People and Dams: environmental and socio-economic changes induced by a reservoir in Fincha'a watershed, western Ethiopia

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Chapter 1

Introduction

Introduction

1.1 Problem description

Dams for storing water for electricity, irrigation, domestic water supply and flood control have been being constructed for more than a century (WCD, 2000; Bird and Wallace, 2001). Now, at the start of the 21st century, one-third of the countries in the world rely on hydropower for more than half their electricity supply (dams generate 19% of electricity overall) and some 30-40% of the 271 million hectares irrigated worldwide rely on dams (WCD, 2000; cited in Bird and Wallace, 2001). Dams may generate revenue from export earnings from direct sales of electric power, cash crops and processed products. They are also used for flood control. Given the ongoing population growth and rising standard of living, new dams will have to be built and the existing dams will have to be maintained (Dixon et al., 1989; Van Duivendijk, 1995).

Though dams have advantages, dam construction often causes major land use changes and has adverse social and environmental impacts on the communities living in certain watersheds (Dixon et al., 1989). The social effects of dams include involuntary resettlement of people, disruption of their productive systems and lifestyles, and inequitable sharing of costs and benefits (Dixon et al., 1989; De Wet, 1999; WCD, 2000). The related environmental effects of dams comprise degradation of the upstream part of the watershed, sedimentation, and changes in water quantity and quality (Dixon et al., 1989; Terry, 1995). Other environmental effects of dams are the loss of forests, wildlife habitat, and species populations (biodiversity), and the emission of greenhouse gases (from decomposing vegetation). Irrigation dams can result in the spread of diseases (e.g. malaria and bilharzias) through the increase of their vectors and create physical problems such as declining soil fertility and soil quality arising from waterlogging, salinisation, and hardpan formation (Terry, 1995; WCD, 2000). Some studies, however, argue that the massive social conflicts and degradation of aquatic ecosystems caused by hydropower dams are often counterbalanced by the economic advantages obtained from the scheme (Bratrich et al., 2004). For instance, electricity generated using hydropower dams often serves regional and national interests, even though the impact of these dams on local populations can be enormous.

In the 1960s, Blue Nile Basin investigations showed that Fincha'a river, a tributary of the Blue Nile in western Ethiopia, had great potential for a multi-purpose dam that would provide power generation and water storage for fisheries, irrigation, and recreation. Following these studies, a dam was constructed in 1973. The entire area draining towards this dam is called Fincha'a watershed. Originally the central part of this watershed was swamp and grazing land fed by numerous streams and intermittent rivers arising from a chain of mountainous plateaus that form the actual watershed. The lake created after completion of the dam initially submerged an area of approximately 100 km^2, but a few years later the area had increased to approximately 149 km^2 (Assefa, 1994).

In 1987, an additional dam was constructed across Amartii river that flows parallel to Fincha'a river. The purpose of this second dam is to divert water from Amartii river to the Fincha'a reservoir through a tunnel and raise the capacity for hydroelectric power generation

(OADB, 1996). It is estimated that after the connection the storage capacity of the Fincha'a reservoir was raised from 185 to 460 million m^3 of water. Currently, the dam, which is owned by the Ethiopian Electric Power Corporation (EEPCO), has an installed capacity of 128 MW and meets 27% of the national demand for power. Other important benefits of the reservoir are the enhanced possibilities for irrigation and fishing, and the creation of an important wetland. Furthermore it has increased water availability and has reduced the risk of flooding in downstream areas.

In a recent study (OADB, 1996) it was shown that 431 km^2 of the watershed area is now submerged. This means that during its lifetime the scheme has submerged an additional 331 km^2 of agricultural and grazing land. The lake is still increasing in size, mainly because of continued sedimentation (OADB, 1996). The sediment originates from the upstream agricultural land, but actual quantities entering the reservoir are unknown.

Before the dam was built, the people living in the area that is now inundated were not taken into consideration, and therefore they were neither resettled nor financially compensated. Assefa (1994) mentions that the then Ethiopian Electric Light and Power Authority (EELPA) attempted to compensate only the landlords whose settlement area and trees were submerged, but the majority of farmers were not considered. However, this "plan" was interrupted by the 1974 revolution. It is not known what happened to the people who were displaced from their dwellings. It is possible that they started farming on steep and marginal areas within Fincha'a watershed, which may have aggravated soil erosion and reservoir sedimentation. It is also possible that they migrated to areas outside Fincha'a watershed to make a living. While the dam victimises the ordinary people, they do not benefit directly from the electricity generated, though some of them may have turned to fishing to earn a living.

The absence of land use planning in the whole country means that the increase in population has resulted in forests being converted into arable land and pastures. It is estimated that over 97% of the forest cover has been lost (EFAP, 1994). Gete (2000) showed there has been an increase in cultivated land at the expense of forest cover in Denbecha, while Kebrom (2000) indicated that the scrub and forest cover had decreased as a result of increases in settlements in Kalu, north-eastern Ethiopia. These changes in land use/cover have induced widespread soil erosion throughout the Ethiopian highlands. Various authors have reported on the severity of the soil erosion problem in the country. Hurni (1993) estimated that on average 4.2 kg m^{-2} of soil material is lost each year from the highlands. Herweg and Ludi (1999) measured losses of 10.4 kg m^{-2} yr^{-1} on cropland with 28% slope at Anjeni, north-western Ethiopia. In Fincha'a watershed, similar changes may have occurred, resulting in erosion problems. There is certainly a general lack of conservation measures in the watershed.

The land that is now submerged by the lake was previously used for arable crops and grazing, sustaining the lives of many farmers and their families. The number of people forced off their land by flooding is probably increasing, even though the exact figure is not documented. It is likely that some of those whose land has been submerged have either settled in other parts of the watershed or have left the area to make a living elsewhere. In addition to those evicted by backwater who have settled elsewhere, the annual population growth rate of 3% (national average) must have added more people to the population, increasing the demand for land. There is no doubt that this process has put pressure on natural resources through deforestation, overgrazing, and poor soil management. The increased population migrated up the hills of the watershed area and cleared land to open up new farmland on slopes steeper than 45% (Assefa, 1994). People who have been displaced from their original area and forced to settle in a different environment may not have sufficient local knowledge of the new location to be able to manage the natural resources properly. This may initially lead to more degradation than would have occurred if the local soil management practices had been implemented.

Assefa (1994) and OADB (1996) have indicated that the lives of the approximately 178,000 people living in the watershed area may be directly or indirectly affected by the dam. People whose villages and farmlands have been submerged have been directly affected, whereas those who hosted the settlement of the evicted people and those living closer to the backwater area are forced to compete for the limited natural resources and are thus indirectly affected by the dam. Moreover, community reports from the watershed area have shown that as a result of environmental changes, villagers near the reservoir have often faced adverse health problems and have lost livestock. However, the lake may have stimulated new economic activities such as irrigated agriculture and fishing that were previously not possible.

Out of the 119 farmers' associations (lowest administrative unit) in the watershed, some 85% of them have experienced recent famine in the watershed area (Assefa, 1994). The question is what caused this famine, a phenomenon that was not known in the area before the dam was built. There are several possible reasons. The first could be a shortage of farmland as a result of an increase in backwater area. A second reason could be reduced agricultural productivity as a result of soil degradation and insufficient agricultural intensification. Field reports in the country have shown that soil fertility and hence agricultural productivity is gradually declining. Consequently, farmers are being forced to rely on imported chemical fertilisers in order to maximise their agricultural production. However, for most farmers fertilisers are nearly unaffordable and hence their use is limited (OADB, 1996). Pender et al. (1999) suggested that constraints on rural credit appear to be discouraging farmers from using purchased inputs and investing in farm improvements. Furthermore, the prices of agricultural products are low due to the poor market network. This has made the use of expensive fertilisers economically unjustifiable for many farmers in this watershed area (OADB, 1996). The absence of formal credit facility forces the farmers to sell their crops when prices are low instead of storing them until prices are higher.

Poor watershed management may have increased the amount of sediment entering the streams and reservoir, thereby reducing reservoir depth and increasing the backwater area in Fincha'a watershed. Studies in various parts of Ethiopia have indicated that the underdevelopment of water resources is causing problems such as flooding (Sileshi, 2001), submergence of settlement sites (Woube, 1999), and disruption of the crop production along basins (Zekaria, 1994) to become recurrent events. Reservoirs and water bodies in the country are suffering from excessive sediment loads that have been caused by deforestation, soil erosion (Sileshi, 2001), and absence of watershed management in the watershed areas (Woube, 1997). Sileshi (2001) estimated a sediment concentration of 16.7 kg m^{-3} in Bilate river, southern Ethiopia, in February 1995, due to intensified soil erosion in the watershed. Such high sediment loads are highly detrimental to reservoirs and lakes.

Improving land management involves identifying land use changes, understanding current land use patterns or features, and assessing the economic and ecological benefits and costs that arise from land management practices, as well as finding alternatives (Wu et al., 2001). In Fincha'a watershed, however, the extent and causes of land use changes and spatial erosion patterns and their effects on the community in the watershed area and the dam have neither been identified nor quantified. The situation is similar in several other watersheds and reservoirs in Ethiopia.

