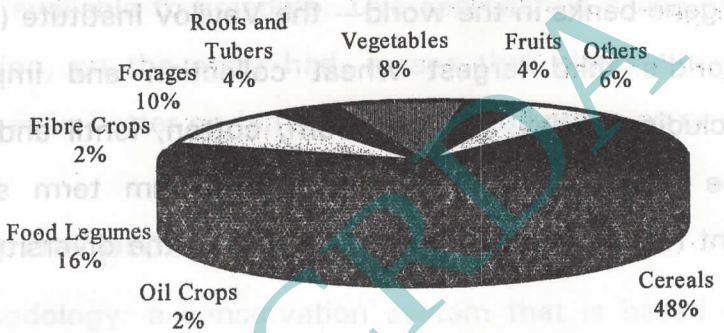


Figure 1. Major crop groups in Exsitu Collections (FAO, 1996)

Incontrast, tubers and root, which include important crops for subsistence farmers like sweet potato, Potato, and cassava only accounts for 4 % of global accession. FAO (1996) admits that there are very few accessions of medicinal plants. The information on the type of accession (whether wild relatives, local varieties or breeding lines) is only available for one third of global accessions. globally, 48 % of accessions are advanced cultivars or breeding line, 36 % are old cultivars or farmers' varieties and only 15 % are wild or weedy plants or crop relatives.

Towards a useful gene bank system

There is no doubt that ex situ conservation is needed and that, if the existing collection are to be saved, an improvement of the security conditions and the

CCRDA

efficiency in the management of genebanks is needed, especially since a large part of the diversity they contain no longer exists in the field. However, the unavoidable erosion of genetic diversity in the genebanks in the long term questions the appropriateness of this technology as a primary conservation tool for agricultural biodiversity. Diversity originated as the result of continuos interaction of plants, animals, environmental conditions and human selection. Storage of seeds away from the fields and forests breaks this critical cycle.

10.4.2..2. In Situ Conservation

Insitu conservation refers to the conservation of plants spp. in their natural habitat. This conservation strategy may be particularly important in areas under traditional farming, where crops are often enriched by gene exchange with wld or weedy relatives (Harlan, 1965). On the other side Security could be low if there is no controlled monitoring system. A conservation system that leaves aside farmers, peasants, pastoralists and their knowledge and expropriates their materials---making them available as raw materials to breeders and bio-technologists that may claim intellectual property rights over their creations' is double perverse. Not only do farmers lose control over their heritage -- the seeds -- but they also loose the possibility of continuing with their sustainable and highly productive agricultural practices which build upon diversity. Ex Situ conservation by its own cannot ensure the conservation of precious plat genetic resources for future generations.

10.4.2..3. Conservation at local farmer/community level

Increasingly, the conservation management of plant genetic resources at the local farmer should be linked with development action, this strategy has been recognized as the third conservation strategy, complementing with Insitu and exsitu strategy. The primary conservation effort has to focus on farmers and their fields. It should go hand in hand with actually making use of that diversity in the complex agro-ecosystems that many of these farmers manage.

CCRDA

10.5. TRADITIONAL FARMING SYSTEMS AND GENETIC DIVERSITY

Small farmers in marginal areas live with great variability in their environment, they lack making maximum use of micro environments and niches, combining crop agriculture with gathering, wage labor, animal labor, the economic and institutional resources to transform their environments to suit the requirements of modern cultivars. Their strategies rely on diversity at all levels; cropping in mixed stands, making maximum use of micro-environments or niches, combining crop agriculture with gathering, wage labor, animal husbandry are production strategies of resource poor farmers.

There are now substantial data and evidence that farmers maintain and select among their Landraces and that this can be considered traditional breeding or management of diversity. Farmers have two particularly important components of farmer strategies for maintaining and managing the variation.

1. The agro-morphological diversity which is largely in response to use and preferences, e.g. colors, flavors, plant architecture, and crop types.
2. The diversity interms of a crop's adaptive characteristics. examples are adaptation to micro-environments, environmental stress, or biological such as pests. In genetic terms, this adaptation is often not based on single characters but multi-locus hazards with complex inheritance or Co-adapted gene complexes.

Trying to breed elite varieties that fit these competing objectives and micro-environments is impossible for formal breeders to achieve. these, however, are the characteristics that resource poor farmers want and which fits their particular environments. Not surprisingly, most traditional Landraces fit all these holistic criteria of hardiness, multipurpose and cultural preferences.

10.6. Farmers contribution to maintaining genetic diversity in crops, and its role within the total genetic resources system

The total genetic diversity in a crop genepool is the result of:

-Natural processes unaided by humans (wild relatives of crops)

-Crop evolution, selection and adaptation in farming systems in highly variable and often marginal environments

CGRDA

formal breeding to create new genetic combinations according to predetermined criteria.

Another important feature of genetic diversity within traditional farming systems is that it allows for gene flow between crops and their wild relatives. One way of conceptualizing the gene flow within a crop genepool is as a plant genetic resources system with interactions and flows between the three sources of genetic variation. Each of these sources of diversity- wild relatives, landrace and formal breeding-is characterized by the increasing degree of human control over the process of exchange of genes, and the reduction of complex environmental factors in the selection process.

CCRDA

10.6.1. Support for traditional farming systems and the maintenance of genetic diversity

We need to conserve not only the genes themselves but also the farming systems and agro-ecosystems that produce and maintain genetic diversity. In this way they can continue to use and develop genetic diversity in crops as an integral part of their own social and economic development. Cases where new and interesting germplasm and diversity is fed back into traditional farming systems are far too rare. The Ethiopian Plant Genetic Resource, currently Biodiversity Center, provides farmers with elite germplasm to further their experimentation and develop initiatives. The project supports an On-farm landrace conservation and enhancement in Shewa, Wello and Tigray. In 1991/92 crop season, landrace seeds of sorghum chickpea, lentil, faba bean, field pea, linseed and maize were distributed to 512 farmers. Farmers are encouraged to plant samples of original stock alongside the selected material for the purpose of comparison and conservation. The current unidirectional flow of genetic resources into formal and centralized breeding of elite varieties with high yields and specific resistance offers little that is useful to small-scale farmers who are engaged in maximing genetic diversity, that is in this way made available to farmers may be considerably less than what was already available in their traditional varieties. Thus for poorer farmers on marginal lands, it reduces their options to cope with variable environmental conditions and to exploit niches and micro-environments in their farming systems.

CCRDA

10.6.2. Bringing farmers into the genetic resources conservation systems

The formal gene bank subsystem cannot hope to maintain all the variation present in traditional cultivars. specifically, a gene bank is not the most effective way of maintaining specific adaptive gene complexes, i.e. the particular combination of characteristics that constitutes adaptation, for use in individual farming systems. It will have to make genetic resources available to farmers as inputs into their own selection and breeding system. genebanks are the principal and most efficient way to conserve genetic resources for use in formal breeding programs. The third source of

genetic variation, the traditional farming system, is seldom included as part of the total system of conservation of agricultural biodiversity. On-farm development and enrichment of crop genetic resources is an appropriate way to support those farming systems which continue to create, maintain and use genetic diversity.

One way to enrich crop genetic resources for low-input farming systems is to provide farmers with more genetic diversity in the form of landrace germplasm from a wider range of sources. This germplasm will have gene through the research, characterization, and evaluation process in a national or regional ,

How farmers use cultivar diversity

Breeding programmes have rarely exploited small farmers' sophisticated knowledge of differences among cultivars, and their use of these differences in cropping strategies. Cultivators classify varieties, and value particular characteristics, for different purposes. They often manage a combination of cultivars in the production process, and multiply or eliminate varieties as they evaluate their performance over time. Farmers themselves are expert experimenters with new plant materials. When testing promising new plant genotypes, scientists can improve the relevance of their research by drawing upon farmers' own informal methods of experimenting with unfamiliar cultivars and practices.

The human population expanded as traditional agricultural societies learned to domesticate animals, select crop varieties, manage weeds and insects, and enhance nutrient recycling. Both ecosystems and social systems were modified to sustain improved agricultural technologies. The transformations occurred through experimentation, fortuitous mistakes, and natural selection. Farmers are less likely than scientific breeders to seek single best cultivar for any given crop. Instead, an accepted new cultivar joins other valued genotypes of the same crop in a farmer's fields. Mixed stands (of cultivars as well as species) are conventional.

CCRDA

10.7. THE DILEMMA OF "GLOBAL 2000" AND LANDRACE CONSERVATION

Many research organizations have undertaken on-farm research projects because the system for generating and transferring technologies has not met the needs of certain target groups. Finally analysis of the results leads to the development of information or recommendation passed to the farmers and led to development of Training and Visit (T & V), Farming System Research (FSR) and other approaches.

The rapid dissemination of green revolution technologies in the third world during the 1970s was widely due to the so-called "training and visit" extension system. This approach seemed to offer considerable improvements over traditional extension methods. But follow up studies indicated T & V was much better at channeling extension to large and middle-sized growers than reaching small-scale farmers. It was also too narrowly focused on involving just "contact farmer" not the wider community, and the type of farmer participation. T & V encouraged was unidirectional-from the top down ward. This result showed that a single contact farmer, especially a big farmer, can not represent the poor.(Oakley, 1994).

10.7.1. The contours and costs of erosion: the Indian case

The last few decades have seen dramatic changes in Indian agriculture. With the advent of the Green Revolution in the mid-1960s, a handful laboratory generated varieties have been promoted over vast areas. Given certain inputs such as irrigation and chemical fertilizers and pesticides, these varieties produce high yields. For farmers, it is understandable who can afford such inputs, or who are offered related bank loans. Intercropping is replaced by monocropping a wide diversity of species is replaced by a handful of profitable ones, and the great genetic diversity within the same crop species is replaced by a narrow genetic range of financially lucrative varieties. Some localized studies exist on the loss of traditional varieties. For example in east Indian state of Andrea Paradesh and estimated 95 % of the rice varieties have been lost. In northeast several India, several varieties of sugarcane have given way to a single hybrid variety. Thousands of varieties of rice, cotton, minor millets, pulses and other crops are no longer in use (Ashish, 1995).

CCRDA

10.7.2. The Sasakawa Global 2000 (SG-2000) extension model in Ethiopia

In Ethiopia, the SG 2000 extension model has been started in 1993. The main objective of this programme is to enocurage the farmers to apply the recommended inputs and increase the productivity of the field crops per unit area. In Tigray, this extension approach started in 1994 at three woredas of western zone with the involvement of 60 farmers. According to the regional extension team (1995) report, a respective average yields of 16.6 qt/her, 29 qt/ha and 5.4 qt/ha were obtained for wheat, maize and sorghum. However, this yield increment is obtained in woredas of adequate rainfall (minimum of 600 mm). In 1995, the number of farmers increased, so that around 4000 farmers in 34 woredas took place.

There could be a risk of loosing most of the precious local varieties, particularly in multi stressed areas, where the rainfall is erratic and unstable. The recently introduced extension packages like Global 2000 have already started to introduce improved varieties and inputs. No one argues, however, on the importance of encouraging food security through enhancement and development of local varieties. Therefore, this has to be critically studied for not facing a dilemma, (i.e. a dilemma of complete replacement of Landraces by single variety, which will no longer suitable for erratic and unpredictable areas). The importance of the Landraces for future crop production should be appreciated and great care should be taken not to loose any more.

10.8. Participatory research

The current interest in farmer participation is related, in large part, to the conduct of farming system research—an approach to adaptive research that has had considerable influence over the past decade (Simmonds, 1986). Although the idea of farmers participation has always been a part of FSR, it has only recently come to the fore in description of research methods and in proposals for insisting reorienting agricultural research. FSR reliant on conventional natural and scientific research methods. FSR remains largely intensive to farmers knowledge, and the flow of

CCRDA

knowledge is generally in the researcher-back researcher flow. It is usually conducted in a top-down fashion, supported by various formal diagnostic and experimental techniques considering the farmer as consultative. As a result FSR regard farmers as recipients of new technologies rather than as partners and initiators in the breeding programme. Hence it fails to capture the real priorities and interests of farmers and the research carried out, denied attention to the majority of resource-poor farmers. Recognition of ITK led to focus on the farmer as innovator and experimenter and more interest in collaborative relations between research and farmers. Conventional on-farm research is, largely designed and managed by external researchers, was thus transformed in to farmers participatory research, where farmers become the central actors in the research and experimentation process. To understand their needs and provide technology and information suited to their resources there must be a mechanism that allows the extension service and small farmers to interact. Participatory research, then, can became a two-way flow that both takes scientists to farmers fields and brings farmers to the scientists fields.

In practice, what is meant by participation covers a wide spectrum, ranging from the most narrow, to the most broadly active people's interpretation. According to Oakley (1994) participation includes as collaboration, targeting, organization and empowering. Participatory research approach attempts to understand different farmer's local knowledge but remain essentially extractive, the researcher is equally in a dominant position, for example farming system research extension (FSR/E) (Cornwall, et al., 1994), Rapid Rural Appraisal (RRA) Khon Kaen University, 1987) and many conventional anthropological studies. By contrast, participatory research may focus on empowerment, either through consultation, activism and confrontation (e.g. the participatory action research or (PAR) (Cornwell, et al., 1994) or Theater for development traditions or through facilitating and catalyzing local-level learning, analysis and action. The fundamental difference a "farmers first " approach and "technology transfer" (Oakely 1994) is outlined in Table 1.

CCRDA

Table 1. The "technology transfer" and "farmers first" approaches

Indicator	"Technology transfer"	"Farmers first"
Main objective	Transfer technology	Empower farmers
Analysis of needs priorities by	Outsiders	Framers assisted by outsiders
Transferred by outsiders to farmers	precepts Messages Package of practices	Principles Methods basket and experiment
Outsiders' desired outcome emphasis	Wide spread adoption of technology adaptability	Wider choices for farmers Farmers' enhanced
Main mode of extension	Agent-to-farmer	Farmer-to-farmer
Roles of extension agent	Teacher	Facilitator
	Trainer	Searcher for and provider of choice

* Source: Oakely (1994)

10.8.1. Impact of farmers participatory research on Biodiversity

Biodiversity in crops is very difficult to define and a number of simplifications are assumed in the following discussions. It is assumed that if one cultivar partially replaces another or, several cultivars replace one cultivar there is an increase in biodiversity. However the degree of increase will vary depending on the genetic dissimilarities among a range of cultivars that are adopted, or the genetic dissimilarity between an existing cultivar and one that partially replaces it. More over biodiversity is not only a function the total number of cultivars. Biodiversity can be over both space and time. When one cultivar totally replaces another there is an increase in biodiversity over time. There is also a temporary increase in bio-diverstiy over space until the replacement is complete because while the replacement is occurring there are two cultivars in farmers fields instead of one. The vulnerability of a crop to a disease is reduced when there are many field-to field differences than when there are few. This strategy of field to field variability has been recommended by Priestly and

CCRDA

Bayles (1980, 1982). However, regional variation in cultivar diversity is also suggested as useful in disease control by Frey et al., 1977.

Participatory Varietal Selection (PVS)

When farmers are exposed to the" basket of choices" if a range of new cultivars in a participatory selection programme the outcome in a specific region may be an increase or a reduction in biodiversity. The situation is complex and changes in biodiversity depend on:-existing variability in farmer's fields

-The variability in the new cultivars offered to farmers and their acceptability

-The variability in the target environment (both physical and socioeconomic).

