Present and future trends in natural resources management in agriculture: An overview

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Abstract

Agriculture is the backbone of the Ethiopian economy engaging more than 85% of the population and accounting for nearly 52% of the country's gross domestic product (GDP). Natural resources like land, water, vegetation, climate and topography and relief play a significant role in the success of agriculture. As a result of population pressure, climate change and poor management of natural resources, components of this sector have been threatened by chronic degradation, recurrent droughts, shortage of skilled manpower and improved technologies.

Efforts have been made to combat natural resources degradation by generating technologies in soil and water conservation and re-forestation, but the result was gloomy because of different reasons. Emphasis to develop the water resource was given top priority only in recent years. The potential for irrigated agriculture is estimated at more than 3.7 million hectares. The major direct threats to the development of water resources for agriculture in Ethiopia include sedimentation of rivers and water reservoirs, reduced infiltration and recurrent drought. The Ethiopian Agricultural Research Organization (EARO) has formulated a strategic research plan for the sector on its mandate area and also for setting priorities to generate technologies for different agro-ecologies. Emphasis is given to water harvesting *in situ* and *ex situ* and the management of irrigation water and drainage at all levels.

Background

Agriculture accounts for more than 85% of the country's work force, 51.6% of the gross domestic product (GDP) and 90% of export earnings (CSA 1999). Proper management of some of the natural resources is vital for the healthy development of the sector.

The country's economic development policy aims at:

1. ensuring food security
2. increasing production of sufficient export products

3. increasing supply of raw materials for the local industries and,
4. ensuring conservation-based development of natural resources.

In recent years, agricultural development has been highly affected by mismanagement of the natural resources. The Ethiopian highlands where most of the population lives have undulating topography and relief. Although stressed by high population density, the highlands have relatively better moisture, economic activities and infrastructure. The lowlands (<1500 metres above sea level, masl) have low and erratic rainfall and, hence, low soil moisture and severe erosion, as well as vector-born diseases that affect both humans and livestock. However, the lowlands have very high potential for the development of irrigated agriculture if water is available and infrastructure can be improved.

Trends of vegetation cover

There is no reliable figure on the trends of forest cover in Ethiopia. However, as some historical sources indicate high forests might have once covered about 35–40% of the total land area of the country (EPA/MEDaC 1997; EARO 2000a). Deforestation accelerated towards the beginning of the 20th century and in 1960, closed natural forest was estimated to cover only about 3.37%. It is believed that, in Ethiopia, agricultural activities must have started about 5000 years ago (EPA/MEDaC 1997) and wide spread deforestation started about 2500 years ago (Hurni 1988). In 1981, the estimated rate of deforestation stood at 200 thousand hectares per year and it is expected that this figure will be much higher today and may continue like this unless some alternative options are made available to the rural population. It has been estimated that high forests covered 16% of the land area in the early 1950s, 3.6% in the early 1980s (IUCN 1990) and only 2.7% in 1989 (EARO 2000a).

There are convincing indications of a downward spiral of forest resources degradation. Some of these are:

1. persistent deterioration of the quality of cultivated land
2. expansion of gullies
3. poor yield
4. poor water holding capacity of the soils, and measured/estimated values of the annual soil loss due to erosion ranging from 10 to 130 t/ha, with a generally accepted average of 42 t/ha (Hurni 1988).

Some re-forestation activities are underway but compared with the deforestation that is taking place it is only a small percentage and most of the replanted species are eucalyptus and cupressus with very low replanting of indigenous species. Re-forestation is a planned activity with a targeted area to be covered each season whereas almost every household in the rural part of the country does cutting of trees as it wishes. Compared with the long years tree species take to reach a productive stage on degraded environment and against an increasing demand and the slow effort in re-forestation, the future for vegetation cover is gloomy.