1.2 Research objectives and questions

Fincha'a watershed of western Ethiopia was chosen as a research site because of the presence of a multipurpose dam in the watershed. The objectives of the study described in this thesis were: 1) to analyse the impact of the dam in Fincha'a watershed on land use, social and economic situations, and soil erosion, 2) to determine the factors affecting the adoption of soil and water conservation, and 3) to develop an integrated watershed management methodology for planning new dams in Ethiopia. The three major objectives are reflected in the following five specific research questions:

1) How did the construction of the dam and the subsequent increase in the lake size affect land use changes in Fincha'a watershed?
2) What were the social and economic consequences of the creation of the dam for the people living in the watershed?
3) If erosion is a problem, what was its magnitude before and after dam construction, and what have been the subsequent on-site and off-site effects?
4) What are the factors affecting the adoption of soil and water conservation?
5) Could an integrated watershed management methodology be developed and applied for planning new dams in Ethiopia and elsewhere?

1.3 Research area

Fincha'a watershed is located in the western Highlands of Ethiopia where mixed crop and livestock production systems are practised. The watershed covers 1318 km^2. Its location is shown in Figure 1.1. The hydropower reservoir covers approximately one-third of the watershed area.

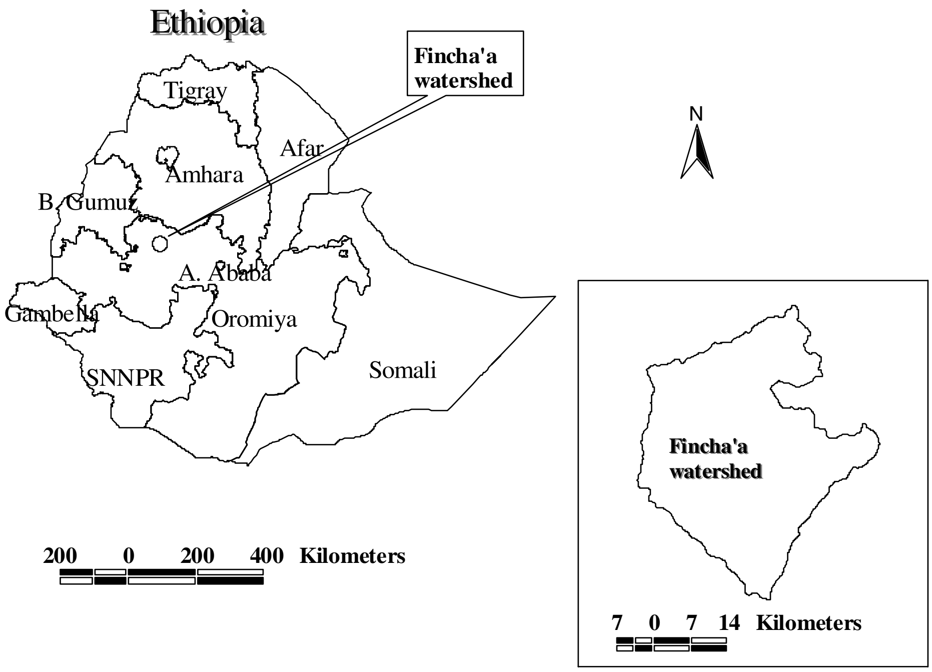

Figure 1.1. Location of Fincha'a watershed in Ethiopia.

Elevation in the watershed ranges from 2200 m to 3100 m. Most of the area (80%) can be described as an extensive rolling plateau, ranging in altitude between 2200 m and 2400 m. About 51% of the watershed is flat (0 to 3% slope) and mainly under the reservoir and swamp. The gently sloping (3 to 8% slope) to sloping (8 to 15% slope) areas cover about 34% of the watershed. Steep (15 to 30%) to very steep (> 30%) slopes account for about 15% of the watershed area. The high elevations along the watershed boundary are formed from Quaternary volcanics, which also occur as isolated outcrops in the middle of the watershed. A small part of the watershed in the northeast is on the Adigrat sandstone formation. This formation is composed of alternating beds of sandstones and shales, which have been deposited unconformably upon the eroded surfaces of the Basement Complex. The dominant soils in the watershed have a texture of clay-loam, clay, or loam.

The long-term average annual rainfall is 1823 mm. About 80% of the annual rain falls between May to September. The monthly mean temperature varies from 14.9°C to 17.5°C (Figure 1.2). The average annual reference evapo-transpiration (based on Penman–Monteith) is 1320 mm, with small monthly variations.

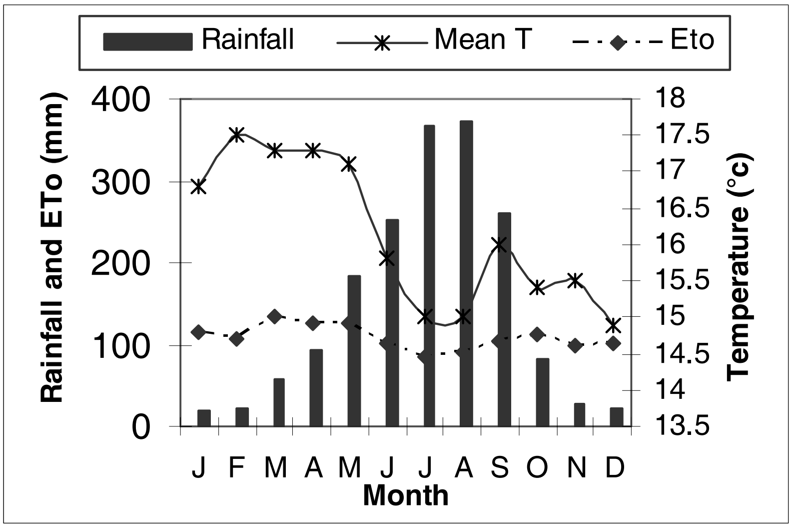

Figure 1.2. Climatic conditions at Fincha'a watershed, western Ethiopia. *Source:* The National Metrological Service Agency (2004). Mean T = mean temperature; ETo = reference evapo-transpiration.

1.4 Thesis outline

This thesis presents the results of the research conducted in Fincha'a from 2001-2005. Chapter 2 presents the dynamics in land use types before and after the dam, analyses the factors that cause land use changes and discusses the implications of those changes in the watershed. The findings are compared with similar land use studies elsewhere in the country. The social and economic impacts of the creation of a reservoir on the community in the watershed are presented in Chapter 3. Household surveys were done in three sub-watersheds and were augmented with interviews with key informants. Chapter 4 analyses the effects of soil erosion factors and gives the predicted rates of erosion and sedimentation before and after the dam, based on studies done in two sub-watersheds. Erosion patterns of the entire Fincha'a watershed are also presented. The revised Morgan, Morgan and Finney (MMF) erosion prediction model was used to predict spatial erosion rates and sedimentation. Observed erosion data were used to calibrate and validate the model. Using data obtained in the studies of the two sub-watersheds, the factors that affect soil and water conservation (SWC) adoption in Fincha'a watershed are analysed (Chapter 5). A sample of farmers was interviewed, using semi-structured questionnaires to gather biophysical and socio-economic data that could be used to analyse the constraints to and opportunities for SWC adoption. Group discussions were also led, to assess agriculture-related problems in the sub-watersheds. Using the findings, recommendations for improved SWC adoption are given. The importance of integrated watershed management is presented in Chapter 6. The social, environmental and economic problems caused by dams in the world are reviewed. The findings of the study of Fincha'a watershed are also used to complement existing knowledge. Chapter 7 summarises the major conclusions and recommendations made arising from the research.

Chapter 2

Land use changes induced by a hydropower reservoir in Fincha'a watershed, western Ethiopia

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Land use changes induced by a hydropower reservoir in Fincha'a watershed, western Ethiopia

Abstract

This paper analyses the land use dynamics caused by the hydropower dam construction in 1973 at Fincha'a watershed (1318 km^2), tributary of the Blue Nile. Aerial photos (1957 and 1980) and an ASTER satellite image of 2001 were used to make three land use maps of the watershed by means of GIS. The 239 km^2 water reservoir inundated 100 km^2 grazing land, 120 km^2 swamp, 18 km^2 cropland and 1.2 km^2 forest. In 2001, cropland covered 77% of the potentially available land for community utilization indicating that there is hardly any free land available for cropland expansion to accommodate new farmers. Crop intensification, reforestation and erosion control methods are lacking. Moreover, undesired land use change may increase erosion and reservoir sedimentation. This could affect food security and power production in the near future.

2.1 Introduction

Dams have been built for thousands of years for electricity, irrigation, flood control and water supply. The World Commission on Dams (WCD; 2000) indicated that one-third of the countries in the world rely on hydropower for more than half of their electricity supply. Dams are often entitled with losses of agricultural lands, forests and grasslands in the upstream watershed areas due to inundation of the reservoir area (WCD, 2000; Bird and Wallace, 2001), alteration of traditional resource management practices (Rooder, 1994), displacement and impoverishment of people, and the inequitable sharing of environmental costs and benefits (Wet, 1999; WCD, 2000).

Ethiopia has about 30,000 MW hydropower potential but it was possible to exploit less than 2% of this by the year 1997 (Solomon, 1998; Assefa, 2003) mainly due to financial shortfall (Assefa, 2003). As a result only 14% of the population has access to electricity. Fincha'a hydropower dam was constructed in 1973 as a strategy for fostering economic growth in the country through generation of hydroelectricity, irrigation, fishery and tourism (HARZA, 1965; 1975). Currently out of the 478 MW installed hydropower capacities generated in the country, this power plant generates 128 MW (Assefa, 2003). The original installed capacity of this scheme was 100 MW but increased to the current level following the diversion of Amarti River into this scheme in 1987. Moreover, the hydropower reservoir supplies water to a sugar factory downstream, created new economic activities such as fishery and has become an important wetland that attracts various bird species.