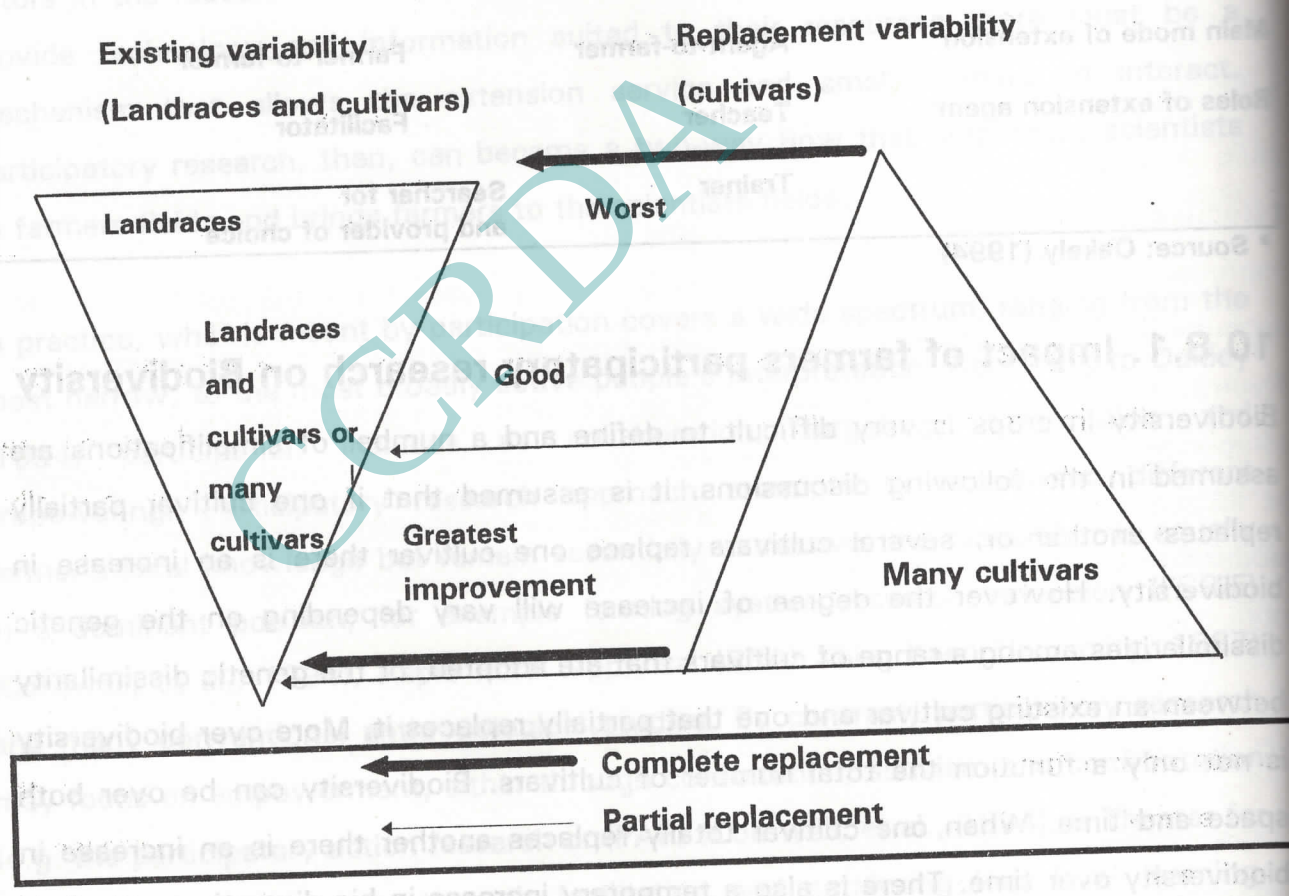


Figure 1. The infinite possibilities of replacement of existing variability with new genetic material (Witcombe and Joshi, 1995).

-Often the most important variable will be the range of diversity that farmers can b offered in the "basket of choices". the more variability in the basket for quality traits

CCRDA

and the better the adaptation of the cultivars to the local environments, the more likely that several cultivars will be adopted.

The greater the physical diversity in the environment the more likely it is that more than one cultivar will be adopted by farmers. Diversity of economic use will also make it more likely that several cultivars are found acceptable and are adopted. High yielding cultivars with poor quality

10.8.2. Farmers participation and its role in plant breeding

The collaboration or/and participation of local people, the contribution of their resources, knowledge and skills are essential to plant breeding. Farmers` own preference may vary according to characteristics such as farm size, rainfall patterns, family structure, gender, wealth, and market opportunities.

Indigenous knowledge: valuable resource

Indigenous knowledge is the systematic body of knowledge acquired by local people through the accumulation of valuable experiences, informal experiments and intimate understanding of the environment in a given culture. The basis for decision making indigenous knowledge systems are adaptive skills of local people, usually derived from many years of experience, that have often been communicated through "oral traditions" and learned through family members and generations.

Indigenous knowledge is valuable resource that includes practical concepts that can be used to facilitate communication among people coming from different backgrounds such as researchers and extension workers. It is cost-effective since it builds on local development efforts enhancing society capacity building. Recent studies recognize that the active roles of rural people in problem definition and in the search for their solution through local experimentation and innovation.

Traditional taxonomy: In one study indigenous soil taxonomic recorded in four eco-zones of Nigeria have clearly provided the basis for basic communication with the farmers and a beginning point for understanding how their indigenous Knowledge

CCRDA

systems influences their agricultural decision making. The degree of Botswana locally soil classification corresponds between local soil analysis with those obtained by laboratory analysis was fairly high (Mayphyne, 1996, personal communication).

Nomenclature for their plants may be well developed. Their naming indicates the parallelism with that of botanical classification. For example, in Ethiopia the naming for barley is related with its Karyoposis type—"Senef Netch Gebse" indicates the variety's weak straw and its white in color. "Arkibi", for maize variety meaning "coming up" to indicate its earliness and "shokerae" for variety sorghum meaning "Sugary/tasty" for its high lysine content. Therefore exploring such untouched resources, through participatory approach, is low cost basis for a breeder to understand the potential and/or drawback of crop varieties dealing with.

Genetic conservation and selection of cultivars: The history of crop domestication is essentially the application of farmers selection techniques to the genetic diversity presented in their fields. Farmers are capable of maintaining a large number of varieties of a crop and can select varieties with desirable characteristics

Several indigenous varieties of crops are being cultivated by farmers. Farmers exercise care and select uniform ears and preserve as seed for next season. They select the best heads, cut , dry and store them separately in long strawed bundles. The practice has helped the farmer to carry forward varieties which he feels superior.

Varietal characteristics and farmers behaviour

Several characteristics besides superior grain yield are often thought to influence farmers to plant new varieties : straw yields tasting and baking qualities, and resistance to moisture stress. However, breeding programmes have rarely exploited small farmers` sophisticated knowledge of differences, cultivars, and their uses of these differences in breeding strategies.To see if particular varietal characteristics had induced farmers to adopt new varieties, some measures of varietal characteristics should be examined along with evidence and participating of farmers` behaviour regarding each characteristics.

CCRDA

Local maturity class/ cultivar ratings: farmers rate their cultivars depending on their maturity, dormancy period (The latter for Horticulture) water content, cooking time, storability, disease insect pest resistance, market acceptability, response to moisture stress, and suitability for inter-crop. scientists failure to identify locally appropriate maturity classes before attempting to maximize yield and biomass can increase the gap between on and off station fields. This occurs , for example, when breeders have not recognized the advantage of short duration cultivars in the context of resource limitations It is also important to understand the local constraints on maturity periods and then to select for high yields within locally appropriate maturity classes. Because if land is scarce, for example, adoption of a longer maturing cultivar may mean, unaffordable delay in the planting of others essential food staple on the same plot. In this case farmers mostly used to plant chickpea, lathyrus etc., on residual moisture after removing of the short cycled cereal crops.

If farmers have to replant because of early drought, or delay planting because of late onset of the rains, they switch to shorter cycle cultivars. Farmers in Burundi rejected a new late-maturing high yielding maize variety although it yielded 20-40 % more than cultivars previously grown (Haugerud and Collinson, 1990), because they have to wait six weeks longer to harvest it, so that a new variety did not permit a good second pea crop.

Economic value: the relative economic value of a given crop may also affect farmers choice of cultivars. Breeders need to determine the appropriate index (ratio of stover to grain) in the context of local production priorities. Where pressures in dry season feed are increasing, the market for fodder increases, the market for fodder expands and the crop's stover quality and quantity become increasingly important criteria in farmers cultivar choice. In the eastern part of Ethiopia and Somalia, there is a market for maize and sorghum stalks that have been cut and dried. So farmers select a variety with larger plant stature to provide more biomass fir stalk feeding if dairy cattle, and as a major cash source for many households. This farmers` interest led to proposals for two adaptive experimental programmes-to increase plant density needed to increase fodder production without sacrificing grain yields and the second

CCRDA

is to examine the effect of defoliation of alternate times of picking the leaves and tops of maize or sorghum when green.

Examining such gaps through farmers participation results in cost effective use of scientists time in building up compatible varieties with farmers preference, matching it with the characteristics of farmers varieties and then allowing farmers to make solutions under their conditions.

10.8.2.1. EXPERIMENTATION

on-station

Involving "research minded " farmers while conducting on-station research is essential and at the same time challenging. During the interactive process scientist at research station should be conduct research by building on recorded indigenous technical knowledge systems. For instance farmers of sorghum, in Kenya faced problems of striga (parasitic weed) resulted on the failure of the crop and the spreading of the weed seeds across, their fields.

The research station scientists could conduct on station research experiments with an objective to screen or evaluate the performance of various sorghum accessions could provide the basis for farmer oriented on-farm research for its validation under farmers field condition.

In experimenting with methods, in Tigray, some small farmers were invited to join scientists on research station in the seasonal selection of accessions (Germplasm screening programme). The entire research team (pathologist, entomologist, agronomist, breeder, anthropologist etc.). were present to select genotypes to keep for further studies and multiplication. Besides, farmers were invited to make their own selections from the station fields and to explain reasoning. At this time, researchers found that, they had previously assumed to narrow a range of local acceptability in traits such as high straw value for linseed and seed color for teff. While researchers favored, for years, short strawed and high grain filling capacity varieties, farmers preference was towards high strawed variety to be acceptable for

CCRDA

its feed value, especially for camels. The only variety farmers strongly rejected was the variety which was believed to be susceptible to orobanche (Parasitic weed).

In other words, scientists were more conservative than farmers and their misconception may led to unnecessary rejection of some potentially useful materials. Hence formal farm survey of existing varieties and preferences through involvement of farmers confirmed this findings. Therefore incorporating farmers in to on station germplasm screening can produce useful information at little cost.

On-farm research: Farmer oriented research

On farm research: Two types of on-farm research has been described by Oakely (1994) experimental on- farm and Developmental on farm . According to him the latter have also been identified and described most present research institutions have made efforts to undertake farm research but have failed because of professional attitude and lack of sustained experimentation in facilitation at the local level. Also a clear understanding should be made between on-farm trial and on-farm research, since the former, frequently used, is unlikely to incorporate the full range of farmers management practices and constraints. They are therefore better regarded as sub-location of the experimental station. Therefore, trials designed to address specific problems faced by farmers, farmer/researcher interaction should be designed to broaden the range of options at the farmer' disposal and to speed up the rate of change achievable through application of indigenous technical knowledge section.

Research scientists should present the interactive technological options developed during participatory on station research stage for consideration of selected farmers. The farmers are encouraged to identify technological options that would fit in to their individual problems had a resource constraints. Involving farmers, at this stage, included on the design of on farm trial can contribute to defining evaluation criteria, before researchers screened out most of the options by fixing the experimental design. When setting up on farm variety trails, scientist can begin by asking answers farmers how they themselves would test a new cultivar on their own land.

CCRDA

Many writers on participatory research believe that farmers should play a major role in the management of on-farm experimental agriculture. Classic experimental methodology, however, has its own shortcomings. Both conscious and unconscious decisions by crop scientists produce more crop environments on research stations than in farmers fields, and lead breeders to select genotypes that respond well to favorable environments. When crop varieties in the controlled environments of research stations not subject to the biotic and abiotic stresses encountered on farmers fields, plant breeders and farmers work across at purposes. Some researchers, however, disagree about the implications of the well-known yield gap that result from differences between conditions on the research station and in the farmers` fields.

Validating farmers experiments

This creates an environment of respect local people and village level extension workers. Thus leading to their increased participation and empowerment. inspite of their significant contributions to the development of farmer oriented technical options. This can be implemented, using academically well-trained and "research minded" extension personnel. This experiment includes various processes. according to the various steps involved during the process of these experiments are:

Understanding the rationale behind farmer experiment for example, testing varieties for yield increase avoiding risks by adjusting sowing and harvesting periods and testing new varieties for local adaptation.

Recording the mode of conducting experiments for example, sometimes conduct varietal trials by raising local and high yielding varieties in two different plots.

Identifying farmers evaluation criteria. the criteria used by farmers to evaluate their own experiments may differ from farmer to farmer and also for the same farmer, from crop to crop.

On-farm research managed by farmers are crucial to the screening process, and the approach, by recognizing the need for diverse varieties within villages, and even within farms, reverses breeders` conventional aspirations to supply a single variety to as wide a recommendation domain as possible. Researchers divergence about the

CCRDA

implementation of the well-known yield gap that results from differences between conditions of the research station and in the farmers fields.

Farmer's as experimenter

Farmers themselves are expert experimenters with new plant materials. When testing promising new plant genotypes, scientist can improve the relevance of their research by drawing upon farmers` own informal methods-experimenting with unfamiliar cultivar and practices. Some farmers already follow scientific methods of experimentation. Farmers experimentation relies on intuition, careful observation, skills acquired over time (i.e. experience), common sense and practical knowledge. It is also true that some station laborers were both very keen observers of germplasm, and experimenters with promising plant material on their own farms

Variety Introduction: **Curiosity experiment:** In drought spells, some farmers from Tigray, were in the refuge camp, Sudan. They observed that a cowpea variety that can be harvested early and yields well. Since the length of the rainy season has been decreasing, he they took a handful seeds to try out back home. The farmers decided to sow and the new variety produced well and resisted pests, even though, the cooking quality is not so good and the colour is black. therefore we can understand from this, farmers have the knowledge to test and analyze their varieties and newly introduced varieties.

Problem solving

Farmers design experiments to address problems of farming practice such as weed control. According to Millar farmers in Tuna found that continuos cultivation of Millet on the field for successive years favors striga, and they farmers in this district are trying to see how long to have adopted crop rotation, to find out which rotation best fights striga. An informal survey in central Tigray also indicate that farmers findings as to striga resistance-i.e. maintenance of soil fertility through the addition of compost or organic manure resulted in compatibility of the crop.

CCRDA

Adaptive experiments

No matter the form or source of an idea, farmers always modify ideas and technologies. Richards (1985) argue that some farmers in Seraleone follow a scientific `rice breeding` strategy through progressive selection of land-races. he suggests that effective linkage with crop breeding best effected through those farmers who follow such scientific methods of analysis.

Farmers rely on empirical observations and experiences derived from experiments to take vital and timely decisions with high degree of precision but with out technical instruments (Millar, 1994). barley gene conferred resistance to yellow dwarf virus is a product of centuries of selection, adaptation by Ethiopian farmers.

10.8.2..2. RESEARCH METHODS AND FARMERS PARTICIPATION

DIAGNOSIS: large scale formal survey, with their well-known problems of data reliability, sampling biases, logistical coastlines, and lengthy processing requirements, are increasingly replaced by less formal and more innovative techniques. Sampling by agro-ecological zone, farm size, or other criteria are sometimes useful at a latter stage is important to refine or comform findings from field observation and interviews in exploratory survey, particularly if the latter suggests the need for program changes.

CCRDA

If a new crop or technique is being tested, the idea of seeking out innovators and bringing them together to discuss their experiences is often helpful, although care must be taken that innovators are not synonymous with progressive farmers which may have conditions unlike those of the majority of farmers in the area. Group meeting can also be used to discuss research priorities with farmers. This is helpful in order to establish a clear understanding of the research agenda for both researchers and farmers. A number of techniques have been described including problem lists, ranking of problems and the use of various type of diagrams including field observation. The recent work on farmer participation has provided some valuable additions to the range of techniques available for carrying out adaptive

The identification of research priorities is an on-going, interactive process that builds on a continuing interchange between farmers and researchers.

Research priorities should be set taking great care to use information derived from surveys and discussion with farmers. Informal opportunities for discussion between scientists and farmers have been as important as formal occasions between scientists and farmers have been as important as formal occasions. However care should be taken to ensure that comments made by farmers have been properly recorded.

Evaluation: farmer participatory research emphasizes the importance of farmers` evaluation of any innovation. It is true that the ultimate evaluation of a new technology is always carried out by farmers. If farmers adopt a new technology the research considered successful., so decision should be taken in the early stages of research regarding which technologies are most likely to be successful. when the trial plots are approaching maturity, farmers in the village assemble and together visit plots. Informal interview could be used immediately after the field review to elicit farmers` preliminary evaluation of varieties tested, following harvesting treshing, milling and cooking. Further interview allow farmers to make any necessary re-assessment their initial evaluation, yield and post-harvest evaluation should also be made. A major change in farmers` attitudes has also been observed, although they previously appeared to expect that no improvements were possible under their resource constrained conditions the standard model of transfer of technology, all key decision are taken by scientists The ICRISAT entomologist said "technology is handed down as extension to farmer" The failure of this model in achieving break through in the tropics may in part, due to not knowing the farmers` priorities or not giving opportunities to farmers to analyze choose, improvise and adapt from a wide variety of choices.