Sustainable smallholder land and water management

Traditional small-scale irrigation innovations

Because of increasing trend of population growth in the last six decades, (from 17 million in 1940 to 63 million in 2000) (EPA/MEDaC 1997), and increased exploitation of land resources, the balance of water resources has also been negatively affected. Although traditional small-scale irrigation practices existed in a few places, scaling-up activities must have started since the 1960s. The traditional irrigation practices by the farmers have some setbacks like:

- high labour requirement to build canals
- loss of productive land due to soil and stone ridging as well as tree cutting for construction purposes
- gully formation as a result of deep canals
- lack of water control to each canal resulting in poor water distribution to the stakeholders
- because of the lack of extension advice on water management, the impact from such practices has been small and should be improved through improvement of the technologies.

However, farmers use simple tools available at their disposal. Today some small-scale irrigation plot owners use watering cans or hoses water plants from the water source. Farmers growing some high cash crops and living near market centres use small pumps and generators to raise water to higher points for gravity application.

Out of necessity, farmers adopt the principle of irrigation from their relatives and neighbours. Some farmers have adopted irrigation practice provided water is available.

However, furrow irrigation wastes water through seepage and evaporation by flowing a long distance. Adoption of concrete tubes or plastic hose can reduce the loss of water. Hand watering can also increase the efficiency of water management and reduce the incidence of disease spread from one plot to another.

Management of irrigation water

Irrigation management under competing use of water

In many places where irrigation water is managed under commercial plantation, many perennial trees are observed near the canal or around the homestead and villages. These trees are planted for beautification of the landscape or for cooling and shading effect. However, the negative contribution of these perennial trees is their consumption of water, which is greater than that of the major crop produced. Renault et al. (2001) reported up to 43% of water consumption by the perennial trees compared with 22% by the crop in a tropical humid environment. Under the present circumstances of unlimited watering by furrow irrigation in the Awash Valley, the high evapotranspiration observed and the high consumption by the non-intended perennial trees planners should reconsider traditional criteria for design and performance assessment.

Salinity

Salinity affects over 11 million hectares of land in Ethiopia (Tadelle 1996). These naturally salt-affected areas are normally found in the dry lowlands and in the Rift Valley. The semi-arid climate of the Awash Valley has contributed to limited leaching by favouring accumulation of soluble salts in the soil. Most of the irrigated large-scale farms in the Awash Valley have been developed without giving due consideration to the delivery of irrigation water and provision of drainage facilities for safe disposal of the excess water.

Sustainable land management

Soil erosion

The unique topography, type of soil, deforestation, intensive rainfall and low level of land management and the land use type practised have resulted in heavy runoff that induced soil erosion particularly in the northern and central highlands. Soil erosion is taking place all over the country but because of the effect of overpopulation on land that is already fragile (steep and mountainous), and mismanagement of the land itself, the northern and central highlands are the worst affected. Estimation made on the amount of soil that leaves the plot and deposited elsewhere or that leaves the country is unpredictable. This is expected because the Ethiopian topography, agro-ecology, type of soil associations, land use type etc. vary from one location to another. Measuring the source of variation in estimation of land degradation is difficult. However, the estimations made by the Ethiopian Highlands Reclamation Study (EHRS) and Soil Conservation Research Project (SCRP) are 100 t/ha with 1.8% loss of productive cropland (Constable and Belshaw 1989) and 42 t/ha with 2% loss of productive cropland per annum (Hurni 1988).

Soil conservation

The Soil Conservation Research Project (SCRP) of the Ministry of Agriculture, and the Institute of Agricultural Research (IAR, now the Ethiopian Agricultural Research Organization, EARO) have conducted major soil and water conservation research at the national level. Limited research activities carried out by the various research centres focused on quantifying the runoff and soil loss under different management and topographic conditions. Results showed that grass cover was effective in minimising both runoff and soil loss as compared with bare fallow and crop cover. If properly implemented, soil conservation practices can be effective in counteracting soil erosion and increasing productivity by reducing nutrient losses and conserving moisture. Recommended actions to combat the constraints in soil and water conservation are contouring, terracing and tree planting. However, because of immense diversity in the social, topographic, agro-ecological and watershed setups adoption rate is slow and sometimes rejected. Therefore, more emphasis has been given to soil fertility management

Adoption rate was low because of:

- poverty
- lack of participation by the end users at the planning stage
- lack of land use policy, e.g. on grazing land, community forest and,
- lack of legislation pertaining to natural resources management.