In spite of these benefits, studies done by the Oromiya Agricultural Development Bureau (OADB, 1996) and Assefa (1994) showed that the reservoir has inundated large areas of different land use types and evicted several people from their original places. Bezuayehu and De Graaff (2006) estimated that some 3100 families might have been relocated against their will after the construction of the dam in 1973. These displaced people mostly moved to available areas within the watershed, and often have started agricultural activities on steep and marginal areas within Fincha'a watershed. This process of migration and new agricultural activities, in combination with the normal population increase in Ethiopia, may have caused land use changes and probably aggravated the degradation rate of the environment in the upstream parts of the watershed (Assefa, 1994). But there has been no study conducted at this watershed that shows the magnitude of land use changes caused by the creation of the hydropower dam and the implication of such changes.

Land use changes have been extensively researched (Lambin et al., 2001) due to its key role in environmental goods and services (Jianchu et al., 2005). Land use changes are a very important aspect of global change. When they are aggregated globally, they directly impact biotic diversity, contribute to local and regional climate change, are the primary sources of soil degradation and by altering ecosystem services, affect the ability of biological systems to support human needs (Lambin et al., 2001; El-Swaify, 2002). The land use studies in Ethiopia, however, give emphasis to estimation of forest cover and deforestation rates that occur at national level (Mesfin, 1985; EFAP, 1994; Ritler, 1997).

So far analyses of comprehensive land use dynamics at watershed level in general are scanty in Ethiopia. Studies of land use dynamics in watersheds where a reservoir was created have not been carried out previously. Hence, the knowledge of spatial dynamics of the magnitudes of different land use types, factors driving the changes and the implications of those changes are scarce in the country. Recent watershed based land use studies in different parts of the country, however, show that there has been an increase in croplands at the expenses of forests, grassland and bush land due to population growth and the land reform of 1975 (Solomon, 1994; Gete, 2000; Woldeamlak, 2003). These studies showed that the land use dynamics have environmental implication at local scale and beyond.

The objective of this paper was to analyse land use changes in Fincha'a watershed over a period of 45 years, and describe the possible causes and implications of these changes on the community at large and the hydropower dam itself. Comparisons were made with the results of the recent studies conducted elsewhere in the country. It was intended to separate between expected land use changes due to population increases, and the changes caused by the reservoir.

2.2 Materials and methods

2.2.1 The setting

The geographical location of Fincha'a watershed is between 9°10'30" to 9°46'45" North latitude and between 37°03'00" to 37°28'30" East longitude. In administrative terms, it is situated in Wallaga, Oromiya region, western Ethiopia (Figure 2.1). It drains parts of the districts Abbayyii-Coomman, Jimmaa-Gannatii, Jimmaa-Raaree, Guduruu and Horro. It covers an area of about 1318 km^2. The Fincha'a hydropower dam has 340 m crest length and is 20 m high above the lowest foundation level (HARZA, 1975). During 1973 to 1986 Fincha'a River alone was supplying water to the hydropower scheme, but in 1987 Amarti river was diverted to Fincha'a through a tunnel. Both rivers are tributaries of the Blue Nile.

Weather data were available from a station at Shambu town, which is situated at the middle part of the watershed (37˚06' latitude and 09˚34' longitude and elevation 2430 m). The station has a dataset of daily values of rainfall, temperature, relative humidity, sunshine hours, and wind speed from 1970 till to day. The yearly average rainfall over the period 1970-2003 was 1823 mm. About 80% of the annual rain falls between May to September. The monthly mean temperature varies from 14.9°C to 17.5°C (Figure 2.2). The average annual Reference Evapo-transpiration (based on Penman-Monteith) is 1320 mm, with low monthly variations.

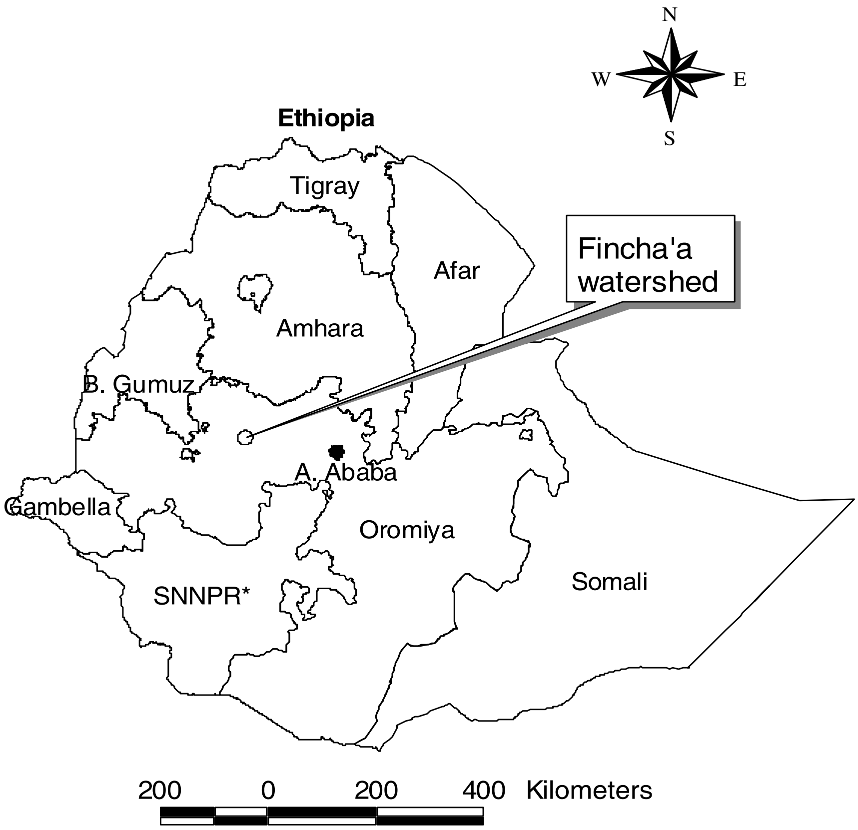

Figure 2.1. Location of Fincha'a watershed.
*SNNPR- Southern Nation, Nationalities and Peoples' Region.

Elevation in the watershed ranges between 2200 m to 3100 m. Most of the area (80%), which can be described as a wide rolling plateau is within the altitude range between 2200 m and 2400 m (Figure 2.3). About 51% of the watershed is flat (0 to 3% slope steepness), which is mainly under water reservoir and swamp. The gently sloping (3 to 8% slope steepness) to sloping (8 to 15% slope steepness) area covers about 34%, steep (15 to 30% slope steepness) to very steep (> 30% slope steepness) covers about 15% of the watershed area. The higher parts of the watershed near the boundary (where the drainage of all the streams begin) as well as the elevated parts in the middle of the watershed, which are isolated outcrops, are made of Quaternary volcanics. A small part of the watershed at the northeastern part is covered by the Adigrat sandstone formation. This sandstone formation is composed of alternating beds of sandstones and shales, which have been deposited unconformably upon the eroded surfaces of the Basement Complex. The dominant soils are clay, loam, and clay-loam.

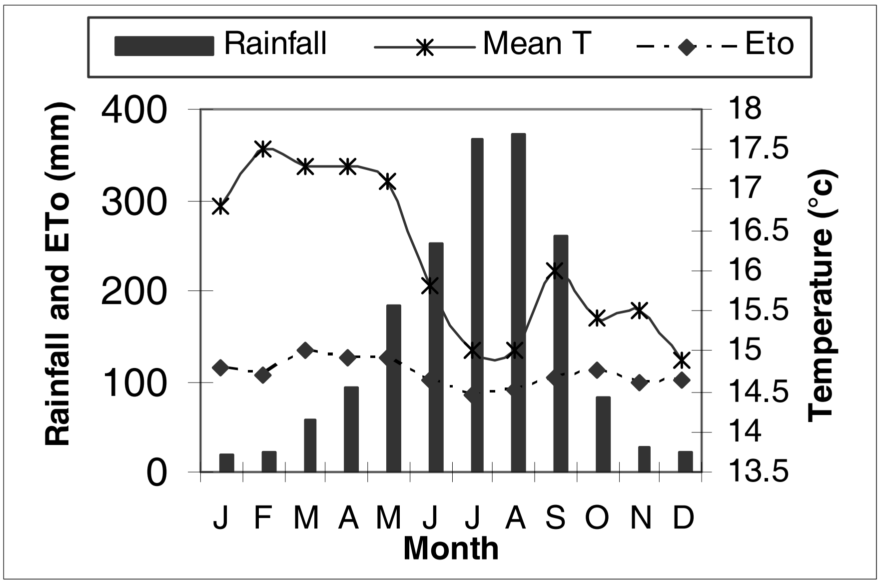

Figure 2.2. Climatic conditions at Fincha'a watershed, western Ethiopia. *Source:* The National Metrological Service Agency (2004). Mean T = mean temperature; ETo = reference evapo-transpiration.