Targeting: in which Previously excluded groups small holders, women-are included in an ongoing project by targeting benefits directly at them. According to Blumberg (1994) One of the most glaring deficiencies is in the extension services. Only 7 % of extension time and resources are devoted to African women farmers. However a

CCRDA

Christian Relief & Development Association
LIBRARY
P.O.Box

new innovative programmes are breaking through to women. This is generally productive, building on the tradition of women's associations in many societies with out violating local social norms. ICRISAT turned to increasingly to increasingly respected process of participatory research to ask women farmers what research was worthwhile. Taking Pigeon pea as taste case, breeders asked a group of women farmers in area of Andhra Pradesh to compare four advanced peat resistance lines with locally available varieties under their own field conditions and management.

Reorientation of extensions agents attitude to think more positively about envolving small farmers. This gives much needed focus and impetus to efforts to make extension more participatory. For truly participatory approach to emerge several key elements were considered by Oakely, 1994 as follows: Further institutional changes are required if researchers bias towards experimentation in 'safe' areas of adequate rainfall which guarantee a result each season is to be corrected. The work of the extension agents, from being mere implementer of policy and targets to being a more involved, committed and direct facilitator of local extension action extension and a recognition of that extension is not just a means of delivering technical message or advice but as learning process whose aim is to develop people's skills and abilities. The inappropriateness of the term "extension client" should be also considered and that extension should relate to people as members of groups, emphasizing the development of group structure and empowerment of members to take responsibility for extension activities. Traditional extension has usually reflected the rule of officials and bureaucrats. This must be admitted, since participation implies movement from grass roots.

CCRDA

Conclusions

Greater participation by farmers identifying problems, conducting trials and exercising on and off-station based work enhances the cost effectiveness of research. Participation facilitated methods in which farmers can identify and analyze their problems, opportunities and establish their own priorities , work plan for their livelihood.

There is much to be learned from local participation of local people, if we are to move towards participatory technology approach. It is feasible, cost-effective to participate, earn from the village-level experts. Because participatory methods that use farmers knowledge and systems logic are now solving problems that conventional cropping pattern research was incapable of addressing.

These include the need for close collaboration among technical scientists and social scientists; the usefulness of multi rather than single commodity approaches (since farmers themselves pursue multiple enterprises and evaluate technical innovations in any one crop in the context of the systems they operate).This less effective alternative has been for researchers to seek, the optimal way to grow crops and to expect farmers to adjust to these requirements.

Crop varieties are based solely on features of the natural environment (such as rainfall soils and temperatures), farmers may reject the high yielding varieties, scientist most admire at ICRISAT the high yielding The selection of new cultivars solely on the basis of single yield trials can lead to the introduction of locally unstable cultivars with determential nutritional and economic consequences for farmers.

CCRDA

Table 3. Examples of the effect of participatory varietal selection (PVS) on biodiversity in a single agro-ecological zone

	Biodiversity		
Environment	Decrease	Increase	Comments
Marginal	New cultivar or cultivars replace Landraces -Single cultivar replaces a range of improved cultivars	New cultivar partially replaces existing cultivar or cultivars	ommon situation in marginal ... where adoption rates of impr... cultivars are so low that lan... remain in farmers fields. Under conventional; varietal te... system the existence of a rang... introduced cultivars in a mar... environment is unlikely. More... PVS exposes farmers to a rang... cultivars and often more than ... will be adopted ncrease in biodiversity over me... to long term
High potential		New cultivar completely replaces existing cultivar. -Replacement rates increased Greater number of cultivars adopted than those existing.	Biodiversity over time increased Increase in biodiversity over tim... Likely because farmers exposed ... greater choice of cultivars.

CCRDA

References

Barrow, C.J. (1991). *Land Degradation: Development and break down of terrestrial environments.* New York; Cambridge Univ. press

Darkoh, B.K. (1989). *Combating Desertification the Southern Africa Region: An Updated Regional assessment.* Kenya, (UNEP).

FAO (1996). *report on the state of world's Plant Genetic resources, CPGR, Rome. CGRFA-X-2/96/2*

Lehouerou, H.N. (1993). Outline of the biological history of the Sahara. *Journal of Arid Environments* .**22,**(1), 2-10.

Pimental, D., brown, N., Vecchio, F., Lacorga, V., Hausman, S., Lee,O. Dazz, A., Williams, J., Coopeer, S. and Newburger, E. (1992). Ethical Issues concerning potential global climate change on food production. *Journal of Agricultural and Environmental Ethics* **5** (2),113-16.

Richards, P. (1985). Indegenous agricultural revolution: ecology and food production in west Africa. London: Unwin Hymen Ltd.

Seyfu, Ketema. 1993. Tef (Eragrostis tef): breeding, genetic resources, agronomy, utilisation and role in Ethiopian agriculture. Institute of Agricultural research, Addis Ababa.

Timberlake, L. (1985). *Africa in Crisis: The causes, the cures of environmental bankruptcy.* London: Earth scan publications, (IIED).

UNEP (1984). *Climate and Development: Natural resources and the environment series;* A.K,Bisawas (ed.). Dublin: dunlakghaire, CO. 13 pp. 65-95.

Witcombe, JR and Joshi, A. 1995. The Impact of Farmer Participatory Research on Biodiversity of Crops. Paper presented at IDRC workshop on Using Diversity Enhancing and Maintaing Genetic resources. 19-21 July 1995 at New Delhi.

CCRDA

11. IPM (Integrated pest Management) in Conservation Based Agriculture

Introduction

The challenge of providing enough food is one of the world's most pressing and urgent problems.The human population has been growing faster than the food supplies, and the imbalance between food production and consumption continues to increase. As much as 56 pe rcent of the world's population is undernourished, and the situation is worse in un development countries, where an estimated 79 pe rcent of the inhabitants are undernourished.

Ethiopia is an agricultural nation with a population of 54.8 million. The country's economy is dominated by the agricultural sector which is responsible for about 45 per cent of the GDP, 85 pe rcent of the national employment, and 80 pe rcent of the total exports. The country is, however, obliged to import significant proportion of the food need for her 54.8 million people. Food production is growing at a rate of about 1 pe rcent a year and population growth rate is presently 3.2 pe rcent per annum. At this rate of growth, Ethiopian's population will be over 66.7 million in the year 2000. If current trends of population growth and food production continues, food aid requirement would increase, which may result in dependency on external assistance.

Sustained increase in crop yields and thereby satisfaction of the food needs of the rapidly increasing human population depend on the continued understanding of plants and putting the achieved knowledge into practical use. In Ethiopia, increased crop production is a matter of great urgency, as the food supply will have to be increased annually by about 4 per cent.

CCRDA

11.1 Major constraints of food production in agriculture

- Backward farming system.
- Lack of improved technology.
- Limited agricultural research.
- Inadequate infrastructure facilities.
- Shortage of technical skill and capital.
- Rapid population growth.
- Pest species(biotic factors).
- Unfavourable environmental factors (abiotic factors).

11.1.1 Biotic factors

Harmful biotic factors can be distinguished in a animal and microbial organisms.Generally, animal organisms which infest plants or stored agricultural products cause damage by feeding that results in a loss of quantity and quality. The infesting animal organisms may also be dispersed through the soil or other substrates. Animal pests include insects, mites, nematodes, snails, rodents, birds and, incidentally, larger animals such as rabbits and wild boards.

A rough estimate is that, there are over 200 major pest species involved on all food crops i n Ethiopia. The categories of pest are migratory insects (n = 3), migratory bird (n = 1), non-migratory field insect pests and mites (n = 55), termites (n = 4), stored insects (n = 12), plant diseases (n = 64), parasitic weeds (n = 4), non parasitic annual and perennial weed complex (n = 52), rodents (n = 7), bird complex (n = 5), and other vertebrate pests (n = 8).

It is generally believed that agricultural pests on food crops in Ethiopia amount to about 20-30 pe rcent of yield loss in the field and 8-12 pe rcent in storage at the traditional farm level.

CCRDA

11.1.2 Abiotic factors

Damaging abiotic factors are conditions of the environment which adversely affect the health and productivity of plants.They include:

- unfavourable climatic conditions such as drought, too high or too low temperature,
- poor texture or toxic properties of the soil,
- deficiency or surplus of soil moisture, nutrients and elementary metals, and
- pollution of the environment.

Therefore control of pests and modification of the abiotic factors must be viewed as an integral part of good husbandry.

11.2 Definition of IPM

The term is synonymous with integrated pest control (IPC) which has been defined by FAO (1996).

- IPM is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible manner as possible and maintains the pest population at levels below those causing economic enjury.

In this definition, the term "pest species" stands for all organisms that through direct action (such as feeding) or indirect action (such as competition) cause damage or loss to crops and harvest.

- IPM - is farmer's best mix of control tactics in comparison with yields, profits and safety alternatives.
- IPM - is an economically justified and sustainable system of crop protection, consisting of a combination of cultural, biological,

CCRDA

genetically control methods, that aim at maximum productivity with the least possible adverse consequences for the environment.

11.3 Factors which favour IPM in the tropics

- climate and physical environment in tropical and sub-tropical areas generally allow populations of both pest organisms and natural enemies to proliferate throughout the year. Regulation of numbers by natural biotic mechanisms thus can function optimally and in relative abundance.
- Agro - ecosystems, which have not yet been subjected to rigorous economic development, generally have been only little disturbed by pesticide applications. They offer a relatively sound base for the development of an integrated pest management system, while farmers do not have to be re-educated.
- If the agricultural production is destined for home consumption, them farmers usually pay little attention to light infestation and some blemishes on the harvested produce; they would hardly spray for cosmetic reasons. However, transformation to market - oriented production introduces the criterion of external quality, which leads to excessive use of insecticides and funqicides on fruits, vegetables and flowers.
- where new areas are opened up for agricultural production there would be an opportunity to introduce IPM from the beginning and to ban unwanted chemical control practices.

11.4 Components of IPM

procedures for controlling pests, diseases and weeds must correspond with the characteristics of the target organisms and those of the cropping environment. The latter not only includes aspects such as the kind of crops grown and methods of cultivation, but also the state of development of agriculture, the knowledge and economic resources of the

CCRDA

farmers, and the expected cost - benefit ratio of the available control options. Some control procedures have a curative effect. Therefore, one needs to learn the advantages and disadvantages of all components which might be applied in on integrated control approach in order to make an appropriate choice.

11.4.1 preventive control procedures

Preventive measures have the objective of precluding the establishment of new pests or the limitation of the numbers occurring so that they will not become a problem.

A. Quarantine and regulatory control

The spread of pests and diseases to new areas from sources of infestation within or outside a country is often caused by the movement of people, commodities and equipment carrying the contaminant. Quarative and containment laws or regulations and other legislation have been enacted and enforced in many countries to help overcome this problem. for example, plant materials to be imported into a country must be free from pests and diseases, and plants with the potential becoming weeds are totally prohibited.

Countries with an efficient quarantive service require a rigorous inspection and fumigation of imported plant material at quarantine stations set up at parts of entry. The ever-increasing world-wide traffic and the weak quarantine infrastructure of many countries leave little hope for keeping such unwanted "guests" out.

Other examples of regulatory control are the prohibition to grow certain trees, plants or crops which are intermediate hosts to important pests or diseases of the economically most important crops of an area or the compulsory arrangement of crop rotation sequences.

CCRDA

B. pest - free propagation material

Infested or infected seed and plant material, such as tubers, rootstock, cuttings and grafts, can be the source of infestation or infection of an entire crop.The use of healthy propagation material, free of infectious material, is of particular importance if chemical control is inadequate or would be too costly as in the case of virus and bacterial diseases in low-values crops. Disiffecting propagation material with fungicides, fumigants, hot water, radiation etc.; kills fungal spores and nematodes on the outside and in some cases also inside the seeds and plant parts in a fungicide dilution can also provide some limited protection against soil-borne pathogens, insects and nematodes. Cleaning seed from contaminating weed seeds is equally important.

11.4.2 Cultural control

cultural control measures aim at modifying the cropping environment to the effect that it becomes less favourable for the development of pest populations, whilst maintaining the best possible conditions for high productivity.

CCRDA

A. Crop rotation

A traditional method of growing in the same field various crops alternately over succeeding years with or without leaving the land uncultivated (fallow) over intermittent periods of time. The principle of a rotating cropping pattern is to interrupt the specific relationship between pests and host plants which favours or limits the development of these damaging organisms. Crop rotation can be an effective measure against soil-borne pathogens, nematodes and soil insects provided the rotation cycle is sufficiently long. As different crops usually require different soil cultivation practices, such as shallow or deep ploughing, harrowing, ridging,, broadcast sowing, crop rotation also plays a very important role

in controlling weeds. It also interrupts the population build-up of above - ground pests.

B. Phytosanitation

Sanitation includes measures aimed at the removal and destruction of infected plant material as the potential source from which the pest or disease could spread. Some of the phytosonitations are:

- collecting or burying crop debris and stubble from the field.
- cutting of weeds.
- Eradication or prohibition of certain ornamental trees or cultivated crops from an area to protect a more important crop.
- cleaning and disinfecting planting tools and machines, containers and soil.

C. Adequate cultivation practices

Management of the water supply by irrigation and drainage, tilling of the soil for proper texture and aeration, fertilizer gifts, mechanical weeding, timing of planting dates, spacing and shading, are examples of cultural control factors.

D. Inter - cropping or mixed cropping

The mixed planting of food crops, vegetables and fruit trees often provides relatively high yields owing to the optimum use of soil, nutrients, water, space and other factors. Losses from pests are generally low where no insecticides are used, which would disrupt natural enemy limitation, and the risk of yield loos is spread over the various crops available.

CCRDA

11.4.3 Host - plant resistance

Resistance means the capability of a host to hinder the growth and activity of a parasite or phytophage and to limit the reproduction of a virus.

Centuries of natural selection in indigenous wild forms and cultivated forms of crops, grown under subsistence agriculture, have yielded "land races" with increased resistance to adverse environmental factors such as drought, soil salinity and low temperature, as well as with a certain degree of durable resistance or tolerance against injurious organisms and viruses. Most important, they are genetically diverse populations that are in equilibrium with both the environment and pathogens, and genetically variable. Land races have low productivity, but respond to selection pressures including selection for higher yields.

In previous decades, highly productive varieties have been developed by means of cross breeding and modern plant breeding technology, land races are being rapidly replaced. As they possess valuable genetic resistance to pests and diseases as well as other desirable traits, all wild forms and land races should be conserved.

CCRDA

11.4.4 Biological control

Biological control indicates the use of control agents in which the active principle is a living organism or virus (the so - called natural enemies) for regulating the incidence of pests or pathogens.

In an undisturbed ecosystem, the population density of a pest is kept within certain upper and lower limits over a period of time by naturally occurring parasites, predators or micro organisms. In a disturbed ecosystem, natural enemy limitation may, for a shorter or longer term, fail to prevent outbreaks of pests or epidemics of diseases. This may also happen when a new pest, pathogen or weed is introduced into a country or region, where its natural enemies are not available.

Theoretically, there are several ways in which insects might be controlled biologically; i.e. by

- specific natural enemies, usually parasites;
- non - specific natural enemies, usually predatory species;
- the sterile male method; and
- micro - organism and sex attractants.

A. Natural enemies

This is the introduction of exotic parasites and predators for the control of a pest.

Concerning the use of natural enemies for biological control, a distinction is made between the importation of exotic species(to control exotic pests rather than indigenous pests) and the conservation of indigenous natural enemies (to control both exotic and indigenous pests).

B. Sterile male technique

This involves the large - scale release of artificially sterilized male insects that belong to the same species as the target pest. The objective is to flood the habitat with sterile males which should compete with the fertile ones in mating with the females. If the inundalive releases are repeated over a long period of time, the pest species may be suppressed or even eradicated owing to the obsence of fertilized females. This technique is, however, really effective if the females mate only once.

C. Microbial pest control agents

Biological control by means of entomopathogens and other microbial pest control agents involves the application of micro - organisms onto the crop for ingestion by insect pests or directly onto the noxious insects, fungus or weed with the objective or destroying them. Microbials include bacteria, fungi, viruses, nematodes and protozoaries. Probably the best known example is *Bacillus thuriniqiensis* against Lepidoptera larvae. Two varieties of *B. thuriniqiensis* are currently widely produced under

CCRDA

trade names such as Bactospeine, Bactimos, Dipel and Thuricide. These formulations are sprayed onto crops and, after having been ingested by leaf - caterpillars, cause the lather's death.