Catchment management

Except in a few cases, research in soil and water has not taken into consideration the catchment management. Hence, the effect of mismanagement of the catchment areas is already being felt in many communities with steep lands and where small-scale irrigation is practised. Sedimentation of micro-dams is becoming a serious problem in the absence of an integrated watershed management practice. The issue may become the concern of many communities as development of small-scale irrigation continues. Catchment management is an important practice to adopt in soil and water conservation activities and agricultural water management.

A catchment area may comprise different soil types or agro-ecological conditions, depending on its extent and the physiographic and climatic conditions of the area. In Ethiopia, however, field orientation of agricultural experiments is on plot or single site basis. With the present situation of land degradation and possible expansion of small-scale irrigation in the highlands, the adoption of a watershed management approach becomes imperative. The country has also been more dependent on rain-fed agriculture but this is no more reliable. Under this approach, each community will develop its own devices to conserve soil moisture *in situ*. Hence, research centres are advised to adopt the watershed management approach. Because of the advantages that watershed management approach offer, few regional states have now initiated several watershed management projects and depending on the success of these more of similar development projects will be initiated.

Infertile soil management

Causes for declining soil fertility

Farmers have a common perception regarding the cause for the decline in soil fertility. These are:

1. continuous cropping
2. decline in manure application
3. little or no agronomic management, particularly cropping systems

4. decline in inorganic fertiliser use and,
5. soil erosion.

Continuous cultivation

An example of the declining size of farms per household is indicated in Table 1. Throughout highland and midland Chiro *woreda* in eastern Ethiopia, farmers were forced to move onto the valley slopes with 50% gradient or more, despite a guideline to cultivate only lands with slopes below 35%. This is the case in many other parts of the country. Farmers are also forced to cultivate the same land year after year without fallowing. Among the cropped land, cereals occupy about 90%. Hence, there is little option left to the farmer to improve soil fertility through crop rotation although resource-rich farmers do practice some rotations and apply manure. Farmers with relatively small farmlands do not adopt soil conservation practices and this has an impact on soil fertility management and soil conservation, which will then cause land degradation because of unsustainable intensification of the land. The continuous cultivation has also aggravated soil erosion because the land where most agricultural activities take place is steep in many areas. The method of land preparation has favoured erosion where essential nutrients have been washed off together with the soil. Severely degraded land has gone out of production particularly in steep slopes.

Nutrient cycling

Nutrient balance studies

Braun et al. (1997) summarised and reported nutrient cycling between tree plantations and natural forests, a few agroforestry tree species and forage species and the use of mineral fertilisers on cultivated crops. Under a situation where almost all cow dung is used as fuel, where most of the crop residues are used as animal feed and as fuel or construction material, the nutrient imbalance would be self-evident (Table 1).

Table 1. *Total nutrient balance for land/water classes in the Ethiopian highlands.*

Land/moisture class	N kg ha^{-1}	P ka ha^{-1}	K kg ha^{-1}
Good rainfall	−52	−7	−33
Uncertain rainfall	−35	−5	−24
Problem rainfall	−41	−4	−24

Sources: Braun et al. (1997).

Water resources

It is believed that Ethiopia has a total volume of 109 billion cubic metres of surface water and about 2.6 billion cubic metres of ground water. The western half of the country receives sustainable amounts of precipitation and has many perennial rivers and streams while the precipitation is marginal in the eastern half of the country. Because of the progressive land degradation that is taking place at present, the amount of water leaving the catchments carrying away soil with it must have increased ever than before. Hence, the amount of available water *in situ* has been reduced particularly in the eastern half of the country. The Ethiopian plateau is the source of the Abay, Awash, Tekeze, Mereb, Baro-Akobo and Omo rivers that flow to the west and south-west. The Baro-Akobo basin is potentially the largest possible irrigable area (about 483 thousand hectares) though only a negligible portion of it has been developed probably because of the large investment cost required and its distance from the central market makes it less favourable for commercial agriculture. Awash River is the only river extensively used for commercial plantations of industrial and horticultural crops in the Rift Valley. Out of the total irrigated area of about 161,125 ha, over 43% is found in the Awash River basin. The remaining potential of the Awash River for irrigated agriculture is estimated at 136,220 ha.