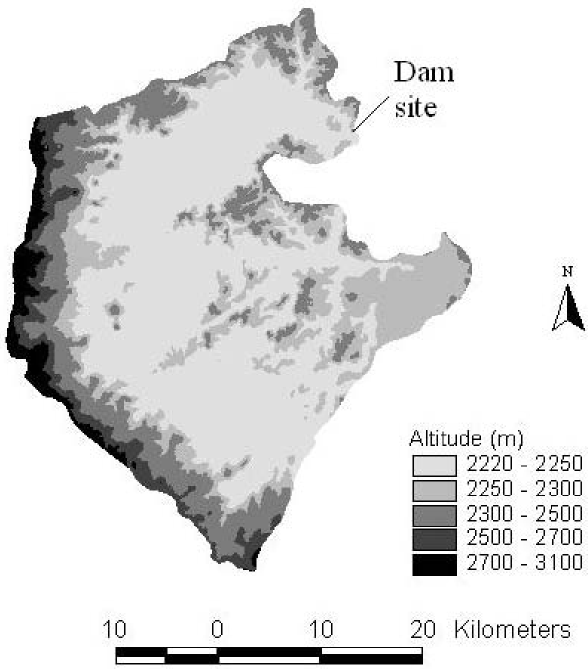

Figure 2.3. Topographic map of Fincha'a watershed and the dam site.

Population density in 2001 was 98 people per km^2, with an average family size of eight people per household (Bezuayehu and De Graaff, 2006). In general population control measures have been unpopular due to cultural and traditional reasons, and limited awareness. In 2002 the average land holding size was 2.5 ha, with an average per capita land holding size of 0.3 ha (Bezuayehu and De Graaff, 2006). Integrated crop-livestock production is the main agricultural system in this watershed. The main crops grown are maize, wheat, tef, barley, beans and Niger seed. Many farmers posses cattle, sheep, goats and horses. The traditional drainage ditches which are applied on tef fields perform well on flat lands. But this performance is poorer on steep lands leading often to increased soil erosion. Farmers intentionally leave some 20 to 45 stands of trees per hectare on their own farms and homestead areas. The trees are regularly pruned and the biomass is used for soil fertility enhancement, fuel wood and construction. Besides, many farmers practise homestead and farm boundary plantation. The Ethiopian Electric Light and Power Authority (EELPA) have also planted Eucalyptus species for production of poles. Generally, tree planting in this watershed comprises eucalyptus and cypresses species.

Land was privately owned before the land reform of 1975. Under this tenure arrangement few landlords owned much land but tenants use the land based on mainly sharecropping arrangements. However, the land reform of 1975, as elsewhere in the country, has relinquished the tenant-landlord relation by dividing the farmlands among the tillers. Since then, land has become state property under which only use right was given to the farmers. On the other hand, the other land use types such as forests and grazing lands have become open access lands leading to encroachment and overgrazing.

2.2.2 Methodology

The technologies of Geographic Information Systems (GIS) and Remote Sensing (RS) were used to analyse the spatial-temporal status of land use in Fincha'a watershed. A combination of aerial photographs and a satellite RS image was used. Aerial photos of the year 1957 taken in November to December (57 photographs) and 1980 taken in January (60 photographs) with base scales of 1:50,000 were obtained from the Ethiopian Mapping Agency (EMA). An ASTER RS image of green, red and near-infrared bands of January 2001 (30 m resolution) was obtained from the internet. While the ASTER image was used due to the absence of recent aerial photographs, the aerial photos were the only sources of information for earlier periods. The timing of all three data sources was such that they represented the dry season, with minimal cloud cover, and could be considered comparable in terms of land cover conditions (e.g. bare conditions on cropland).

The aerial photographs were orthorectified and visually interpreted using a mirror stereoscope to derive the land use maps that existed before- and six years after the creation of the hydropower dam. Six topographic maps (1980 edition) of scale 1:50,000 were obtained from EMA and used to delimit and cut out the study watershed by tracing the boundary of the watershed and digitising it separately into Arc INFO 7.2.1 and then superimposing the view on the spatial databases created from the aerial photographs. The false colour composite of the ASTER image was created and geo-referenced based on the Universal Transverse Mercator, UTM 1983 and Zone 37. The rectified image was then interpreted in IDRISI GIS using the method of supervised classification. In this method spectral signatures were developed from the specified locations that were verified to be of a particular land use type known as “training sites”. Then a vector layer was digitized over a raster scene to separate different land use types. A Global Positioning System (GPS) was used for collecting information in the field that was useful for complementing the interpretation of the satellite image.

Preliminary land use classes were defined prior to aerial photo interpretation but then some modifications were made while interpreting the satellite image. Using aerial photographs eight land use classes were identified: waterbody, cropland, swamp, grassland, bush-covered grassland, forest, plantation and town. But the ASTER image was less detailed, which resulted in a poor differentiation between forest and plantation, and between grassland and bush-covered grassland. Hence, we merged forest and plantation to one class and called it forest, and also grassland and bush-covered grassland were combined into grazing land. Finally, six classes, namely, waterbody, cropland, swamp, grazing land, forest and town were used for the aerial photo and ASTER image interpretations (Table 2.1).

Analysis of annual rainfall was carried out to determine the amounts of rainfall in the year prior to the remote sensing datasets of 1980 and 2001. Only rainfall data from 1970 to 2003 were available, so no information on the rainfall prior to the 1957 dataset existed. This analysis was made to see if the rainfall has affected the land use of the watershed area. It was expected that a relatively wet year prior to the land use classification may have resulted in a larger extent of the waterbody and perhaps more swamp land than when the antecedent rainfall was below average.

Overlays of the 1980 and 2001 waterbody areas on the 1957 land use map were made to determine the spatial distribution and magnitude of the land use types directly affected by the reservoir. A comparison was made between the results of this study and the results of other land use change studies conducted elsewhere in the country (Solomon, 1994; Gete, 2000; Woldeamlak, 2003). This was done to differentiate between the effects of the reservoir and other land use change drivers, such as population increase.

Table 2.1. Land use classes and their description in Fincha’a watershed, western Ethiopia.

Land use class	Description
Waterbody	Areas completely inundated by water.
Cropland	Areas used for cultivation, including fallow plots and complex units such as homestead.
Swamp	Areas flat & swampy (locally called *raatuu)* during both wet & dry seasons; mainly covered with grass.
Grazing land	Areas covered with grass, bushes and trees, and used for grazing; usually communal.
Forest	Areas covered with natural and plantation trees and some times mixed with enrichment plantations, forming nearly closed canopies of 70-100% cover.
Town	Areas covered with urban land use.

Altogether five elderly people were interviewed and used as a key informant for their past and current knowledge regarding the extent and environmental effects of land use changes in the area. This information was used for complementing the interpretation of the aerial photos and satellite image. Moreover, their traditional knowledge was used for analyses of the onsite and downstream implications of the land use changes in the area.

2.3 Results

The mean annual rainfall at Shambu station was 1823 mm, but showed some variation over the period of analysis (1970-2003) (Figure 2.4). The obtained coefficient of variation was 22.5%, which indicates a relatively low variation. The annual rainfall ranged from 1281 mm in 1994 to 3195 mm in 1980. We assumed a range of 600 mm around the average (1523 – 2123 mm) as being normal fluctuations. Years with rainfall above or below this range were considered abnormally wet or dry, respectively. Wet years occurred from 1977 till 1981, and another wet year was experienced in 1985. Dry years occurred around 1975, which coincides with the famine that struck Ethiopia, and again several dry years were experienced since 1987.

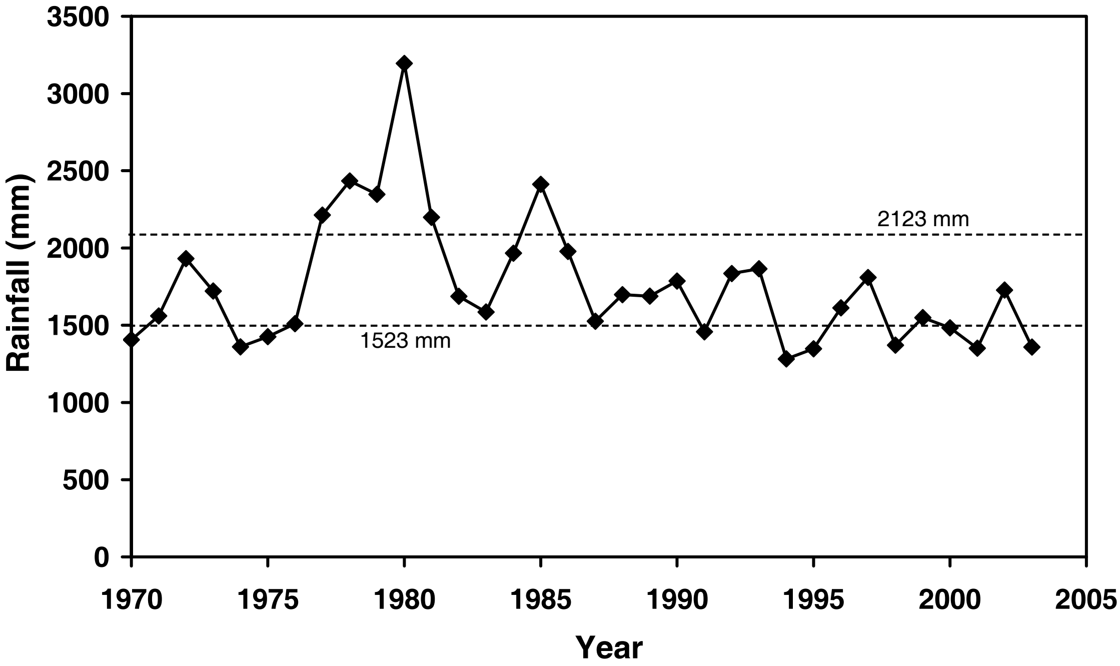

Figure 2.4. Annual rainfall at Fincha'a watershed, western Ethiopia. Dotted lines indicate the range for assumed normal variation in annual rainfall.