D. Pheromones, hormones and growth regulators

1. Pheromones

Pheromones are substances emitted by insects and mites for communication between individuals of the same species. These pheromones modify the behaviour of the other insects to the benefit of at least on of the species involved. Sex attractants, for instance, are pheromones that enable adult male insects to find and recognize females of the same species. In biological control, sex pheromonous are used for trapping male adults and for communication disruption. Sex pheromones - baited traps are used to:

- monitor the distribution and abundance of an insect pest in order to achieve better timing of insecticide applications; and
- catch a large number of male adults in order to reduce the population density. This technique is less effective at high densities and when the adults of the species are capable of multiple matings.

CCRDA

2. Juvenile hormones

Juvenile hormones are substances that regulate development in insects and that may prevent insects from reaching maturity.

3. Growth regulators

Growth regulators are natural chemical substances in plants and animals that control their processes of growth and that are very specific in their action. Obviously, any serious disturbance of growth may interfere with, for instance, vital processes of hatching, matting and pupation in

insects or with process of cell division and cell elongation in plants. Some of these man - made chemicals posses a high efficacy either as insect growth regulator (IGR) or as plant growth regulator (PGR). Because of their selectivity and relative harmlessness to mammals, the growth regulators fit well within the IPM concept.

4. Biotechnology

Biotechnology is the application of molecular biology in the fields of agriculture, environment and health. This definition emphasizes the improvements of the genetically characteristics of the cell (of either plant, animal, bacterium or fungus) by exploiting recombinant deoxyribo - nucleic acid (DNA) and other molecular technologies in order to develop improved methods and modified organisms.

Biotechnology encompasses the following technological developments:

- genetic manipulation;
- in vitro regeneration;
- transformation systems; and
- hybridoma technology.

A. Genetic manipulation

Genetic manipulation refers to the technique of altering genetic material (DNA or genes) or transferring such material of different origin into one organism where it becomes functional.

This can be achieved by means of "recombinant - DNA technology" or somatic cell fusion. Recombinant - DNA technology offers, in principle, the possibility of overcoming incompatibilities between species and to pave the way for the development of a genetic manipulation of micro - organisms, cells and eukaryotic tissues. The incorporation of resistance - genes in crops renders them less susceptible and vulnerable to injurious organisms and viruses or to the phytotoxic effect of pesticides.

CGRDA

B. In vitro regeneration

In vitro regeneration techniques offer the possibility to grow complete plants from plant - cells, calluses and plant - tissue fragments in laboratory glassware on special media containing growth factors and hormones. The technique is used for the vegetative production of disease - free plants from plants infected by viruses, fungi or bacteria. For example, from a shoot - tip or from the auxiliary buds of a plant, the meristemdome and first pair of leaf primordial are excised and aseptically cultured on a medium. The meristem tissue may form further side shoots from dormant lateral buds which in turn are placed on a medium for rooting. By using an adequate medium and chemicals such as cytokinine, it is possible to obtain closes of virus - free plants from many food crops, fruit trees and ornamentals.

C. Transformation systems

These systems exist for transferring alien DNA to cells of a different species, where upon the arriving DNA is firmly integrated in the genetic constitution of the recipient cell. such methods are commonly used for the transformating of plant cells and animal cells and to overcome barriers to interspecific hybridization in plant breeding.

D. Hybridoma technology

Hybridoma technology pertains to the production of monoclonal antibodies which can be used for the detection and identification of viruses in crops. The hybridoma technology makes use of two properties: namely,

- that each lymphocyte (antibody - producing cell) produces an antibody which reacts specifically with one antigen and
- that transformed (tumor) cells can demonstrate understrained growth.

CCRDA

11.5 Chemical control

Chemical control consists of the application of botanical or inorganic and organic synthetic compounds that have a killing, inhibiting or repulsive effect on injurious organisms threatening mankind, animals and plants.

Pesticides can be applied either as a preventive treatment to protect crops or stored products against infection by diseases or infestations by animal pests, or as a curative treatment to destroy or limit population development of noxious organisms.

IPM was initially conceived as a response to world - wide pest problems created by excessive use of synthetic pesticides and increasing rates of pest resistance to those chemicals. More recently, IPM has taken on important economic and social overtones. The lower costs of IPM, as compared with conventional pest control, are of economic significance both at the national level, where many of the poorest countries spend tens of millions of dollars to subsidize pesticide use, and at the farm household level, where scarce funds are spent on pesticide applications that may give little or no benefit. At the same time, governments, farmers and consumers are becoming increasingly alarmed at the health implications of pesticide use.

11.5.1 Pesticide use in relation to IPM

The IPM concept was stimulated by the deleterious effects of over - dependence on pesticides. pest control, if practised at all, is based on indigenous methods such as cultural controls. If, it is necessary to use pesticide it may be used in conjunction with other non - pesticide controls (pesticide use in balance), or different pesticides may be rotated to discourage the build - up of resistance.

CCRDA

11.6 Rationale for IPM implementation

A. Environmental quality

Pesticides nearly always affect non - target species along with the intended targets, upsetting the local ecological balance.

B. Economics

The shadow price of chemicals may be much greater than the nominal price, due to several layers of subsides. When environmental costs are included, the total social cost of pesticides may become higher as a result of improper use.

C. Health

Handling and application of chemicals poses health hazards to the poorest sectors of the population, who obtain menial jobs in the agrochemical production/marketing business, and to poor farmers who know nothing about the hazards, or who do not posses the equipment to use chemical safely. Moreover, in hot climates the use of protective clothing is often impractical. pesticide residues in or on food can pose a serious health hazard to consumers.

CCRDA

D. Social criteria

The addiction of farmers to heavy use of pesticides in conventional agriculture imposes new levels of dependency on the outside world.

E. Political criteria

The stability of agricultural production which IPM makes possible has important benefits for political stability at the national level.

12. FARMING TECHNIQUES FOR MOISTURE STRESS AREAS

12.1 Parameters of moisture stress

- Climatic variables
- Crop/vegetation variables
- Soil type characteristics

12.1.1 Climatic variability

- Untimely onset of rainfall
- Untimely (abrupt) cessation rainfall
- Intermittent rainfall

12.1.2 Crop varieties rainfall

- Variation among crop species to withstand moisture stress (maize versus sorghum)
- Escape mechanism of crops to moisture stress

12.1.3 Soil characteristics

- Physical characteristics
  - texture
  - structure
  - pore space
  - depth
- Chemical characteristics
  - presence of soluble salts
  - salinity/alkalinity
- Biological characteristics
  - role of microhyzea

12.2 Approved practices for crop production in moisture stress areas

12.2.1 Choice of crop varieties

- To fit the growing period
  - define types of growing periods
- Sustained yield level or increase in yield
- Harvest index versus total biomass

12.2.2 Land preparation

- in-situ moisture conservation
- tied-ridging
- timely cultivation

CCRDA

12.2.3 Seeding

- dry seeding (MN = aF)
- problem of seed dressing (high input)
- availability of seeds
  - credit
  - source of seed
  - alternative varieties/crops
- Seeding rate
  - moisture level in the soil is important
  - avoid competetion among seedlings
  - avoid weeds that compete for moisture
  - low seeding rate, well spaced between rows and plants

12.2.4 Moisture conservation techniques

- tied ridges - problem of proper plough
- earthen bunds - land productivity
- problem of spacing of bunds
- use of crops of different rooting habits

⇒ Presentation to be supported with data obtained from research studies.
- A.U.A
- I.A.R.

⇒ Slide presentation on different techniques

⇒ Visit to soil and water conservation schemes around Mekelle

⇒ Visit screening of tree species using different moisture conservation schemes
- in campus
- at Messebo

⇒ Group discussion on indigenous moisture conservation schemes
- Project experience
- Situation analysis
- Suggesting solutions

CCRDA

13. Information Base for Sustainable Agricultural Development

13. 1 On Sustainability

There is in our time an uneasiness among politicians, scientists and citizens alike, that the biological foundations upon which all life depends are being heavily eroded. The concern takes many shapes. e.g. the concern about losing biodiversity of species, the chemicalization of toxic elements into the environment to an extent which was never there before, or of man-induced climate change, thereby threatening certain forms of biological life in certain places.

In this situation many have recognized the need for a "sustained" performance of the natural world. This has been linked conceptually to the possibility in the social sphere of a continued development, may be in different form than the present one .

But it has to be argued that this "framing concept" of our time is indeed contextual in character and thus can not be treated as an absolute frame. Instead we have to ask ourselves questions like; Sustainable, how? -Sustainable, for what purpose? - Sustainable, in which sense? Sustainable, for whom? -Sustainable under which condition? We may even have to define the actor who makes the statement as to what is sustainable and what is not.

So what is sustainablity? Or to rephrase the question: what do we mean when we say something is being sustained? Is it something to be kept constant or is it the capacity of something to have some endurance over a considerable time? It is reasonable to adopt the later approach, still realizing that at some level, some indicator has to signal constancy of behavior. The means by which this "constancy" is achieved is could either be *static* or *dynamic*. In the static case, we are considering some prevention of disrupting external factors having an effect on the " sustained function". In the dynamic case in contrast we are discussing the maintenance of the balance of supporting forces which among themselves could change in composition as well as in strength. The important point is that a dynamic equilibrium is maintained irrespective of the means by which it is maintained.

If we say that sustainability has this dynamic feature, we still have to address the issue of *what it is* that should be sustained. Is it

- the specific material expression of something (e.g. a specifically localized grove of trees)?
- the specific type of material expression (e.g. a certain type of forest at a certain place with specific age distribution, species variety, quality of trees, etc.)?
- the capacity to generate a specific feature (e.g. the capacity to grow pine trees)
- the more general capacity to generate any biological product (not necessarily specific species of trees but more generally "biomass", e.g. in a toxic environment).

Thus we have to move from a specific material expression to more general functions. But at the same time we also have to acknowledge the spatial expression of this. Within which geographical domain are we operating? -Are we considering homogeneous or patch-wise types of distributions?

CCRDA

In addition, the spatial dimension has to be combined with a temporal one. For how long should the entity be sustained? The answer probably has to be " a considerable time duration". But this indeed is a very type of statement; "considerable time" with regard to what type of measure of time spans? In addition you could have a long term sustainability of an aggregate over a wide geographical territory without keeping any part of it very sustained at micro level. Or at least the micro level geographical unit could expose quite vivid temporal cycles of performance, as is the case for forest fire prone regions or for that matter of "slash and burn" agriculture.

So you have to ask at which "system level" something has to be sustained, in addition to the issue we raised earlier regarding what type of features should be kept, and by whom and for what purpose. But the sustained feature does not need to be limited to the realm of performances of an ecosystem. e.g. in terms of the biomass production capacity. It could equally well address a certain level of material standard for a certain population, or societal or cultural order of some kind.

We then have to demonstrate the issue of a relationships between sustainabilities of one level and those at the other connected systems levels. This could infact go in two directions. There might be a need for sustained performance at a higher systems level in order for something at a lower level to be sustained.

But we also have to consider the reverse direction from bottom to top. Are certain sustainabilities at lower levels required for sustainabilities at higher levels?

There are many examples of more or less coping types. We have to discuss coping patterns or coping characteristics. But what are the criteria for the design of "coping patterns"? We may frame our problem in terms of "Veto-rules" or "promotion of sustainability rules". And we have to address the issue in relation to the situational context, i.e. to talk about sustainability promoting situations and sustainability breaking situations, which in tern calls for the introduction of a normative element.

We thus have to introduce the contextual characteristics of keeping something sustainable and what breaks it. What, for example, is the regenerative capacity of a biological species above a certain breaking point of toxic contamination? Or what is the level of lack of basic needs in a population which forces a local destruction of the environment?

We also have to discuss situations which might change characteristics under certain conditions, e.g. which over time flip their behavior from a sustained to a nonsustained one. The time dimension is in general one of the most important issues with regard to sustainability contexts. Often the intergenerational equity criteria is placed at the core of sustainability
definitions.

How then is the contextual character of sustainability concept influencing the interference between economy and ecology?

First of all the contextuality as such has to recognized. This is probably more easily done in a social science tradition than in a natural science one.

Secondly the interconnectedness of the various levels of sustainability must be recognized. Environmental, socio-economic and cultural forms of sustainability mutually enforce each other in complex ways. There are no easy causal links to be identified, rather patterns of causality enabling settings. Often this takes the form of disrupting

CORDA

vicious circles. This web of interlinkages has to be recognized from both sides. The economy side has to encompass more strongly the absolute need for certain environmental functions and making room for it in the economic theory. This involves, for example, a limiting of the perception that vast substitutability's between different forms of assets are in fact possible. The ecological side, on the other hand, has to accept that disruption in the socio-economical or cultural sphere might not only be a dominant cause of environmental degradation, but also hold the key to designing solutions.

There exists a gallery of definitions on sustainable development, varying from those believing that it is possible to grow in physical terms in sustainable fashion and to substitute natural capital for man-made capital to those advocating that sustainable development is actually a question of development in qualitative improvement as opposed to a quantitative growth, emphasizing that there is a strong complementary between natural capital and the development of human societies. There is, however, a consensus that the term sustainable development is still vague, and that it means different things for different groups of people involved with environmental economic issues.

Robinson et al. (1990), have attempted to defining a sustainable society and summarized the principles of sustainability as in table 1. In addition to the necessity for the continued existence of biophysical life-support systems - the natural capital - sustainability has socio-political dimensions as well, which implies that a sustainable society must be sustained in both ecological and socio-political terms. Increasing the sustainability of a system is not equivalent to maintaining the system in its current form, but rather to preserve the capacity for the environmental-socio-political system to change. Sustainable development is continuous development that is never achieved once and for all, but only approached. It is not a state but a process, and as such can only be reinforced not attained.

Obviously, a better understanding of how to link the environment and the economy is urgently required. For this, environmental and economic modeling and planning using a geographic information system is in no doubt a means to achieve our objectives.

Table 1. **Principles of Sustainability** (from Robinson et al., 1990)

BASIC VALUE PRINCIPLES
The continued existence of the natural world is inherently good. The natural world and its component life forms, and the ability of the natural world to regenerate itself through its own natural evolution, have intrinsic value.
Cultural sustainability depends on the ability of a society to claim the loyalty of its adherents through the propagation of a set of values that are acceptable to the populance and through the provision of socio-political institutions that make realization of those values possible.

CCRDA

DEFINITION OF SUSTAINABILITY

Sustainability is the persistence over an apparently indefinite future of certain necessary and desired characteristics of the socio-political and its natural environment.

KEY CHARACTERISTICS OF SUSTAINABILITY

Sustainability is a normative ethical principle. It has both necessary and desirable characteristics. There therefore exists no single version of sustainable system.
Both environmental/ecological and socio/political sustainability are required for sustainable society.

We can not, and do not want to, guarantee persistence of any particular system in perpetuity. We want to preserve the capacity for the system to change. Thus sustainability is never achieved once and for all, but only approached. It is a process, not a state. It will often be easier to identify unsustainability than sustainability.

PRINCIPLES OF ENVIRONMENTAL/ECOLOGICAL SUSTAINABILITY

Life support systems must be protected. This requires of decontamination of air, water and soil and reduction in waste flows.

Biotic diversity must be protected and enhanced.

We must maintain and enhance the integrity of ecosystems through careful management of soils and nutrient cycles, and we must develop and implement rehabilitative measures for badly degraded ecosystems.

Preventive and adaptive strategies for responding to the threat of global ecological change are needed.

PRINCIPLES OF SOCIO-POLITICAL SUSTAINABILITY

Derived from environmental/ecological constraints

The physical scale of human activity must be kept below the total carrying capacity of the planetary biosphere.

We must recognize the environmental costs of human activities and develop methods to minimize energy and material use per unit of economic activity, reduce noxious emissions, and permit the decontamination and rehabilitation of the degraded ecosystems.

Socio-political and economic equity must be ensured in the transition to the a more sustainable society.

CCRDA

Environmental concern needs to be incorporated more directly and extensively into the political decision-making process, through such mechanisms as improved environmental assessment and an environmental bill of rights.

There is a need for increased public involvement in the development, interpretation and implementation of concepts of sustainability.

Political activity must be linked more directly to actual environmental experience through the allocation of political power to more environmentally meaningful jurisdictions, and the promotion of greater local and regional self-reliance.

Derived from socio-political criteria

A sustainable society requires an open, accessible political process that puts effective decision-making means and power at the level of government closest to the situation and lives of the people affected by decision.

All persons should have freedom from extreme want and from vulnerability to economic coercion as well as the positive ability to participate creatively and self-directedly in the political and economic system.

There should exist at least a minimum level of equality and social justice, including equality of opportunity to realize one's full human potential, recourse to open and just legal systems, freedom from political repression, access to high quality education, effective access to information, and freedom of religion, speech and assembly.

CCRDA



13.2 On Information

What is a Geographic Information System?