Because of deforestation, soil erosion and over-exploitation by the population, the highlands are significantly degraded. This has resulted in increased acceleration of runoff along the slope thereby reducing water infiltration. Acceleration of runoff movement down the slope has also increased sedimentation in the downstream flat bottoms contributing to poor quality of water. Consequently, some small rivers, streams and springs have their volumes reduced or dried particularly during the dry season.

Social factors such as demographic pressure, land shortage, and social and cultural aspirations affect the quality of soil and the environment. These socially driven forces lead to several activities with major changes in soil and environmental characteristics such as deforestation, and new land development. Some may argue that trees increase evapotranspiration during the dry season thereby reducing the amount of water received by the soil, but in a steeping slope like in many parts of the Ethiopian highlands, trees can reduce the velocity and increase infiltration contributing to the more ground water recharge.

Goal and objectives of the soil and water research strategy

General objectives

The general objective of the soil and water research strategy is to improve the utilisation and minimise the degradation of natural resources for the sustained benefit of the nation at large and farmers in particular.

The goal of the strategy is therefore:

- increasing land productivity per unit area through the adoption of the integrated plant nutrient management (IPNM) approach
- improving the conservation and efficient utilisation of soil and water resources
- intensifying and diversifying land use-based knowledge and characteristics of the soil and ecological resources classification

- optimising the scientific capacity of all centres in soil and water research to attain all the above.

Agricultural Water Management Research Program

The importance of irrigation in agriculture to overcome food deficiency in the rapidly growing population of the world is rapidly increasing (EARO 2000b). Ethiopia is already suffering from food shortage because of its increasing population and chronic drought occurrence in most parts of the eastern and northern part of the country. The estimated six million hectares of land used for cereal production has become under-productive while some of it could have been producing twice a year. At the same time, Ethiopia is endowed with water resources, which could be easily tapped and used for irrigation.

This programme will handle basic soil–crop–water relationships, water balance, agro-hydrology, irrigation and drainage methods. Drainage of heavy clay soils will be an important component in the programme as a large area of the heavily populated land is covered by waterlogged soils. Reclamation of degraded soils and implementation of runoff farming for supplementary irrigation, efficient utilisation of water resources with special emphasis on the development of small-scale irrigation will be emphasised in the different agro-ecological zones (AEZs). Until now, research on irrigation has focused at the Werer Center, which is located in the midst of irrigated agricultural land. However, the centre is deficient in skilled manpower and facilities compared with the service it renders to irrigated agriculture in the country. However, the research being conducted on agricultural water management at Werer may not cover the interest of the highlands or other potentially irrigable areas in the lowlands because of differences in agro-ecology and soils.

Summary

The current government's policy for economic development and pathways to industrialisation is through the development of the agriculture sector. There are some obstacles facing the development of the water sector such as land tenure and land use issues, and water basin development vs. ethnic bound development planning. However, there are some positive sides, too, regarding agricultural development. These include:

- emphasis has been given to support the development of private smallholder agriculture despite the fragmented and small-size land holdings
- large sizes of commercial enterprises are encouraged in areas with sparse population in the lowlands with large opportunity for irrigated agriculture
- conservation based development of agriculture to combat soil degradation, deforestation and improvement and maintenance of soil fertility
- the institutionalisation of strong soil and water and forestry research programmes at directorate level equivalent to that of crops and animal science research in EARO to generate technologies to combat desertification
- agro-ecological and watershed management approach is being adopted in EARO

- the emergence of institutions like the Arbaminch Water Technology Institute and Mekelle University College of the Drylands that train students in irrigation and hydrogeology and soil and water conservation skills, respectively
- the National Extension Improvement Program which has soil improvement as part of its packages
- a number of non-governmental organisations getting involved in natural resources development and
- the emergence of market-oriented soil fertility improvement/management programmes.

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