A general decline in annual rainfall can be observed following the peak rainfall in 1980. But since the number of years with rainfall data was limited (only 34 years) this is not necessarily a trend. The year prior to the aerial photographs of 1980 was very wet, with a total rainfall of 2347 mm. The year prior to the ASTER RS image of 2001 was relatively dry, with an annual rainfall of 1484 mm. The land use in the three years (1957, 1980 and 2001) was classified according to the classes defined in Table 2.1. The areas covered by the different land use classes are shown in Table 2.2. The same results were plotted in Figure 2.5, excluding the class ‘town’ to improve clarity of the maps.

Table 2.2. Land use classes of Fincha’a watershed in 1957, 1980 & 2001.

Land use	Area in 1957		Area in 1980		Area in 2001	
	km^2	%	km^2	%	km^2	%
Waterbody	0.0	0.0	151.1	11.5	239.3	18.2
Cropland	403.3	30.6	478.8	36.3	607.1	46.1
Swamp	286.1	21.7	376.6	28.6	95.5	7.2
Grazing land	555.2	42.1	272.9	20.7	332.2	25.2
Forest	70.5	5.4	34.1	2.6	37.9	2.9
Town	2.5	0.3	4.1	0.3	5.6	0.4

Waterbody: There was no significant waterbody in this watershed before the impoundment period. The interpretations of the 1980 aerial photos, however, show that about 151.1 km^2 (11.5%) of the watershed was converted to waterbody, which is equivalent to the estimate given in HARZA (1975). This value has increased to 239.3 km^2 (18.2%) in 2001, a net increase of 88.2 km^2. From the 1980 land use map it appeared that there were two major waterbodies (i.e., upper part also called Coomman and lower part also called Doonje) that were physically separated. It is indicated in HARZA (1966) that there exists a ridge of approximately 8 meters height and about one kilometre wide across the lakes. The ridge acts as a natural dam and created a large area of seasonal swamp in Coomman before the construction of the dam. This was evidenced while interpreting the 1957 aerial photos, which showed traces of river courses in the Doonje part, but none in the Coomman part. The analysis of the RS image, however, showed unified waterbodies. This was obviously a result of increased reservoir level following the Amarti river diversion into Fincha’a in 1987. This diversion project was affected by means of a 16 m high dam and a tunnel of 1500 m length and 3 m diameter and provides an annual runoff of 138.8 Mm^3 to the Fincha’a reservoir (EELPA, 1982). The increase in the area of backwater following the dam construction and Amarti river diversion has mainly inundated swamp, grazing land and cropland.

Cropland: This category also includes rural villages (dispersed settlements) and homestead plantations because it was practically difficult to treat them as a separate land use type. Most homestead areas are set in such a way that tree plantation and cultivation are intermingled. Generally cropland has increased from 403.3 km^2 in 1957 to 478.8 km^2 in 1980 and 607.1 km^2 in 2001; a net increase of 50.6% during a period of 44 years. Overlay analysis of the waterbody in 1980 and the land use map of the 1957 show that 11.5 km^2 of croplands that were situated at western, northern and eastern sides of the lower lake (Doonje) were inundated. The waterbody that existed in 2001 has inundated an additional 6.5 km^2 areas of croplands that were situated in the western and northern parts of the lower lake. This makes a total of 18.0 km^2 of cropland loss to the farmers due to the creation of the hydropower dam in the watershed area. Most croplands were situated in relatively flat areas in 1957 and 1980. In 2001, however, many steep lands (as steep as 90%) in the southern and western parts of the watershed were converted to cropland.

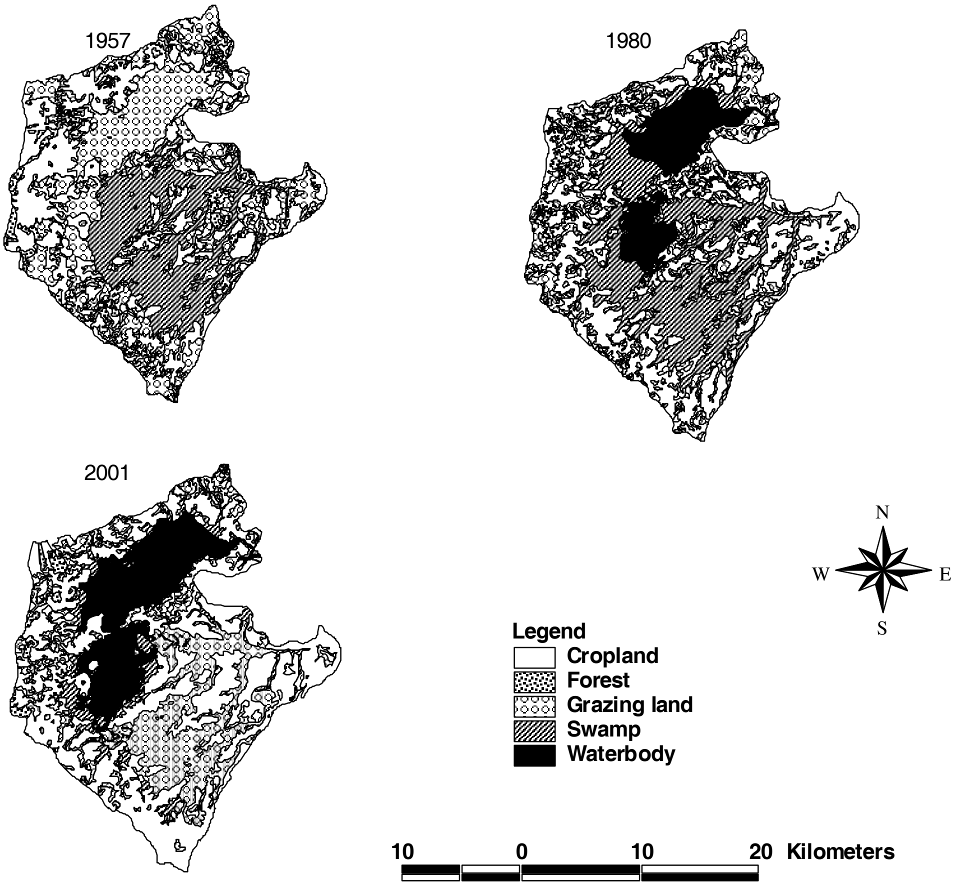

Figure 2.5. Land use maps of Fincha'a watershed for 1957, 1980 and 2001.

Grazing land: The area of grazing land has decreased by 50.8% between 1957 and 1980 but increased by 21.7% between 1980 and 2001, which means a net decrease of 40.1% between 1957 and 2001. Overlay analysis of the 1957 and the 1980 land use maps show that 94.2 km^2 of grazing land in the Doonje area and western part of Coomman have been inundated. An additional 6.0 km^2 of grazing land that was situated in the western sides of the current lake became inundated between 1980 and 2001. This makes a total of 100.2 km^2 grazing land that was lost to the farmers due to the creation of the dam in 1973 and the Amarti river diversion of 1987. Grazing lands were situated at depression areas of the watershed where seasonal water logging occurred and along the water divide lines in the western and south-western parts of the watershed, on the hills and along embankments of streams and rivers.

Swamp: Much of the flat areas of the upper part of the lake (Coomman) used to be seasonal swamp before the creation of the dam. This land cover type has shown a pattern of increase in the first period and a decrease in the second period, i.e., an increase of 90.5 km^2 between 1957 and 1980 but a decrease of 281 km^2 between 1980 and 2001. Overlay analysis of the waterbody of the 1980 and 1957 land use maps show that 44.5 km^2 of swamp in the Coomman area have been inundated. But an additional 75.4 km^2 of the same land use category that were situated in the western, southern and eastern parts of the current lake have been inundated between 1980 and 2001. Consequently, leaving much of its original places for a waterbody, the swamp has engulfed a large area of grazing land and cropland, mainly in the southern and western parts of the watershed between 1957 and 1980. The analysis of the RS image of 2001, however, detected that the swamp size has considerably reduced in favour of grazing land; the spatial distribution being at the fringes of the waterbody following stream courses and depressions, but gravitates towards the upper part of the watershed.

Forest: There was a general lack of forest cover in the watershed area before 1957. The remaining forest cover has changed from 5.4% in 1957 to 2.6% in 1980 and 2.9% in 2001, i.e., a net loss of 46% in 44 years. Overlay analysis of the waterbody of 1980 and 1957 land use maps show that 0.9 km^2 of forests that were situated around the Doonje area were inundated. An additional 0.3 km^2 that were situated in western and northern part of Doonje were inundated between 1980 and 2001. The forests were mainly situated along water divide lines in the western and south-western parts of the watershed, hillsides, along embankments of streams and rivers and adjacent to towns and settlement areas. In general rapid forest reduction was detected between 1957 and 1980 perhaps due to cropland and grazing land expansion and as wood sources for household energy, farm implements, construction and cash income. In 2001 the forest cover was increased compared to the amount in 1980. This could be due to the reforestation activities carried out at forest areas, hills and settlements in the 1980s.

Town: Urbanization as land cover, in the form of built-up or paved areas, covers 0.3 to 0.4% of the watershed area. The construction of the hydropower dam and population growth has contributed to the increase in the size of this category. The construction of the dam and electrification have created limited job opportunities and attracted people to the towns. Towns showed mixed impacts on land use. On one hand urbanization affects the land use through increasing use of forests for construction and fuel wood but on the other hand plantation activities have been intensified in and around the towns.