Introduction

The problem of sustaining the environment is no longer limited to the third world, or portion of it; but affect all levels of hierarchy of living systems, from the cell to the world economy. The need for some form of deliberate planning to make optimal use of resources at our disposal is evident. Solutions are unlikely to come from single discipline or theoretical schools, but will require the contributions of many thinkers from as many backgrounds as possible.

In recent years the awareness of complexities and diversities in the natural and human environments has led to an increased demand for location specific information. Consequently, data collection efforts on natural resources, from ground truth as well as from aerial photography and remote sensing, have expanded substantially, resulting in more refined systems of classification and evaluation of physical and biological variables.

Because of the finite nature of resources, it has become imperative that resource conservation and allocation decisions be made in a broader land use planning and management context. Ever increasing competitive demands for resources now require a greater understanding of the effects of our resource-related decisions in the natural, social, and economic environment. Data, which will yield the types of information required for rational decision-making, are the foundations of this understanding. Determining data needs and developing data handling methodologies are required to support sophisticated analysis so that these management needs can be met.

To cope with the myriad of causes and effects encountered in the management, conversion, and use of land, the data that support planning will at least be partially processed by automated, information handling equipment. The development and characteristics of such a computer based tool is called ***Geographic Information System***. This paper will try to briefly overview the basics, application and benefits of this technology in perspective of sustainable planning activities.

From the earliest civilizations maps have been used to portray information about the earth's surface. Navigators, land surveyors, and the military used maps to show the spatial distribution of important geographic features. Land surveying and map making were an integral part of ancient Roman Government.

It was not until the eighteenth century that map making again rose to prominence in Europe as governments realized the value of mapping as a means of recording and planning the use of their lands. National Institutes were commissioned to produce map coverage of entire countries. General purpose maps showing the topography of the land and boundaries of national and administrative units were produced. As the study of natural resources developed, thematic maps were used to develop portray the spatial distribution of such features as geology, geomorphology, soils and vegetation.

ICRDA

In the twentieth century, the pace of science and technology accelerated. This increase created demand for ever greater volumes of geographic data to be presented in map form more quickly and more accurately with the development of reconnaissance technologies, such as aerial photography, and satellite-based remote sensing, and radar technology, there has been an explosion of geographic data production, wider use, and more sophisticated analysis. Geographic data are now being generated faster than they can be analyzed.

Geographic data have traditionally been presented in the form of a map. Until computers were available, geographic data were represented as points, lines and areas drawn on a piece of paper or film. They were coded using symbols, textures, and colors that were explained in the map legend or accompanying text. The map and its documentation constituted the geographic database.

The use of thematic maps of natural resources began as an inventory tool used to record and classify observations. The analysis methods were primarily qualitative. That is, retrieval and analysis of map data depend primarily on visual inspection of the map and an intuitive analysis of the map data. Quantitative map analysis could be done using a scale to measure distances and a dot grid or a planimeter to measure areas.

While it was relatively easy to retrieve small amounts of data or consider the spatial relationships of a few elements, these methods became unwieldy when large volumes of data were involved. It was only in the 1970s with the availability of suitable digital computers that the technology to handle spatial data leapt forward. The computer-based geographic information system was developed to provide the power to analyze large volumes of geographic data.

The physical map can be relatively easy to produce and if stores a considerable amount of spatial information in a compact and accessible form. However, it has a number of important limitations. The data used to make the map usually have to be generalized (i.e. the data have to be presented with less detail) for the map to be easily read. Areas that are large relative to the map scale have to be represented by a series of maps. Problems arise when maps don't match correctly at the ages and areas of interest extent across map edges. Often these problems are handled by shifting the maps to achieve the best fit for the area of the map being used. For critical applications, re-drafting may be needed.

Updating a map can be an expensive procedure. For changes to be made the film masters of the map sheet must be manually edited and the map reprinted. As a result the physical map is a relatively static document. Retrieving small amounts of information from a physical map is relatively easy; however, the process of retrieving large amounts of information and of combining the spatial information from several maps are costly and difficult. During the 1960's and 1970's the need to evaluate multiple sets of geographic (information) data was recognized. For example, the rapid and accurate integration of such diverse data as soils, land use, current vegetation, and administrative districts was needed for analysis such as environmental impact assessments. Even local zoning decisions were beginning to require the consideration of multiple geographic factors. The accurate and rapid analysis of diverse geographic data sets was perceived as a requirement for more effective planning.

CCRDA

Data integration could be done using physical maps. Map information was combined and integrated by overlaying transparent copies on a light table and visually analyzing the co-occurrence of factors. Then these areas with the desired combination of factors could be delineated by drawing the boundaries on a separate overlay. The transparent maps were usually redrawn for the analysis both to transform the diverse source maps to a common map base and to code each map with different shades of gray to represent different levels of constraint for a particular planning application. But the procedure was time-consuming, and, as the number of factors and number of levels of each factor increased a practical limit was quickly reached.

There has been systems developed in the late 1960s by the United States and Canada. Both systems made extensive use of aerial photography, as well as existing mapping to map resource information. Information layers such as agriculture, forestry, wildlife, soils, and geology, were included. The geographic information on the maps was then encoded into digital form for computer analysis. Although development began in the 1960s, the computer-based portions of these systems become operational only in the early 1970s when computer technology such as random access disks became available. These early implementations of operational GISes for resource information stimulated the development of technical innovations. They also provided valuable experience on how to manage the creation and operation of large geographic information systems.

The rapid development of computer technology over the past two decades has enabled computer-based geographic information systems to develop quickly from those early systems to the full-featured GISes now available. The quantitative improvement in the speed of analysis has provided the means to change the way the analysis of geographic information can be approached. Perhaps the two important improvements have been the ability to keep georeferenced data current and to integrate multiple data sets efficiently.

The ability to quickly update the geographic database coupled with the fast and inexpensive production of single maps has meant that a physical map can be used as a snapshot of a continuously changing geographic database. Since re-analyzing the data is relatively inexpensive and can be rapidly executed, complex planning scenarios can be progressively refined by re-analyzing the plan to assess proposed changes. Decision-makers can propose a number of alternative plans and assess each one by re-running the analysis and comparing the results. This iterative approach would be prohibitively expensive using manual methods.

Using a GIS for decision making

There is a fundamental strategy that underlies all analysis of georeferenced data. An understanding of this strategy will not only lead to better use of the available methods, but is also needed to understand how different levels of data abstraction are related.

We have to make decisions that require knowledge about our complex world. Because we don't have complete knowledge, we are used to making decisions with incomplete information. We select a relevant information to remember and record. Using this selection process, we create a conceptual model of our world. The term 'Model' is used to mean a set of relationships or information about the real world.

CCRDA

Our conceptual model of something is our understanding of what it is and how it behaves. When we need to make decisions about the real world, we refer to our model, which is much simpler than the real world itself. It is simpler because we have preselected the information in the model to include the things that are relevant to us. Other details that we don't need tend to be selectively forgotten.

The process of using a GIS can be illustrated by a familiar geographic information processing task - planning a vacation. Notice that our task begins and ends with the real world (fig.) we've collected information about the real world. This information is necessarily an abstraction; we couldn't handle and wouldn't want every last detail. We will use this information to make decisions, and finally we will implement those decisions - we will apply our abstract reasoning to the real world, i.e. we will take a real vacation.

The decisions of where to visit and what to do will require that we collect some information. We will want to know about vacation spots that we are likely to enjoy and when is the right time to visit. Probably the list of potential vacation spots will come from such sources as our own experience, recommendation from friends, and accounts we have read. Then we will collect some data about the different destinations. This data about the real world come in the form of maps, books, articles, and even tables of data such as average daytime temperature etc.

This collection of information constitutes a data set or data base that will be used in the vacation planning process. If there are several possible destinations and many documents it may become a bit tedious sifting through the pile every time some useful bit of information has to be retrieved, so we may decide to organize the information. The organization, such as filing the literature by destination, makes the process of storing and retrieving items more efficient. The organization of the data base constitutes a simple database systems.

Having collected and organized our documents, we review the information. This may be done by randomly reading the most attractive brochures or perhaps by systematically thinking about what we enjoyed doing on a vacation. Whatever the method of analysis we use, in the end we come to some decision and select a destination. To put the decision into action we implement the plan by going on the trip. If we made the right decision we'll have a good vacation and return satisfied that we made a suitable choice. A 'good' information system is one that provides us with the necessary data relevantly organized so that we can make the right decisions about the real world. What is really meant by the "right decision"?

The "right decision" is the one that best achieves the objectives of whoever the system is to serve. To do this it is necessary to know what those objectives are and to be able to correctly predict the results of alternative choices. To make the "right decision" requires that the relevant data be presented in the framework of an appropriate model that is evaluated using two criteria.

The success with which a geographic information system can be used is determined by several factors that can be grouped under four headings: the data set, the data organization, the model, and the criteria.

CORDA

Getting the relevant data

The data used in a GIS represent something about the real world at some point in time. They are always an abstraction of reality because we don't need or want every bit of (information) data, just the ones we think would be useful. the bits we decide to take are the first constraint on the capabilities of a GIS.

You can't use data you don't have.

Then why not take all the data? First, you could never collect all the data, and second, you wouldn't want all the data even if you could get it. Data are costly to collect.

The most cost-effective data collection is to collect only the data you need.

It is costly to collect, store, and sift through large quantities of unnecessary data. Excess data makes it more difficult to use the data you really need every expenditure of effort that doesn't contribute to the solution detracts because it represents time, effort, and resources that could have been used elsewhere to improve the analysis. The some argument holds two true for the quality of the data.

The optimal data quality is the minimum level of quality that will do the job.

The most important aspects of data quality are accuracy, precision, time, currency, and completeness. Accuracy measures how often, by how much, and how predictably the data will be correct. Precision measures the fitness of the scale used to describe the data. Time indicates at what point or over what period of time the data were collected. Time can often be a critical factor of data quality. Some information may quickly become out-dated. Currency measures how recently the data were collected. In some cases the suitability of the data will depend on the season or the year they were collected. completeness refers to the portion of the area of interest for which data are available. The term is also used with reference to the classification system that has been used to represent the data. There is always a trade-off between higher data quality and higher data cost.

How do these principles apply to our vacation example? or database may consist of road maps, vacation brochures, travel guide books, as well as our own personal knowledge of vacation spots. If we've selected an appropriate set of data we should be able to retrieve some information about several likely vacation spots that meet our criteria. There is of course a trade-off; we could easily swamp ourselves with travel guides, maps, etc., making it difficult to find any particular piece of information, not to mention expensive to acquire. Furthermore, if we are not careful in screening for data quality, we could end up with boxes of material, much of it unreliable.

A more effective approach is to select a set of information that we consider to be reliable and that covers all the regions we might realistically consider visiting on this trip. By judiciously selecting our data in this way, we can make it much easier to retrieve reliable information. We trade off data quality and cost throughout this process.

CCRDA

The Data Organization

The organization of the data is the second major factor for successful use of a GIS. A database is used to provide this organization. The data base is critical because:

Data is of no value unless the right data can be in the right place at the right time.

Our vacation data might be organized by alphabetically filing or by simply putting the maps in one box and the brochures in another. Depending on the quantity of data and the performance we need from our data base system, these simple forms of organization may suffice. In a computer-based GIS, however, the quantity of data is large enough that the form and performance of the database are critical to the overall usefulness of the system.

The Decision Model

A model represents an object or phenomenon that exists in the real world. A good model is the simplest model that correctly and consistently predicts the behavior of the real world for the phenomena of interest. Models are created to predict how certain aspects of the real world will behave. They describe the relationships among data elements in order to predict how events in the real world will occur. The quality of the model is limited by the data that has been selected and the way they are organized. It is also limited by the cost to use it. The more complex the model, the more costly it is to use. The most cost-effective model is the simplest model that gives results that achieve the minimum required level of accuracy with the minimum cost data.

The most cost-effective model is the simplest model that does the most with the least.

Why this concern with cost? The reason is that there is always a cost. It may not be money; it may be time, it may be incorrect answers only by predicting and evaluating these costs can be a rational decision be made about performance.

Too low a performance level can be too costly in errors caused by inaccuracies, by getting results to late, or by missing better solutions. Too high a performance level can also be too costly by paying for efforts that does not improve success.

It is expensive to tolerate performance levels that are too high or too low.

For our vacation, a relatively simple decision model can be used. We want a two-week holiday that is enjoyable to all members of the family and fits within our budget. This may constrain us to areas that can be reached within a two-day drive and limit the types of accommodation and activities. Our model will be used to analyze our data, i.e. to test different candidate destinations proposed after studying the information we collected. The decision process will probably be a fairly informal one based on consensus - with senior family members having power of veto. The relative merits of different destinations will be compared according to some more or less well-defined criteria.

CCRDA

Valid Criteria

The fourth major factor in successful GIS applications is the degree to which the criteria used to evaluate the model timely reflect the values of the people to be satisfied. At the end of the information analysis procedure, action is to be taken. The action to be taken must be decided by weighting the alternatives, and by considering the consequences of each alternative as predicted by our models. The decision may be as simple as sending an overdue notice for an unpaid bill, or it may be as complex as deciding to build a dam and drawn a valley.

Fundamental to the process are the decision-makers. The decision makers are those with the mandate, the responsibility for the consequences of the action to be taken. No matter how high the quality of the data; how appropriate the models used, if the wrong criteria are used to evaluate the information produced by a GIS, then the results will probably not be satisfactory. People make decisions guide by criteria.

The criteria used by the people making the decisions must be the same ones used by the people who are to be satisfied.

In the context of our vacation example, if one member of the family is designated as the decision maker, then her or his success in choosing a destination will depend on whether the selection criteria used truly represent the values and wishes of the rest of the family, i.e. the people who are to be satisfied.

The success of our vacation depends on the decision we consciously or not-so consciously made throughout this planning process, just as the decisions made using a GIS depend on the success of each step. We began by deciding what type of information to collect. Though perhaps done in a rather informal way, it is a critical step. Too much data and we'll be researching forever, too little and we might miss a key attraction or make a poor choice of destination. As part of making this trade-off decision, we must accept that we can't review every possible vacation spot, but we'll be satisfied with some minimum level or quality. Because if would take too long to find the best possible vacation spot, we'll accept a destination that gives us all a good time and meets our budget of time and money. We defined a simple decision model. These decisions influenced how much data and what kind of data we collected.

The accuracy of our data is important. The level of accuracy we require will depend on the types of decision-making for which the data will be used. The cost of collecting the data and our ability to analyze it are also factors. There are limits to the time and resource, money we can sped collecting and analyzing data - for our decision. The effort we are willing to expend depends on how important the decisions are to us. For the decision-making process to be successful, valid criteria must be used.

The success of a GIS application depends on an appropriate selection of the data to be used, the way the data will be organized, the decision model, and the decision criteria.

CSRDA

Georeferenced Data.

Geographic data are commonly characterized as having two fundamental components:

1. the phenomenon being reported such as a physical dimension or class, and
2. the spatial location of the phenomenon.

Examples of a physical dimension might be the height of a forest canopy, the population of a city, or the width of a road. The class could be a rock type, vegetation type, or the name of a city. The location is usually specified with reference to a common co-ordinate system such as latitude and longitude.

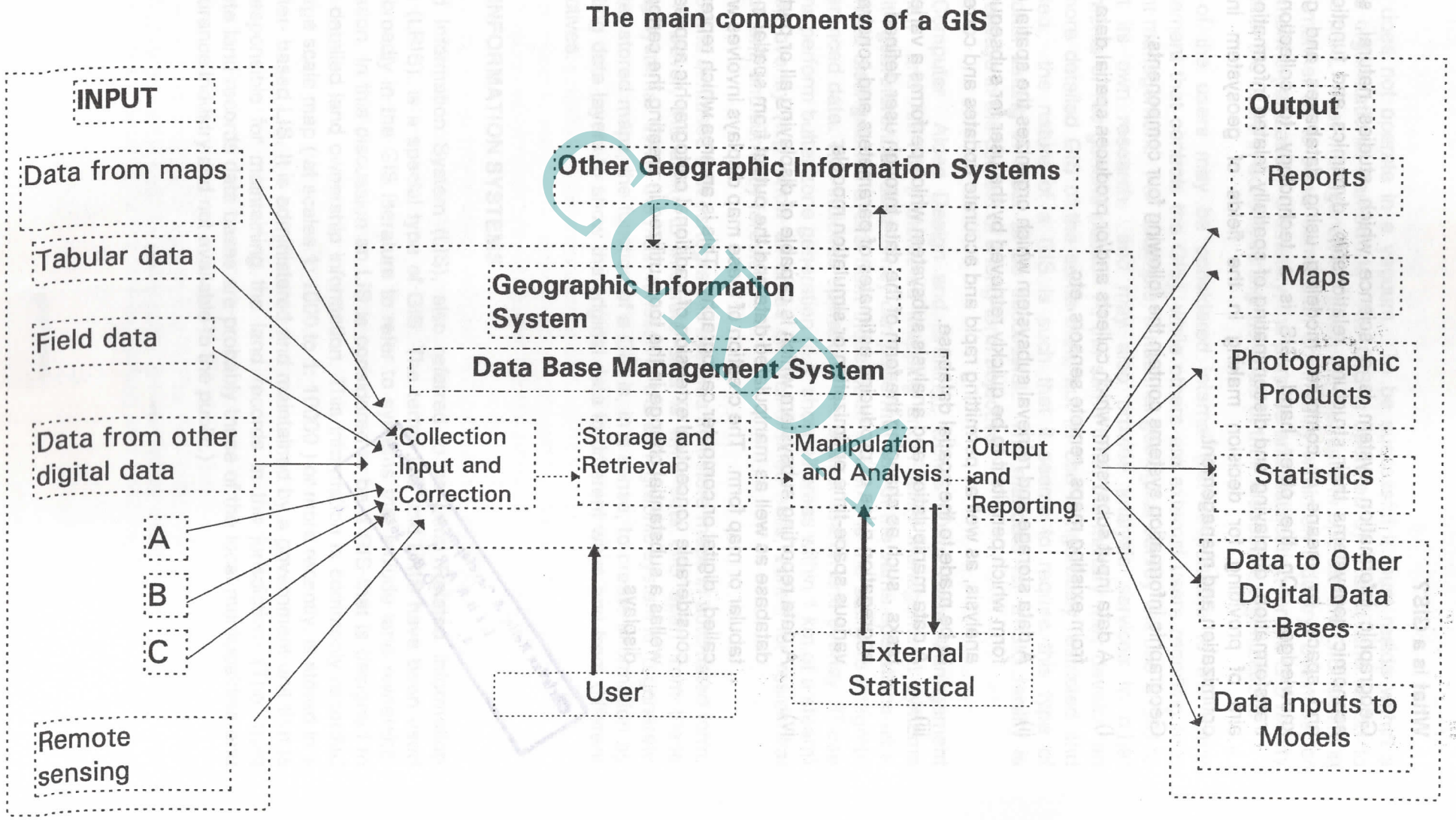
A third fundamental component to geographic information is time. The time component often is not stated explicitly but if often is critical. Geographic information describes a phenomenon at a location as it is existed at a specific point in time. A land cover map describes the location of different classes of land cover as they existed at the time of data collection. If the area is changing rapidly, this information may quickly be out dated. The information may then be unsuitable for decision-making that requires the current status of the land. However, the data may be invaluable for analyzing historical trends, such as the conversion of agricultural land to other uses. Yet the historical information about the tree species composition may be invaluable for preparing the forest regeneration plan.

Geographic data are inherently a form of spatial data. Geographic data can be represented on a map or in a geographic information system as either point, line, or area features. Points are used to represent the location of geographic phenomenon at a point or to represent a map feature that is too small to be shown as an area or line. The location of a city (on a small scale map), a mountain peak, or an airstrip could be represented by a point element. A line feature consists of an ordered set of connected points. Lines are used to represent map features that are too narrow to be shown as an area or features that theoretically have no width, such as political boundary. A share line, a contour line, a roadway, or an administrative boundary are examples of line features. An area feature is a region enclosed by line features. the geographic extent of a city, a forest stand, or a lake could be represented by an area element. Area elements are often represented in a GIS by a polygon. (A polygon is a closed plane figure bounded by straight lines). By making the straight-line segments small, curved boundaries can be closely approximated. The polygon shape is produced from curvilinear boundaries when the geographic information is entered in the GIS). Spatial data that pertain to a location on the earth's surface are often termed georeferenced data.

Taken in its broadest sense, a geographic information system is any manual or computer based set of procedures used to store and manipulate geographically referenced data.

CORDA

The fundamental components of a GIS and its environment are illustrated in the figure below.



CORDA

What is a GIS?

Geographic information system is a science which studies natural, social and economic geosystems their structure, relationship, dynamics and function in time and space, by means of computer modeling using databases and geographic knowledge. On the other hand, GIS is a technology to collection, storage transformation, displaying and disseminating of spatially related information with the aim of providing for decision making in the fields of geosystem inventories, optimization and management.

Geographic information systems contain the following four components:

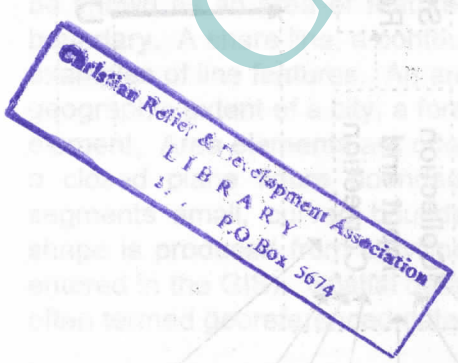
I) A data input subsystem which collects and/or produces spatial data derived from existing maps, remote sensors, etc.

ii) A data storage and retrieval subsystem which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and corrections to be made to the spatial database.

iii) A data manipulation and analysis subsystem which performs a variety of tasks such as changing the form of the data through user defined aggregation rules or producing estimates of parameters and constraints for various space-time optimization or simulation models.

iv) A data reporting subsystem which is capable of displaying all or part of the database as well as manipulated data and the output from spatial models in tabular or map form. The creation of these map displays involves what is called digital or computer cartography. This is an area which represents a considerable conceptual extension of traditional cartographic approaches as wellas a substantial change in the tools utilized in creating the cartographic displays.

CCRDA



A GIS does not operate in a vacuum. To be successful it must reside within a suitable organizational framework. The GIS is operated by a staff who report to management. That management is given the mandate to operate the GIS facility in such a manner as to serve some user community within an industry, business, or government organization. Ultimately, the purpose and justification for the GIS facility is to assist the users in accomplishing the goals of their respective organizations.

Some of the users may be considered internal (i.e. responsible to the same management that controls the GIS), while others are external users reporting to a different management. For example, a national geological survey will use a GIS to support its own research and may also provide analysis services to other departments or the general public. At the same time, the military may develop an even more detailed GIS of the same area, but its use is rigorously restricted and controlled. the nature of a GIS is such that it seems to require this type of institutional setting in order to be successful. The mandate for a GIS facility is almost always in the context of a long-term objective.

CAD (Computer Aided Design and Drafting), DBMS (Data Base Management Systems), and AM-FM (Automated Mapping and Facility Management) systems work with georeferenced data. They can perform many of the same operations as a GIS. What distinguishes a GIS from these other systems is the ability to integrate georeferenced data. This includes operations like spatial search and overlay. These functions perform butter zone generation (e.g. show all areas within 1 km of a steam) and map overlay (e.g. show all areas on well-drained soils, zoned for residential development, and currently forested).

Often GIS is confused with cartographic systems that store maps in automated form. Again, however, the ability to integrate data is what sets GIS apart from these mapping systems. While the main function of the cartographic system is to generate computer stored maps, the function of a GIS is, in a sense, to create information by integrating data layers to show the original data in different ways and from different perspectives.

CCRDA

LAND INFORMATION SYSTEMS

A Land Information System (LIS), also referred to as Land Related Information system (LRIS), is a special type of GIS. The terms LIS and LRIS have been used rather broadly in the GIS literature to refer to systems that include land ownership information. In this discussion an LIS is considered to be a GIS that is designed to handle detailed land ownership information. This information is commonly recorded on a large scale map (at scales 1: 1000 to 1: 10000) or more recently, is stored in a computer- based LIS. It is administered and maintained by a government unit that is legal responsible for maintaining the land records in the jurisdiction. (The most complete land records data bases are probably those of the local municipalities and the insurance industry and not available to the public.)

The official record of interest in land is termed the **cadaster**. It is the legally recognized registration of the quantity, value, and ownership of land parcels. A cadastral system, the system used to store and maintain the cadastre, consists of three components: these are as follows:

1. Records of cadastral parcels - the continuous areas of land (i.e. the land units) within which unique and homogeneous interests are recognized.

2. The cadastral record - the graphic (e.g. maps) and text information describing the nature and extent of the land interests.

3. the parcel index - the system for relating parcels and records.

A GIS used for municipal and regional level applications is typically structured as an LIS. The data base will usually include such data layers as the street network, location and attribute records for land parcels and lots, floodplain hazard, a base map, geodetic control (points for which accurate geographic co-ordinates have been measured), and utility networks (e.g. water and sewage facilities). A municipal LIS may contain on the order of 50 or more separate data layers.

Regional level LISes tend to include more natural resource and environmental data layers such as wet land conservation areas, ground water recharge areas, soil erosion control plans, land use, and zoning. These broad environmental information categories are more important in describing the actual interests in the land at the regional level of the government. Other data layers commonly included are land parcels, geodetic control, zoning, land cover, geology, geomorphology, elevation, hydrology, and soils. A number of zonal, regional, or federal jurisdictions may exercise regulatory control over an area. For this reason, the land parcel tends not to be a central a unit of reference in a regional level LIS as in a municipal one.

Utility companies often use automated mapping systems to maintain schematic diagrams of the facilities, such as telephone lines, power lines, and water systems. Often the diagrams are used for facility management applications alone and are not accurately referenced to geographic co-ordinates. This types of facility management/ automated mapping systems are not included in the term LIS as used here.

Land information systems integrate property rights information with information on the uses, values and distribution of natural and cultural resources. They are used for a wide variety of such applications as the maintenance of tax and parcel information, the analysis of changing land use, the scheduling of road maintenance activities, the maintenance of utility inventories, and the management of watersheds. The user groups range from emergency service co-ordinators and school boards to utilities, public works departments. planners, development agents, financial institutions and the general public. land information systems represent one of the fastest growing GIS application areas, largely because and LIS provides the only practical means to organize and integrate large volumes of land-related information. As more land information is converted to digital form, as legislation defines more stringent information requirements, and as the technology to support an LIS becomes less expensive and more powerful, the automation of land information will become a *defacto* requirement.

CCRDA

WHY USE A GIS ?

A geographic information system is a powerful tool for handling spatial data. In a GIS, the data are maintained in a digital format. As such the data are in a form more physically compact than that of paper maps, tabulations, or other conventional types. Large quantities of data can also be maintained and retrieved at greater speeds and lower cost per unit when computer-based systems are used. The ability to manipulate the spatial data and corresponding attribute information and to integrate different types of data in a single analysis and at high speed are unmatched by the manual methods. The ability to perform complex spatial analysis rapidly provides a quantitative as well as a qualitative advantage. Planning scenarios, decision models, change detection and analysis, and other types of plans can be developed by making refinements to successive analysis. This iterative process only becomes practical because each computer run can be done quickly and at a relatively low cost.

It is the spatial analysis capabilities of the computer-based GIS that distinguish it from related graphics-oriented systems like computer-aided design and drafting. The analysis of complex, multiple spatial and non-spatial data sets in an integrated manner forms the major parts of a GIS's capabilities. It is a function that can not be done effectively with manual methods or with computer-aided design and drafting systems. These spatial analysis capabilities of GIS together enable georeferenced information to be created and used in a completely different context than before.

Not only diverse data sets be integrated, diverse procedures can also be integrated. For example, data handling procedures such as the data collection, verification, and updating procedure can be integrated instead of compartmentalized into separate operations. At the time that data, such as a change of land registration or land use, are entered in the GIS, the GIS can check the accuracy of the changes, whether zoning and other restrictions would be violated, and update the relevant maps and tabular data. In this way, the users get more current information and can manipulate it to meet their specific needs.

THE GIS AND THE ORGANIZATION

As an organization becomes more familiar with a new system, people find new ways of getting a job done. They will develop analysis procedures different from those originally anticipated. While it is not possible to predict what these new methods will be, changes can be expected. The type and variety of functions provided by a specific system will influence the types of innovations that will occur. A system that excels in modeling functions, for example, would encourage the development of new analysis that capitalize on these functions.

There is also a tendency for the principal use of an information system to evolve. New technology tends first to be used by an organization to perform the tasks in the 'old' way using the new technology. Later, as familiarity with the technologies gained, new ways of providing the same functions are developed that more fully take advantage of the technology. Finally, new approaches are developed that take full advantage of the potential of the new technology and meet the information needs.

CCRDA

The new technology is used to provide new functions. In the case of GISes, the first applications tend to be inventory operations. Later the emphasis shifts to satisfying analysis and finally, management needs.

For this reason, the management environment of the GIS facility is perhaps the most important single factor in determining its success or failure. It is the organization that in the end determines whether the physical equipment or human resources will function as an effective information system. The provision of effective user services, from training materials to qualified consultants, is critical to the effective utilization of the benefits that a GIS can offer. Budgeting and organizing for user services often receive much less attention than they warrant. The organization must also be able to deal with political, financial, and technical issues on a continuing basis. A successful management environment will enable the organization to be flexible enough to change while continuing to satisfy its mandates.

GIS APPLICATIONS IN AGRICULTURE AND LAND USE PLANNING

Agriculture, the production of food, is of such national and economic importance that it is usually better inventories and monitored than other natural resources. Industrialized nations have well -developed national statistical reporting services that survey farmers, monitor growing conditions, and predict national and international market demand and supply.

Many food product companies that are dependent on large volumes of agricultural products have well developed in-house agricultural monitoring groups. They use a wide range of data sources including field reports, information on past production, meteorological satellite data, and the data from earth resource satellites such as Landsat and Spot. This data may be used in an analysis of relative production levels by comparing current with past years' crop condition. More sophisticated analysis may involve the use of computer models to simulate the growth of a crop using weather data (e.g. temperature, precipitation, and hours of direct sun) and land use information (e.g. farming practices and previous production levels). Much of this information can be obtained from the satellite observations.

At the national level, the monitoring of agricultural production has generally developed as a statistical reporting activity rather than a mapping one. The assessment of major agricultural areas is a well-developed science carried out by national agencies using procedures that were developed before powerful GIS software became available. Mapping activities are generally focused on soils and agricultural suitability mapping. They are important mandates assigned to national and regional government organizations.

Many of the organizations responsible for monitoring agricultural land use have now adopted GIS methods. Land use and weather data provided from satellites and field measurements as well as production information from previous years are analyzed together to predict for each region the expected yield of one or more crops. Often the procedure is repeated at regular intervals throughout the growing season as conditions change.

CCRDA

In addition to crop production, GIS procedures have been used to evaluate management practices for grazing lands. By tracking grazing type and intensity over time, and collecting data on vegetation condition and weather data, grazing practices can be assessed and improved.

It is perhaps at the local level that GIS technology will have the greatest effect on the way agricultural land is monitored. Relatively simple GIS techniques can provide a level of information processing that allows alternative scenarios to be evaluated, amended, and re-evaluated at a reasonable cost. The production of maps showing the coincidence of conditions important for planning and management, such as erosion control, environmental pollution control, and changes in land use, becomes relatively forward using a GIS.

Land use management and policy decisions are almost always based on the analysis of the interplay of factors pertaining to an issue. For example, the preservation of prime agricultural land involves political, institutional, and economic factors. A GIS can provide better information to support this type of complex decision-making. Such basic information as the distribution of current land use activities, the relationship of these activities to agricultural capability, land prices, and urban demand for land can be developed quickly using GIS tools. GIS technology can foster better decision-making by allowing managers to conduct analyses that would be impractical or infeasible otherwise.

A major issue in the adoption of GIS techniques for land use planning at the local level has been how to put the technology in the hands of the decision-makers. One approach has been to organize co-operative projects in which a potential user agency makes use of a facility operated by GIS experts. Another approach has been to bring the technology to the decision-makers.

CONCLUSION

Human societies have become increasingly dependent for the well-being on the ability to collect and analyze geographic information. The world is becoming more crowded and resources are becoming more scarce. A new urban subdivision, a mine, a power plant, or a waste disposal site are projects now scrutinized by diverse regulatory agencies and frequently subject to public opposition. At the international scale, nuclear fallout, acid rain, desertification, toxic chemicals, and deforestation have become widely recognized problems that directly affect the economic and social well-being of the global living population.

Organized spatial information is essential for good management, whether at local, regional, national or international level. In order to know how the resources of soil, water, minerals and people can most effectively be changed into sustainable goods and services for mutual, long-term benefit requires information about *where* the resources are, *how* they function and change in space and time and *how much* it costs to make them available to markets. The information on *what* the resources are, and *how* they can best be used must be both timely and relevant if it is to be of any value.