2.4 Discussion

2.4.1 Comparison to other watersheds

In this section the results of land use studies conducted in different parts of the country are compared with the situation in Fincha'a watershed. Only the most important land use classes, namely cropland, grazing land and forest were considered. We combined the individual land use classes defined by the authors based on the definition given in Table 2.1. The studies were conducted at Mettu (Solomon, 1994), Denbecha (Gete, 2000) and Chemoga (Woldeamlak, 2003) watersheds. The farming system at Mettu is (perennial) coffee based, but those of Denbecha and Chemoga are cereal based and similar to Fincha'a. The sizes of those watersheds, study years and relative areas of the land use types are shown in Table 2.3. In all three cases the land use changes were attributed to population increases in the watersheds.

Table 2.3. Major land use classes at Mettu, Denbecha, Chemoga and Fincha'a watersheds in the Highlands of Ethiopia.

Land use class	Mettu ($146\ km^2$)		Denbecha ($271\ km^2$)		Chemoga ($364\ km^2$)		Fincha'a ($1318\ km^2$)	
	1957 %	1982 %	1957 %	1995 %	1957 %	1998 %	1957 %	2001 %
Cropland	30.5	40.4	39.5	77.1	60.4	66.6	30.6	46.1
Grazing land	32.9	18.6	32.9	17.9	14.7	6.8	42.1	25.2
Forest	36.6	41.0	27.1	2.2	9.1	6.5	5.4	2.9

Compared to the other study areas, the forest cover of Mettu was higher and the cover increased during the study period. Moreover cropland was increased by 32% to 40.4%, which is a relatively low proportion of the entire area. In 1957, Denbecha had a better forest cover compared to Chemoga and Fincha'a, but the forest area was much reduced in 1995. In Denbecha, 77% of the area was cropland in 1995 showing a low possibility for further expansion (Gete, 2000). The proportion of cropland was already high in Chemoga in 1957, and had increased in 1998 only by 10% to 66.6%. Hence, in Chemoga continuing cropland expansion is difficult as well. Based on the numbers in Table 2.3, the land use changes in Fincha'a between 1957 and 2001 were not very different from the other watersheds. The cropland area has increased with 50%, but the proportion of cropland is only 46% of the entire watershed. At the same time the areas of grazing land and forest decreased, which is a similar trend as in the other watersheds.

Due to growing populations, the cereal based farming systems at Denbecha, Chemoga and Fincha'a demanded more land for cultivation and increased deforestation. At Mettu, however, the coffee production system encouraged forest plantation. Grazing land showed a decreasing trend in all the study areas due to cropland expansion. There was no system in place that protects the grazing lands and forests that were not distributed to individual farmers from encroachment in all the study areas. Hence, these land use types have been the potential cropland sources for mainly the newly emerging farm households.

This comparison between watersheds where land use changes have been studied does not reveal any major differences between Fincha'a and the three other watersheds, where land use changes were mainly caused by population increases. Population pressure has been a driving factor of land use changes in many countries in the world (e.g. Mungai et al., 2004; Semwal et al., 2004), and it certainly has played an important role in Fincha'a watershed as well. But, according to the key informants that were interviewed as part of this study, the creation of the hydropower reservoir also had an important impact on the land use in the watershed. The next section will deal with these effects in more detail.

2.4.2 Land use changes in Fincha'a watershed

In this section the major land use changes, underlying factors of these changes and opportunities available for the community in Fincha'a watershed are discussed. The major land use changes in Fincha'a watershed were the creation of 239.3 km^2 area of waterbody that inundated 18 km^2 cropland, 120 km^2 swamp, 100 km^2 grazing land and 1.2 km^2 forest between 1957 and 2001. In the same period, the area of cropland has increased by 203.8 km^2, mainly at the expense of grazing land and forest. Recently the dynamics in the area and location of swamp and grazing land became unusual for the community as well as the EELPA power company. Before 2001, many people thought that the reservoir area was expanding but after 2001 it has receded in all directions due to reduction in annual rainfall amounts. The inter-face between swamp and grazing land fluctuates depending on the magnitude of rainfall and the gradient of the reservoir bed. In the inundated area, a low longitudinal gradient of 1:476 m/m was determined between the dam and the remotest part of the reservoir (southern part of the watershed). This is the main reason for such a large reservoir area of 239 km^2 to be impounded by a dam of only 20 m height and a crest length of 340 m. Depending on the annual rainfall, the areas of waterbody, swamp and grazing land in the lower part of the watershed vary from year to year.

Given these fluctuations in the areas of reservoir, swamp and grazing land, it useful to make a distinction between land that is potentially available to the community, and land that is not suited for permanent agriculture (i.e. the reservoir and swamp land). Parts of the latter class could be used for grazing during relatively dry years, when the extent of the reservoir and swamp are limited. Since the amount of annual rainfall that occurred before 1970 is unknown, it was assumed that the 1957 classification of swamp area represented the area of non-suitable land before the dam was constructed. After the construction of the dam, the year 1980 had a peak rainfall amount, and it was assumed that the land use classification of that year gives a good estimate of the boundary between potentially available land (well drained area), and non-suitable land in the watershed. Accordingly, the total area that was potentially available for community use was 1032 km^2 (78%) in 1957 but reduced to 790 km^2 (60%) in 1980. In other words, after the construction of the dam 40% of the watershed is not available anymore for permanent cropland and grazing land.

Table 2.4. Major land use classes in the potentially available land in Fincha'a watershed in 1957, 1980 and 2001.

Land use	1957		1980		2001	
	km^2	%	km^2	%	km^2	%
Cropland	403.3	39.0	478.8	60.6	607.1	76.8
Grazing land	555.2	53.8	272.9	34.5	140.1	17.7
Forest	70.5	6.8	34.1	4.3	37.9	4.8
Town	2.5	0.2	4.6	0.6	5.6	0.7

*Out of the 332 km^2 of grazing land detected in 2001 about 187 km^2 was seasonal grazing land and 145 km^2 was permanent grazing land.

The areas of potentially available land before and after the construction of the dam were used to reclassify the major land use classes in Fincha'a watershed (Table 2.4). In this way, a dramatic increase in cropland, and a sharp decrease in permanent grazing land becomes apparent. These changes are quite similar to what happened in Denbecha, where nearly all available land was used for rainfed crop production already in 1995 (Gete, 2000). The main difference between Denbecha and Fincha'a is the much bigger loss of grazing land in Fincha'a. Due to the current shortage of grazing land, livestock numbers have decreased

(Bezuayehu and De Graaff, 2006) and farmers were forced to graze the swamp that resulted in drowning of animals.

The Fincha'a population depends mainly on the extensive cereal based farming system that mounts pressure on the remaining fragile lands. Besides, 20 to 35% of the farm households, who have recently formed their own families, have already become landless (OADB, 1996). Following the inundation of the vast grazing lands and cropland expansion, livestock production activity, which is equally important as crop production, has faced a serious challenge. The two major economic activities have entered a state of competition rather than supplementing each other. Crop intensification is still lacking and improved livestock feed sources were not developed in the area either. Hence, the free grazing practices have been one of the major causes of land degradation in Fincha'a watershed as well as the country. But so far, there has been no meaningful policy implementation, which either regulates the livestock numbers or promotes the production of improved fodder sources.

2.4.3 Implications of the reservoir in Fincha'a watershed

Based on the susceptibility to erosive rainfall, the land use of Fincha'a watershed could be categorized into four groups: (i) areas that are bare when erosive rain occurs and exposed to accelerated erosion (i.e. cropland), (ii) areas that have a relatively better vegetation cover but exposed to indiscriminate tree cutting and overgrazing (i.e., grazing land), (iii) areas with better vegetation cover all year round but subjected to limited encroachment (i.e., forest), and (iv) the waterbody and swamp. Thus, the proportion of the watershed exposed to the possible maximum soil loss is cropland, amounting to 31% in 1957, 36% in 1980 and 46% in 2001. This shows that the area potentially subjected to accelerated erosion is increasing from time to time. Consequently rill and gully erosion are the abundant forms of erosion in cropland and grazing land. Field observation showed a high sediment influx into the waterbody (Figure 2.6), which caused a reduced surface area and volume of the lake.

In spite of this, reforestation and soil and water conservation activities are lacking in the watershed. At the receded parts of the reservoir many farmers have already started to grow potatoes and maize, and graze their animals. This situation was not detected using the satellite image because these practices must have started after the image was taken. The population of phreatophytes (floating grasses) growing from the floor of the lake has recently increased, perhaps, due to the enhanced sediment influx. This may result in more evapotranspiration losses and reduced electric power generation.

The dam plays a significant role in supporting the national economy through electric power generation, supplying water for a sugar factory downstream and introduced fishery in the area. But the rural community in Fincha'a watershed is not benefiting from the electricity. According to the key informants the reservoir and swamps have caused economic as well as environmental side effects to the community in the watershed area. For instance, often animals and sometimes human beings drowned in the swamps and reservoir. Streams often burst and cause habitat destruction. When the watershed was with good vegetation cover, clean water was obtained from streams and springs the whole year round, but today water supply from these sources is short-lived. Water shortage for people and livestock, as well as famine have become recent phenomena in this watershed (Assefa, 1994; Dechassa, 2003).