CORDA

Geographical information systems are a powerful resource for analyzing the interrelated systems involved in this types of problems. They provide flexible methods for exploring relationships among geographic data and assisting experts from diverse fields in pooling their knowledge to solve complex problems. Indeed, our success in dealing with many global environmental issues will depend on this type of multidisciplinary effort.

Using GIS technology, geographic information can be assembled and applied in new ways. The GIS offers a practical means to manage large and diverse spatial data bases and provides effective tools to understand the relationships among diverse phenomena. An increasing number of decision-makers and managers have recognized that GIS technology will be essential if they are to address the expanded mandates and complex decisions they now face.

GIS technology has developed at a remarkable pace over the past two decades. Yet, the technological changes have occurred much more rapidly than the institutional ones. We are only beginning to grapple with the many material, legal, and social issues that are accompanying the wide-spread use of geographic information system.

A NEW WAY OF LOOKING AT GEOGRAPHIC DATA

the printing press not only made the production of written material faster and less expensive, it revolutionized the way information flowed within the society. In a similar way, GIS technology has dramatically changed the rate at which geographic information can be produced, updated, and disseminated. Map updating tasks that required months of manual effort are now done in hours, and spatial analysis capabilities that were unavailable a decade ago are now common place.

The GIS has not only made the production and analysis of geographic information more efficient, it is changing the way geographic information is perceived and used. It is a technology that makes geographic data more malleable, more easily shaped by the user into the form best-suited to the application at hand. It makes geographic information more easily customized. In the past, a production of a special purpose map was a costly undertaking. Today a GIS can make the special purpose presentation of data quick and inexpensive.

The traditional map is like a "snapshot" of the geographic data from which it was compiled. It represents a set of geographic information, usually at a single point in time. The map is updated at infrequent intervals, owing to the cost and time to produce an updated version. For this reason, the map tends to be a standardized, general purpose product designed to serve as wide a range of users as possible.

In a GIS, the storage of the data is independent of the mode of presentation. The physical map becomes a relatively inexpensive output product that can be generated quickly and customized for a single application. In addition, the geographic database used to produce the map can be continuously updated. As a result, the physical map becomes a customized "snapshot" of a continuously changing geographic data base. It is a view of the data, selected and organized by the user to best serve the application at hand.

CGRDA

The processing of the GIS has also enabled geographic information to be used in a qualitatively different way. Complex analysis can be iteratively refined towards an optimum solution, an approach that would be prohibitively expensive using manual methods.

GIS TECHNOLOGY

GIS technology has continued to develop at a rapid pace. An ever increasing demand has created a competitive environment for producers of hardware and software. GIS technology has become less expensive and more reliable. Hardware prices continue to fall. However, software prices have tended to remain steady, reflecting the increasing cost of developing and maintaining ever more complex software.

The increasingly acknowledgeable user community has been a significant factor in the direction of technology development. GIS users are demanding that systems accept data in diverse formats from existing digital data bases, that they be easier to use, and achieve ever higher levels of performance. As a result, GISes have incorporated advanced graphics, more powerful computers, more competent data exchange and data base functions, and, in some cases, expert system techniques to reduce the operator's workload. Although important technology issues still remain, particularly in the area of data capture, current market forces are providing the necessary incentive to continue the fast pace of development.

DATA BASE CREATION

Perhaps the greatest technical impediment to implementing a GIS is the creation of the data base. It is difficult and costly undertaking to develop a suitably accurate data base from diverse error prone source materials. It is a task that commonly represents 75% or more of the total cost of implementing a GIS. Once the data base has been developed, there is also the substantial on-going maintenance cost to keep the data base current.

Much of the source material used to create the geographic database is in the form of paper maps. Manual digitizing remains a very versatile and important means of encoding paper maps. However, in many situations, scanning systems are providing a more cost effective means of data entry. the continuing improvements in scanning technology, particularly the introduction of expert system techniques, will further extend its use. There is also a steady increase in the use of digital methods in the data collection process itself, thereby eliminating the digitizing step entirely. Although the data entry problem is acute, it is one that eventually will lessen.

Unfortunately, the rush to digitize often compromises the need for a careful data base design. The creation of a large data base does not in itself guarantee that the data needed will be of adequate quality. Data can be simply dumped in to storage; they must be in a form that can be efficiently retrieved and analyzed. Also, the priorities used in creating the data base must take into account the user needs to be supported. This requires considerable planning by experienced and highly trained personnel - which are currently in very short supply.

CORDA

One of the perplexing problems in data base development has been justifying the considerable expense to create and maintain it. It represents a significant investment with an undefined asset value. the value of the data being collected and the information produced is largely unknown. To develop a more rational means of setting data capture and analysis priorities, a realistic measure is needed of the value of GIS data and their actual effect on final decisions.

OVERCOMING INSTITUTIONAL BARRIER

It is the political and institutional issues more than the technical ones that have been the major obstacles to the introduction of GIS technology. A GIS is not "bought", it evolves and becomes part of the information system of an organization. Its introduction fundamentally changes the way an organization can and will use data. It affects the political power structure of the organization as much as it affects the mechanics of work. Managers need to understand not only the principles of the GIS technology they use, but also the associated social, economic, and political issues. For example, the digitizing of maps can involve enter-agency negotiations to share data costs, issues of data ownership and copyright, and consideration of legal liability and individual privacy rights.

The implementation of a GIS with its diverse data sets, all accurately registered, and with the analytical power to serve multiple organizations is very costly and long term undertaking. It is a project with large up-front costs and future benefits that are difficult to quantify.

In most cases co-operative agreements among government agencies and with the private sector have enabled conversion costs to be shared and quality standards to be set. However, the considerable administrative overhead to initiate and manage data sharing agreements has proved to be a significant obstacle. As a result, there is an incentive for individual public organizations to minimize their digitizing efforts and maximize their use of publicly provided data. Co-operation among government agencies has been more successful in the sharing of GIS expertise and existing digital data.

The demand by local levels of government, such as municipalities, for geographic data in digital form has put pressure on mapping agencies to speed up the digitizing of the geographic data. It has also led some users to generate their own data sets. While this may solve their immediate short-term information needs, it compromises longer-term objectives.

These short-term solutions have tended to undermine efforts to share data conversion costs and to standardize data formats and quality. Instead, the data collection effort is duplicated and the data quality and compatibility issues are handled on an *ad hoc* basis. This tendency has been particularly evident in land information system application at the municipal and local levels.

CCRDA

For example, utility companies and departments of public works have proceeded quickly in converting land records into digital form and implementing a GIS to manage them. They have tended to proceed more quickly than the agencies actually responsible for the land records. Strong institutional incentives are needed to encourage co-operative, long-term perspectives in the creation and maintenance of GISes.

Traditional concepts of data ownership have also been an impediment to the introduction of GIS technology. For example, there is often for individual departments or organizations to think of data as "their data", when, in fact, the data were gathered at the expense and for the benefit of a larger constituency. It is sometimes difficult to shift this perception to a view of the GIS data base as a "corporate resource" to be managed primarily for the benefit of the entire user constituency it was created to serve, not for the convenience of the data base custodian. Controversy over control of data has compromised many GIS implementation efforts.

Bibliography:

Aronoff Stann, "A Geographic Information System from Management Perspective".

Burrough Peter, "Possibilities and Constraints of GIS Applications in Developing Countries".

Fikru Yifter, "Soil and Landscape Information System from Users Requirement Perspective".

CCRDA

Part IV

14. Conservation Based Agricultural Development: A synthesis

14.1 Agricultural Development Strategy

A Development strategy is defined as "a mix of policies and programs that influences the pattern as well as the rate of growth." (Johnston and Kilby, 1975). Any strategy for agricultural development will embrace some combination of (a) programs of institution building related to such activities as agricultural research and rural education and farmer training, (b) programs of investment in infrastructure, including irrigation and drainage facilities and rural roads, (c) programs to improve product marketing and the distribution of inputs, and (d) policies related to prices, taxation and land tenure. The efficiency of a strategy will depend in part in promoting optimal use of available resources, and still more on modifying existing constraints.

The efficiency of an alternative strategies should be assessed in terms of their contributions to attaining three major objectives: the first major objective of an agricultural strategy focuses on the need to achieve a rate and pattern of output expansion in the agricultural sector that will promote overall economic growth and structural transformation and take full advantage of positive interactions between agriculture and the other sectors. This objective encompasses what has often been referred to as agriculture's "contributions" to development.: (a) providing increased supplies of food and raw materials to meet the needs of the expanding non-farm sectors, (b) earning foreign exchange through production for export, and (c) providing a net flow of capital to finance a considerable part of the investment requirements for infrastructure and industrial growth.

The second objective is that of achieving broadly based improvement of the welfare of the rural population. This is especially important in countries such as Ethiopia because the majority of the population is destined to live and die in farming communities. Achievement of that objective depends in the long run on altering the predominantly agrarian structure of these economies. The possibility of enlarging the income of the agricultural sector, and still more of the average income of farm

CCRDA

household, is determined mainly by the rate and character of structural transformation, particularly as manifested in the decline of the relative and eventually, absolute size of the farm work force and the associated growth of commercial demand for agricultural products.

The third objective is fostering a pattern of agricultural development that will have a favorable impact on social modernization as a result of inducing changes in rural attitudes, behavior and institutions.
Agricultural development strategy can take either what is commonly known as "unimodal" or "bimodal" strategy.

Because of their structural and demographic characteristics, countries like Ethiopia face a fundamental choice between a strategy aimed at the progressive modernization of the entire agricultural sector and a crash modernization strategy that concentrates resources in a limited dynamic sector, what is commonly known as the "modern sub-sector."

In the last four decades, in the face of the ever growing food demand, poverty and poor performance in economic development in the developing world, governments focused on economic growth. This made possible an increase food production on a large scale. The agricultural revolutions enabled 2.5 fold increase in food production since the 1960s in the developing countries, though Africa's performance in per capita food production failed at an average annual level of 1 %. (Auslandskurier 2/1993: 43).

Though countries and regions came to record successes in the field of food production and economic growth, this was attained at the cost of social marginalization and massive environmental degradation. It may be the ultimate irony that, in our efforts to make the earth yield more for ourselves, we are diminishing its ability to sustain life of all kind - humans included. Cropland is scarcely expanding anymore, and a good portion of existing agricultural land is losing fertility. Grasslands have been overgrazed and fisheries over harvested, limiting the amount of additional food from these sources. And natural forests - which help stabilize the climate, moderate water supplies and harbor a majority of the planet's terrestrial biodiversity- continue to recede. (Postel: 4).

CCRDA

Attempts at rural development have followed the sole aim of attaining modernization, and this has proved unsuccessful. Specially in Africa, there is still mass poverty and hunger and increased food imports, and environmental deterioration.

The visible and impending environmental impacts has forced us to recognize that the environment consists of scarce and exhaustible resources and growth and higher standards of living are associated with high resource depletion and environmental degradation.

Focusing on environmental factors, it has become evident that ordinary economic institutions do not provide any incentives for furnishing such resources or commodities or for using them efficiently if they occur naturally. In particular, resources in the environment, which no private person owns, tend to be used heedlessly, with results that are all too obvious. This does not however, lead to the conclusion that more extensive private ownership is the solution to our environmental problems, though it makes us aware that there exists an essential relationship between these two variables: the question of ownership and environmental problems. This has to do with the fact that, firstly, the resources that make up the environment are unsuitable for private ownership because they lack the 'excludability property', i.e. it is typically not practical to exclude people from benefiting from them, either because of physical impossibility, or because controlling access would be inordinately expensive or cumbersome, or because limiting access would be socially unacceptable. (e.g. atmosphere, public roads, waters, forests, beeches, etc.). Another peculiarity of environmental resources is that there are likely to be enormous economies in the joint consumption or use of the resource as contrasted with individual use.

The difficulty that this common use creates is that each user may interfere with the others, reducing the serviceability of the resource to them; moreover, he has little incentive not to do so. This what is known as the general phenomenon of externalities. An externality occurs whenever the activities of one person affect the welfare or production function of other people who have no direct control over these activities. We have to decide both what we want and what means to use for.

CCRDA

Though environmental problems do have a global character, the nature and magnitude of these problems differ in different regions of the world. In sub-Saharan Africa, severe land degradation and desertification is taking of unprecedented magnitude affecting the productive performance of a whole set of countries, exposing them to recurrent drought, famine, migration and conflict. This is more evident in Ethiopia.

CCRDA

14.2 Development and Natural Resource Conservation: Policies and strategies

As indicated above, during the past 50 years, agricultural development policies and practicies have successfully emphasized external inputs as the means to increase food production.

These external inputs have, however, tended to substitute for natural processes and resources, rendering them more vulnerable. Pesticides have replaced biological, cultural and mechanical methods for controlling pests, weeds and diseases; inorganic fertilizers have been substituted for livestock manures, compost and nitrogen-fixing crops; information for management decisions comes from input suppliers, researchers and extensionists rather than from local sources: machines have replaced for labour: fossil fuels have been substituted for local energy sources. (Pretty 1995)

As in the past decades the satisfaction of the ever growing demand for food, in the face of deteriorating and dwindling resource base in the world, the question of sustainable agricultural development has increasingly drawn the attention of world community.

Sustainable development, a, rather controversial, concept introduced by the World Conference on Environment and Development (WCED) by the Brundtland Commission in 1987, attained international attention and acceptance. Here the term is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1978). That is to say it constitutes the utilization and conservation of natural resources in achieving technological and institutional changes in such a way that it ensures the steady satisfaction of human needs of the present and future generations. Such development in agriculture, forestry and fishery which at the same time conserves land, water and genetic resources of flora and fauna is ecologically sustainable, technically and economically feasible and socially fair. (FAO, The State of Food and Agriculture 1989: 65). In general terms sustainable development implies the continued improvement in living standards, particularly that of the poor and underprivileged groups, which implies increased consumption of resources. Development

CCRDA

and increase in productivity are supposed to be the way outs to environmental degradation. Though it seems a paradox, environmental problems can be solved if it is possible to rashly increase productivity. Then ecologically not sustainable areas could be relieved out of production. So it is implied that the present levels and methods of production and resource exploitation should not degrade the environment to the point that resource availability in the future will decline.

Since living levels are related to environmental factors unrelated to economic or physical resource yields, including the availability of clean air and adequate living space, and in many circumstances, people's ability to maintain spiritual, cultural or aesthetic relationship with their environment. This definition, therefore, implies that ecosystem conservation plays an important part in sustainable development.

Finally, the question of traditional resource management must be incorporated in development concept: in many cases, traditional ways of interacting with the environment provide a fundamental basis to community's well being, and the abolition or preservation of traditional lifestyles, besides being a good basis for conservation, thus becomes a human right issue. When cultural and social identity is inextricably bound up in traditional forms of resource use, and when such communities desire to maintain this identity, resource management policy decision should not be made only on the basis of which system will provide maximum economic yield (Vivan 1991:10). It is also important, however, not to idealize all indigenous practices or communal societies.

To sum up, resource management and increase of productivity must be synchronized for without an efficient resource management there cannot be any sustainable development. Making natural resource management concerns an integral part of economic and social policy is of great practical importance to development. In this case developmentalists should increasingly recognize the importance of preserving natural resources if development is to be sustainable and similarly conservationists should accept the fact that without development preservation is not possible.

CCRDA

The issue at stake is how to ensure development that is dynamic as well as sustainable? For any development to be sustainable it need to be initiated and promoted by the resources users, have technologies that are relevant, dynamic and economically rewarding. It requires huge public commitment and investment. Finally, it calls for an integrated approach in development.

14.2..1 Community Participation and empowerment

One of the main reasons why 'conventional ' development approaches have failed is that have tended to ignore the resources users, the local knowledge systems and practices. Today there is a consensus on the need to see development in terms of long-term sustainability. This has led many people to argue that in order to ensure a more socially and ecologically sound approach to development, it is necessary to understand, respect and utilize the local knowledge systems. This could be attained by giving due respect and attention to resource users to participate in whole development effort.

The voluntary participation of small holders in the development process is a prerequisite for success of most interventions, and is of value in its own right. (Ruthenberg 1985: 120). A principal reason for most project conservation work to late being so short lived is that land users have been either being ignored or instructed, rather than consulted or trained. As chamber indicated:

> Soil conservation programs ... have provided examples of arrogant ignorance and insensitivity, of imposing standardized bad practice on rationally resistant small farmers. Often 'we' - professionals - have been confident that our bookish education has given as superior insights, that "we" know and "they" are ignorant, that "we" should plan for "them" that our packaged technology from research stations and laboratories are superior; that in short we know best and they know worst. But the ignorance has been ours".(1991:2)

As a result the usual approach in such development efforts has been more of imposition than involving farmers in the whole process. Farmers usually respond to such "top-down" approaches with indifference,

CCRDA

incomprehension or hostility. True participation of the grass roots is indispensable for such intervention to be successful. but what do we understand by (genuine) participation?