Figure 2.6. Sediment load transported by a stream into the hydropower reservoir in Fincha'a watershed, western Ethiopia. (Photo: February 2003)

2.5 Conclusions

The creation of the hydropower reservoir in Fincha'a watershed have claimed about 239.2 km^2 of land which include 100 km^2 of grazing land, 18 km^2 of cropland, 1.2 km^2 of forest and 120 km^2 of swamp. Information from the key informants show that the parts of the watershed currently inundated were the most productive areas in terms of grass and crop production.

Though cropland expansion into grazing land and forest is a common trend elsewhere in the country (Solomon, 1994; Gete, 2000; Woldeamlak, 2003) and other developing countries (Kammerbauer and Ardon, 1999; Semwal et al., 2004), the creation of the reservoir in Fincha'a watershed enhanced the cropland expansion. This was most likely caused by those dislocated inhabitants who were self-resettled in upstream parts of the watershed by encroaching into forests and grazing lands. The land reform of 1975 should have contributed to some extent to land use changes in this watershed because following this reform grazing lands and forests became free for opening up of croplands and settlements. Consequently, out of the potentially available land for community utilization, cropland covered 77% in 2001, indicating that there is hardly any possibility for further expansion to accommodate new farm families. The fact that, today, 25 to 30% of the community members are believed to be landless (OADB, 1996) and off-farm activities were not developed show that further undesired land use changes are imminent.

Out of 332.2 km^2 grazing land available in 2001 about 56% is difficult to graze during the wet season because of an increase in the reservoir level easily inundates this part of the watershed. Consequently, many animals get drowned into the reservoir and swamps. Rural farmers in this watershed complain that they do not benefit from the electricity generated, but face serious limitations for livestock grazing.

In general, land use changes in Fincha'a watershed are mainly the effect of the construction of the hydropower dam, population pressure (induced by forced migration and normal growth) and annual rainfall fluctuations. The factors of land use change in this watershed have been interacting in a very complicated ways; the overall implication could be onsite soil erosion and offsite sedimentation of water reservoir. Therefore, the changes in land use in this watershed affect the livelihood of the community and will also affect the ability of the dam to deliver the planned economic benefits. Fincha'a River is a tributary of the Blue Nile, the onsite and offsite effects of this watershed may have local, national and international dimensions the solution also calls for the cooperation of all levels. For instance allocation of part of the revenue generated from the power generation on agricultural intensification and implementation of erosion control measures is justifiable in terms of property rights and equity.

Chapter 3

Social and economic impacts of a hydropower reservoir on upland farming in Fincha'a watershed, western Ethiopia

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Social and economic impacts of a hydropower reservoir on upland farming in Fincha'a watershed, western Ethiopia

Abstract

This paper analyses the social and economic changes as a result of a hydropower reservoir in Fincha'a watershed, tributary of the Blue Nile in Ethiopia, and explains the possible causes and implications of these changes on the community and the hydropower dam itself. Semi-structured questionnaires were used to interview 120 households in three sub-watersheds and checklists and key-informants were used to gather additional information. The survey showed that the relocated households owned 23% less land and 24% less livestock units than in the neighbouring areas. They achieved only 65% of the crop production realized in neighbouring districts, due to less utilization of chemical fertilizers, poor extension services and smaller farm sizes. Lands potentially available to the community have been reduced from 78% before the dam to 60% after the dam. The relocated households were moved to the upstream extremely steep parts of the watershed inducing undesired land use changes. Currently cropland has expanded to the extent that there is less possibility for further expansion to accommodate the increasing population pressure. Implementation of social and economic development initiatives requires cooperation at local level and beyond.

3.1 Introduction

Globally, many water reservoirs have been constructed to provide electricity, irrigation, flood control and water supply for the ever-increasing population and to improve its standard of living (WCD, 2000). However, dams often show negative environmental effects that can be social, economic and physical (Dixon et al., 1989). The social effects of a dam include the involuntary resettlement of people and the disruption of their productive systems and lifestyles (Dixon, et al., 1989; De Wet, 1999; WCD, 2000; Sims, 2001) and the impact of the relocation on the population inhabiting the new host areas (Dixon et al., 1989). Besides, problems such as lower amounts and delays of payment and lack of participation in the resettlement process cause dissatisfaction in resettlements and hence affect the sustainability of the projects (Rooder, 1994; De Wet, 1999; WCD, 2000). The environmental effects comprise changes in water quantity and quality, and soil erosion and sedimentation (Dixon et al., 1989; Terry, 1995). The construction of the Kariba dam in the Zambezi river in the late 1950s, for instance, led to the flooding of an area of 4,000 km^2 and relocated about 57,000 people and disrupted their cultural systems and traditions (WCD, 2000). The limited compensation made (WCD, 2000) and the failure to make the affected people part of the planning and management initiatives (Fujikura et al., 2003) make the construction of many dams less interesting to the inhabitants. Furthermore, dams usually submerge more areas and dislocate more people than anticipated in the project design and this often takes place on the relatively better land.

In Ethiopia, the Gilgel-Gibe hydropower dam has dislocated 10,000 people from their villages (WRDA, 1994). The communities have been resettled in accordance with the

National Villagization Programme (EELPA, 1996). Similarly, the Dirre dam water supply project has evicted 140 households (765 people) against their will from the total area of 478 ha (WRDA, 1995). The design report shows that the evicted community received very limited monetary and land-by-land compensation. Since monetary compensation was known not to support the livelihood of rural households on a sustainable basis it was not the preferred compensation option for them. On the other hand, since the land-by-land compensation was implemented through land redistribution in the neighbouring areas it was not appreciated either because the land redistribution has reduced the holding sizes of the recipient communities (WRDA, 1995).

Fincha'a hydropower dam was constructed in 1973 as a strategy for fostering economic growth in the country through generation of hydroelectricity, irrigation, fishery and tourism (HARZA, 1965; 1975). Currently, out of the 478 MW installed hydropower capacities generated in the country, this power plant generates 128 MW (Assefa, 2003). The original installed capacity of this scheme was 100 MW but increased to the current level following the diversion of Amarti River into this scheme in 1987. Moreover, the hydropower reservoir supplies water to a sugar factory downstream, creating new economic activities such as fisheries and attracted various birds to the area.

In spite of this, it has caused major land use changes with multiple on-site and off-site implications (Bezuayehu and Sterk, 2006a) and evicted several people from their original places (Assefa, 1994; OADB, 1996). HARZA (1965) proposed two forms of resettlement options, depending on the landownership title: 1) the resettlement of the landlords in the upstream part of the watershed, and 2) the resettlement of the large group of tenants in the malaria infested downstream part of Fincha'a valley. For the latter option, HARZA proposed to drain and reclaim the Coomman swamp, which should provide sufficient land for an estimated 2000-3000 households. However, resettlement was not undertaken for both landlords and tenants altogether. But what happened to those people displaced from their dwellings is not well known. It is possible that they have started agricultural activities on steep and marginal areas within Fincha'a watershed or left the area to make a living elsewhere.

Fincha'a watershed was known for surplus crop production, vast expanses of pasture and great herds of livestock (Ritler, 1997). Contrary to this, Assefa (1994), OADB (1996) and Dechassa (2003) showed that the community in Fincha'a watershed is nowadays confronted with a decline in crop and livestock production and recently even with famine. But it has not yet been investigated what caused this famine. Information about the social and economic consequences of the construction of dams is scanty in the country in general and in this watershed in particular. The objectives of this research were, therefore, to analyse the social and economic changes after the dam construction, and to explain the possible causes and implications of these changes on the community and on the (functions of the) dam itself. To meet these objectives, an analysis was made of the farm households, their holding size and fragmentation, relocation, resettlement, land use changes, soil erosion and sedimentation, crop and livestock production, and rural infrastructure. With this kind of information the impact of the inundation of different land use types and the relocation of the community in the watershed, as a result of the dam was explained.

3.2 Materials and methods

3.2.1 Research area

The geographical location of Fincha'a watershed, a tributary of the Blue Nile, is 9°10'30" to 9°46'45" North latitude and 37°03'00" to 37°28'30" East longitude. In administrative terms, it is situated in eastern Wallagga zone, Oromiya region, western Ethiopia (Figure 3.1). About 178,000 people live in the watershed area (Assefa, 1994).

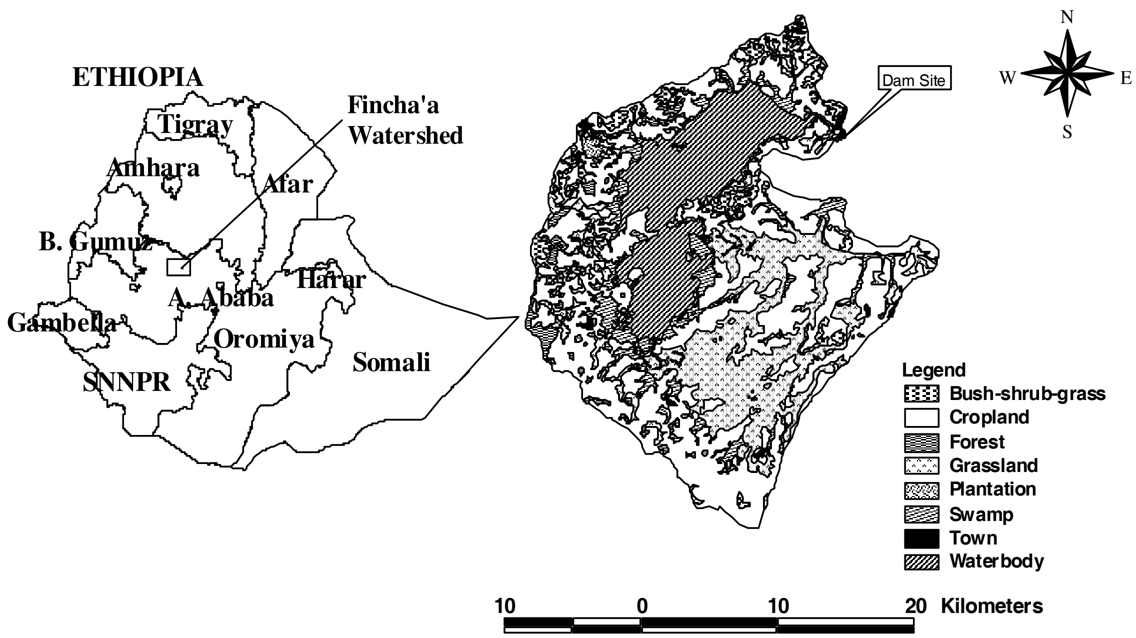

Figure 3.1. Location of Fincha'a watershed in Ethiopia, and land use map.