Participation is a process of providing people with the opportunity to take an active role in decision making at all stages of identifying designing, implementation, monitoring and evaluation of programs/projects that are intended to affect their lives. It is concerned with allowing people's involvement in decision making process about what would be done and how; their involvement in implementing programs and decisions by contributing various resources or cooperating in specific organization and activities; their sharing of the benefits of development and in efforts to evaluate such programs. Genuine participation, hence, goes beyond the mere provision of labour and other inputs (thought it is often reduced to it), it involves decisions being taken and plans being formulated on the local level. In soil and water conservation, participation means placing primary emphasis on motivating individual farmers, and providing them with the means to adopt good land use and conservation practices. Participation in soil and water conservation is usually seen as a voluntary contribution by people within the community in achieving the planners' conservation objectives and the project's predetermined targets. It is a passive exercise, externally initiated and directed by the project staff. More often than not, people are asked or dragged into partaking in operations of no interest to them, in the very name of participation.(Rahnema 1992).

At best only the community leaders are involved in the problem analysis and project design stage. Their involvement is usually limited to providing information initially, and subsequently explaining the project to the community. Such approaches, though important to rapidly mobilize labour, which often is a major constraints in implementing soil and water conservation measures, the participatory spirit will die no sooner the project is complete so that the maintenance activities are completely neglected.

Farmers are usually reluctant to participate in such intervention measures, and this can be explained by a lot of factors the main of which are structural reasons (tenure insecurity, policy neglect of agriculture or small farmers) and their alienation as a result from the whole official

CCRDA

development strategy. Moreover, soil conservation measures are required to encounter processes of erosion and degradation that take place over long periods. This entail immediate costs and the likelihood of their collecting the long-term benefits is small. An individual normally differs from society in his time horizons; by taking a more limited view. There can thus be an inherent conflict between the individual's and society's interest in countering these processes. In addition, externalities seem to be involved (e.g. overgrazing-negative effects shared by the community where as the individual benefits through grazing of his animals). Hence whether land users are able and willing to engage in soil and water conservation depends in a range of often interrelated aspects, such as incentives, land tenure, labour availability, the selection of techniques, training opportunities, the impact of conservation techniques on yields, crop prices and the economic position of the land users. Then land users may get such benefits to their participation as :

- the construction of conservation works in private fields,
- yield increases,
- the improvement of skills as a result of training provided by projects,
- shorter distance to cultivated land, if those near villages are rehabilitated,
- shorter distance to fuelwood, where rehabilitation programs include successful plantings near village, etc.

Like other rural development activities, soil and water conservation may in some circumstances increase economic differentiation between groups of land users (poor households, women-led households). The challenge is to design interventions and techniques which not only raise production for the rural majority, but also give special recognition to the constraints surroundings the poorest groups.

Farmers leadership not only ensures that all the good elements of agriculture that were known and used in the past are maintained, but it also advance their empowerment.

One of the main objectives of agricultural support institutions must, therefore, be greater involvement with and empowerment of diverse groups of people, as sustainable agriculture is threatened without it. (Pretty 1995)

CCRDA

14.2..2 The role of the public sector

Environmental issues, in contrast to other issues requiring economic decisions, cannot be solely solved by the market, or market forces.

A market is an arrangement by which buyers and sellers of a commodity interact to determine its price and quality. In a market system, everything has a price - each commodity and each service.

A market system contains an internal logic. It works. A market economy is an elaborate mechanism for unconscious coordination of people, activities and business through a system of prices and markets. The market relies on supply and demand to solve the trio of economic problem whereby prices provide important signals to market participants and thereby affect resource allocation decisions. It could squeeze the maximum amount of useful goods and services out of the available resources.

But markets does not always behave perfectly. Markets suffer from monopoly and pollution, along with unemployment and inflation, and income distribution in market economies is found unacceptable. This phenomenon is described by the concept "market failure" which denotes the inability of private markets to deliver all the ingredients of development, taken together with the non-working imperfections conditions and that state's action is considered necessary to overcome. These market failures are:

- Failures of Competition (due to monopoly);
- Failures of Provision (Case of public goods), etc.

This calls for government interference and this necessity is more pronounced as regards environmental problems. The reason why there is a necessity for high government interference in natural resources management is reflected in some economic concepts such as externality, open access resources and common property regimes, public goods, etc., concepts which are closely associated to natural resource management.

CCRDA

14.2.3 Incentive policy instruments

In the view of the attitudes of farmers about land degradation the measures initiated to tackle such problems and the constraints farmers have, it is important that farmers receive incentives that encourage them to adopt technologies that conserve resources and simultaneously increase yield. Incentives to soil and water conservation, for instance, could take different forms depending on the nature and site of these regenerative measures. That is to say, a useful distinction between conservation by individual land users on their own lands and conservation activities collectively undertaken by villagers on communal land is necessary. In the case of individual used land training is a good stimulus in itself and small implements in order to improve the quality of their work and to facilitate the rate of conservation. Provision of inputs such as seeds and inorganic fertilizer, at a subsidized price for that matter, to enhance first season benefits may be a justifiable incentive. In the case of collective conservation of communal land, food aid could be provided is year of food shortages. other forms of incentives as community infrastructure water wells, health center, tools, fertilizers during no food shortage seasons are important.

The issue of incentive in soil and water conservation measures or other development efforts is essential in the sense that such incentives help encourage farmers to actively participate in such endeavors. But especially food-for-work programs have also other unwanted effects: the tendency of creating a certain dependency farmers on the food they acquire from such measures and the neglect of agricultural activities which may have adverse long-term effects. Moreover, if land users are given any form of payment to conserve their land and water, they tend to assume that government will also be responsible for maintenance of what has been constructed, either by paying them or by undertaking maintenance itself. They regard themselves as labourers than as participants. (IFAD 50). And this may be accompanied by the feeding that the "treated" areas/closure areas, forestry areas, etc.) to belong to the government than to themselves. This feeling is exacerbated when there feel insecure about their tenure rights. Hence, another way of creating incentives to farmers to undertake conservation measures is to create favorable macro economic climate (includes secure tenure patterns,

CCRDA

fair pricing policies, emphasis to far agriculture - lead development strategy, etc.) to farmers.

14.2.4 Economic considerations

Alternative demands on time, labour and others productive resources must be set aside alongside that of adopting technologies, and the ratio of these costs to their social and economic benefits compared. In some cases this implies a comparison of agricultural production (and the conservation and management practices that support it) with off-farm economic opportunities.

To the extent that they can be valued, the price response of farm input and produce markets to new input demands and higher yields must be taken into account. Such efforts involves physical structures like terraces, land users consider maintenance costs as well as construction costs. Hence, in determining appropriate execution methods, it is necessary to consider the long term viability of conservation works and their direct impact in improving the welfare of resource users. In general, the higher the costs per ha, the smaller the chances that they techniques will be adopted by land users. (IFAD 1982: 60).

An important dimension to cost - benefit analysis resource conservation measures should be the calculation of the economic, social and political costs of doing nothing. (IFAD, Ibid.). There include agricultural production decline, migration costs, future costs of famine relief, urban infrastructure and the down stream damage of flood and silt deposition, etc. In this case surrogates and shadow pricing can be utilized, while in turn presupposes a systematic collection of data about costs and benefits. Monitoring and evaluates activities should be initiated timeously and given thorough technical support and supervision.

CCRDA

14.2.5. Integrated agriculture

From what we have seen so far sustainable development requires more than the preservation of traditional resource use systems or the application of external high input. "Both overstretched traditional systems and green revolution high input, high output regimes, are now being recognized as not having the best long-term solutions for feeding growing populations and managing natural resources." (Lightfoot 1996).

The importance of integration is the general need for a much more productive form of farming that will also conserve the natural resource base. Hence, integrated agriculture, as the future form of farming, is not just an option but an imperative. (Lightfoot 1996).

CCRDA

Technical proposal for training of trainers on sustainable agriculture in semi-arid lands for CCF Shashemene project

Background

In country like Ethiopia where 85% of the population earn income from agriculture, economic development cannot be expected without the development of the agricultural sector. The performance of agricultural sector in Ethiopia has been very disappointing over the past three decades. The agricultural production (crop and livestock) has not kept pace with ever increasing human population. As a result, the country remained food insecure and has been dependent on food imports and relief assistance.

The reasons for declining agricultural production are many and complex. These include unreliable rainfall (erratic pattern and timing), declining soil fertility (land degradation) due to erosion and deforestation, technological backwardness in the peasant agriculture, fragmentation of land holding and lack of draught animals. Mitigating land degradation and increasing agricultural production is a major national concern. But the issue is not something to be left to the government alone, but it is one that requires concerted actions by all professionals, NGOs, civil society organisations and the community at large.

Christinan Children Fund (CCF) is an international non-profitable humanitarian organisation serving needy children and their families. The agency has been working in Ethiopia since 1971. Among the various rural development projects currently implemented by CCF is the Shashemene area project located in the East shewa zone of the Oromiya regional state.

CCRDA

The project and the need for training

Shashemene woreda is characterised by arid and semi-arid climate with average temperature of 26°c and a mean annual rainfall of 750 mm. The average land holding is about 1 ha/family. Maize is the major food crop and co-staple with other cereals. However, maize yield has been too low (19 q/ha) which is far from being adequate to feed farm families (average size of 5.5 persons).

The major constraints on crop production are shortage of moisture due to low rainfall, declining soil fertility as result of deforestation and soil erosion and traditional nature of crop production especially lack of improved (drought resistant crop varieties) in that order. To this can be added the lack of farmers' access to inputs and agricultural knowledge of improved agricultural practices which hindered adoption of improved cultural practices.

material. The thematic areas are identified on the basis that growth in agricultural production in drylands can be achieved through combining three elements:

- Soil fertility enhancement through integrated soil management strategies)
- Soil moisture availability (moisture conservation, water harvesting using appropriate farm tools, etc) and
- Soil conservation (physical, biological and agronomic measures)
- Use of improved crop varieties (early maturing, drought tolerant and high yielding)

A general outline of the course contents in each thematic area will be as listed here under (although subject to addition or adjustments for maximum impact in consultation with the client):

Concepts of sustainable agriculture

- Introduction and definition of conceptual terms
- What is sustainable agriculture (features and components)
- high vis-à-vis low external input agricultural systems
- Sustainability and farmers (the farm as a system, decision making at farm level, productivity and food security objectives of farm households, etc).
- Farming systems in semi-arid regions.

Soil fertility management for sustainable agriculture

- Basic concepts and principles of integrated soil fertility management
- Application and management of mineral fertiliser
  - Role of fertiliser in food production
  - Fundamentals of fertiliser application
  - Application of right type and amount of fertiliser at the right time
  - Designing and conducting participatory on-farm fertiliser trials to adapt recommendations to local conditions.
- **Management of organic sources of fertility**
  - Advantages of organic manure (improvement of the physical and chemical properties of the soil such as increased organic matter conetent, erosion control, nutrient retention from loss, etc.
  - Use and management of animal manure for soil fertility maintenance.
  - Crop residue restitution for soil enhancement
  - Methods of compost making and application of compost (composting techniques, compost materials)
- Legume rotation, intercropping and fallowing for soil fertility enhancement

Soil and water conservation

- Soil erosion factors (rainfall erosivity, soil erodibility, topographic factors, cover crops and land management).
- Physical soil conservation measures or earth structures (terraces, bunds, cut off drains, etc)

CCRDA

- Biological measures (vegetative barriers such as grass strips and hedge row, surface cover with living plants or plant litter or mulching, cover cropping)
- Agronomic measures maintaining soil resistance to erosion (minimum tillage, manure application, residue or grass mulching, intercropping, rotation).
- Tied ridges for soil moisture conservation and fertility enahncement.
- Agroforestry (alley cropping with multi-purpose legume shrubs such as sesbania and leucaena, plaanting trees on erosion-control structures, etc).
- Catchment protection (up stream vis-a-vis down stream management).

Introducing and testing improved crop varieties

- Methods of on-farm verification and multiplication of seeds of improved crop varieties such as early maturing and drought resistant varieties of maize.
- Farmer-led research process (planning, implementation, evaluation and dissemination).
- Layout and design of participatory on-farm variety trials for identification and selection/screeining of suitable varieties.

Water management

- Water harvesting and surface water control techniques
  - Principles of collecting and using precipitation or rain water (from roofs of individual houses, ground catchment, etc).
  - Collection and storage of surface or farm water (runoff or creek water).
  - Flood water harvesting (large bunds, diversion structures, etc).

- Small-scale irrigation (river diversion, construction of earth dams, etc) to increase the number of crop harvest per field per annum and subsequently secure household food supply.
- Tied ridges, improved land preparation.

These topics plus some sessions on farm tools for soil and moisture conservation and participatory approaches will be covered in $5^{1}/_{2}$ days of training. The programme structure and training schedule will be prepared in due course.

Methods of the training

The TOT participants are to be prepared for participatory training process with farmers. This requires visual and experimental methods to increase participants' understanding of sustainable agriculture practices, rather than presentation of mere facts. The underlying principle to followed is that if participants' attitudes are challenged and changed through participatory process, they are more likely to change their way of extension work with farmers. To this effect, the training approach will be more participatory and interactive, although course facilitators will prepare a structured programme and course material.

CCRDA

Christian Relief ... Association
P.O.Box 5674

A combination of participatory techniques/methods such as PRA, role-plays and visual methods (slide and video shows, transparencies, pictures and flip charts) will be used during deliberations of each session. Facilitators have adequate knowledge and practical experience in participatory approaches. Lectures will be used to outline key issues which will then be followed by question and answers and group discussion after each session. Good facilitation will be required to encourage group learning, experience sharing by participants. Presentation of case studies and simulation exercises in the plenary will be used for reflection of personal experience of the participants. Formal training in the class will be supplemented by practical fieldwork in the CCF Shashemene project area.

Professional inputs

The core professionals required for the study will include well a soil and water conservationist, an agronomist (soil fertility specialist), an agricultural engineer with adequate experience in water harvesting and farm tools and machinery expert (an agro-engineer as well). Research and development consultancy together with another sister firm, namely, sustainable development associates has identified professionals with appropriate academic qualifications and work experience and who are agreed to be available for the proposed training. These are summarised in table below and their C.Vs are attached here with for detailed information.

Name of consultant	Area of specialisation	Role in the training

Dr Eyasu Elias (Ph.D in agronomy/soil science and specialist in sustainable agriculture), Ato Amare Muguro (M.Sc. in conservation and land reclamation engineering with special experience in water harvesting), Ato Andualem Taye (M.Sc. in soil conservation and land management) and Ato Melese Temesgen (M. Sc. in agricultural engineering with special experience in farm tools). The professional experience

CCRDA

As one of the development actors working in the area, CCF identified farmers problems and provides agricultural support services to farmers such as agricultural extension and training. The present training proposal is designed to train farmers on techniques and practices of sustainable agriculture in sem-arid land to achieve family food security.

The major components or thematic areas to be covered by the training include:

- Concepts and philosophy of sustainable agriculture.
- Soil fertility management practices for sustainable agriculture.
- Soil and water conservation, which also includes soil moisture conservation practices;
- Water harvesting and utilisation techniques such as surface and roof water harvesting, etc
- Introduction and dissemination of improved (drought tolerant) maize varieties.

Understanding and appreciation of the TOR

The terms of reference (TOR) describes the need for the training, its objectives, expected outputs and the various training activities to achieve those outputs. The primary objective of the training is to improve the understanding of CCF Shashemene project staff and the development agents of the woreda office of agriculture on concepts of sustainable agriculture and the various agronomic and land management techniques for sustainable production. The planned training is said to be training of trainers (TOT) and the participants are expected to conduct further training with farmers. So, it is expected that the TOT participants (about 30 of them) will be equipped with practical skills and participatory training techniques to conduct further training with farmers.

Although the objective of the training is to provide participants with hands on experience on practical aspects of sustainable agriculture techniques suited for semi-arid areas, brief sessions on participatory approaches and appropriate farm implements particularly for soil and moisture conservation will be included in the training.

CCRDA

Christian Relief & ... Association
... P. ...

Expected outputs

The expected outputs of the training course are:

- Improved knowledge and understanding of the trainees on sustainable agriculture concepts and semi-arid farming techniques to achieve sustainability.
- Handouts and/or TOT manual will be developed for use by participants in their future training programmes.
- Participants are acquainted with some participatory approaches of training.

Course content

The various thematic areas to be covered during the training course are as mentioned above, which will eventually comprise the major chapters of the training