There are five neighbouring districts that are partially drained by this watershed, namely, Abbayyii-Coomman, Jimmaa-Gannatii, Jimmaa-Raaree, Guduruu and Horro. The watershed covers an area of 1318 km^2 and elevation ranges from 2200 to 3100 m. The dam has 340 m crest length and is 20 m high above the lowest foundation level. During 1973 to 1986 Fincha'a river alone was supplying water to the scheme, but in 1987 Amarti river was also connected to the system. The reservoir now inundates an area of about 239 km^2. The average annual rainfall is 1823 mm, ranging from 3040 mm in 1980 to 1281 mm in 1994. About 80% of the annual amount falls between May to September. The mean monthly temperature varies from 14.9°C to 17.5°C.

Figure 3.2. Location of the sample sites in the Fincha'a watershed.

Three sub-watersheds, namely Balbala, Hulluqa and Walda were selected for the survey representing the upper-, middle- and lower parts of the watershed (Figure 3.2). The sizes of Balbala, Hulluqa and Walda sub-watersheds are 63.8, 12.4 and 41.2 km^2 respectively. A total of 1716 families (9046 people) live in Balbala, 76 families (447 people) live in Hulluqa and 342 families (1993 people) live in Walda sub-watersheds. The integrated crop-livestock production is the main agricultural system in this watershed. Major crops grown are maize (*Zea mays*), horse bean (*Vicia faba*), Niger seed (*Guizotia abyssinica*), tef (*Eragrostis tef*), barley (*Hordeum vulgare*) and wheat (*Triticum species*). Many farmers posses cattle, sheep, goats and horses. Cattle rearing is practiced for draught power, food, soil fertility enhancement and cash income. Natural pasture is a major source of fodder for livestock but crop residues are used to supplement this during dry seasons.

There was private ownership of land in this watershed before the land reform of 1975. In the 1890's, the area was occupied by the Minilik II regime, when private ownership of land was of the 'egalitarian' type. However, following Minilik II's occupation this egalitarian type of land ownership was transformed into a tenant-and-landlord type of relationship. This latter tenure arrangement made the majority of the original inhabitants a tenant and the few settlers a landlord. The tenants were operating land given by the landlords mainly based on sharecropping arrangement. However, the land reform of 1975, as elsewhere in the country, had relinquished the tenant-landlord relations by dividing the farmlands among the tillers. Since then, land has become state property under which only use right was given to the farmers.

3.2.2 Methodology

The lake has converted large areas of the watershed into waterbody and swamp (Figure 3.1). This inundation could have enriched people from their original places, and may have led to increased population pressure on steep and relatively fragile ecosystems. The evicted people would have caused undesired land use changes for crop and livestock production and establishment of settlements, which may aggravate soil erosion and decrease crop and livestock production. In order to meet the objective of the research we, therefore, analysed the changes that occurred on holding size and fragmentation, relocation, resettlement, land use changes, soil erosion and sedimentation, crop and livestock production, and rural infrastructure following the construction of the dam. A socio-economic survey was undertaken for which use was made of a semi-structured questionnaire, checklists, key informants and secondary data. The questionnaire was structured in such a way that the above issues are covered. The research methodology included the following activities:

1) Delineation of the boundaries of Fincha'a watershed and the sub-watersheds from the topographic maps with a scale of 1:50,000 (1982 edition), which were obtained from the Ethiopia Mapping Agency. After making ground verification, these boundaries were digitised into Arc Info 7.2.1, exported into Arc View 3.2.
2) Discussions with the respective relevant district offices and community representatives at each sub-watershed were held based on checklists in February 2003.
3) After compiling lists of the inhabitants, 40 households were randomly selected from each sub-watershed for interviews using the semi-structured questionnaires. This makes about 6% of 2134 households residing in the sub-watersheds. The selection was made in such a way that households residing in lower, middle and upper parts of each sub-watershed are represented. The interviews were conducted after visiting the residences and plots of each interviewee between March and June 2003. However, from a total of 120 households, two had to be removed from the list because of incomplete information. The survey data were analysed using the Statistical Packages for Social Studies (SPSS 11.5).
4) Periodical reports from different offices and census records were reviewed for complementing the information obtained during this survey.
5) Nine elderly farmers (three from each sub-watershed) were used as key informants. Their long time experiences were used to complement the information obtained from interview and periodical reports.

3.3 Results

3.3.1 Farm household size

The 118 sample households comprised 980 persons. The average family size was 8 (ranging between 3 and 15 people per household) with a slight variation between the sub-watersheds, i.e., 7.5 in Balbala, 8.2 in Hulluqa and 8.4 in Walda (Table 3.1). Information gathered from the neighbouring districts based on the checklist showed a household size of 7 people per household. The obtained result is also higher than the average household sizes of 6.3 in

Chemoga (Woldeamlak, 2003) and 6.0 in Ginchi (Selamyihun, 2004), which are both watersheds in Ethiopia as well.

Only 39% of the sample household replied that they practice family planning based on the knowledge they got from technical trainings given by health officers. In spite of this lack of contraceptives is a major problem for the practitioners. Average family size in Walda is relatively higher than the other two sub-watersheds. Walda is situated along all weather roads and adjacent to Fincha'a town. This improved family planning awareness of the families, because more training was received. Also, the location created better opportunity of access to contraceptives, but still the family sizes in this sub-watershed were the highest of the three sub-watersheds. Therefore, the high family size in Fincha'a watershed may correspond to low number of families using birth control methods. The attempt to compare the status of the family planning practices of this area with other parts of the country was not successful due to limited data.

Table 3.1. Average household size and family planning in three sub-watersheds of Fincha'a watershed, western Ethiopia.

Sub-watershed	Number of respondents	Family size	Extent of family planning*			
			A	B	C	D
Balbala	40	7.5	11	14	3	12
Hulluqa	38	8.2	7	6	4	21
Walda	40	8.4	20	10	2	8

*A= Received training and applied, B= Received training but didn't apply, C= Didn't receive training but applied, D= Have no knowledge.

The average population density was 98 people per km^2 (i.e. medium density) with a significant variation between the sub-watersheds, i.e. 142 in Balbala, 36 in Hulluqa and 48 in Walda. The population density of Balbala was much higher because the sub-watershed drains parts of Harato town. Many inhabitants were from the rural parts of Fincha'a watershed that were relocated due to the water reservoir. But the population density of Hulluqa was low due to its rugged topography that may affect settlement patterns and the fact that much of its area is situated along the reservoir that may prohibit settlement. Population density of the neighbouring districts was about 90 people per km^2.

3.3.2 Land holdings and fragmentation

Land is the basic asset for the rural people in Fincha'a watershed. Access to land has been achieved through 'family allocation' and government redistributions. Whereas land redistribution through family allocation has always existed, the government made redistribution only in 1975. The average land holding size in the sub-watersheds was 2.5 ha, ranging from 0 to 6 ha (Table 3.2). This is slightly lower than the regional average which is 2.66 ha (ORCS, 1998) and that of the "non-affected" part of Fincha'a watershed which is 2.74 ha (OADB, 1996). Despite the land redistribution of 1975, the farm size of the relocated households was 1.9 ha, i.e. 24% lower than the average holdings in the sub-watersheds. The average per capita holding size was 0.3 ha. The average number of plots operated was 3.9 ranging from 0 to 15 (Table 3.2).

Table 3.2. Holding sizes and number of plots in Balbala, Hulluqa and Walda sub-watersheds, western Ethiopia.

Sub-watershed	Respondent (no)	Holding (ha)		Plots (no)	
		Average	Range	Average	Range
Balbala	40	1.6	0-4	4.3	0-10
Hulluqa	38	3.1	0-6	3.7	0-8
Walda	40	2.8	1-6	3.8	0-15

Source: Results from 2003 field survey. Farm size data were collected in local area unit *oolmaa* and converted into hectare assuming that 1 *oolmaa*= 0.25 ha.

A significant difference in both holding size and number of plots was observed between the sub-watersheds. For instance, in Balbala the holding size was below average, while the number of plots was above average. This sub-watershed is the one with the high population density. According to the interviewee the creation of water reservoir and population growth have reduced holding sizes and increased fragmentation of farmland.

3.3.3 Relocation, resettlement and compensation

Dams often inundate large areas, force many people to relocate, and disrupt cultural systems and traditions. According to this study 14% of the survey households were relocated from their original villages between 1973 and 1995, with some differences between the sub-watersheds: 20% in Balbala, 18% in Hulluqa and 5% in Walda (Table 3.3). About 82% of the relocation occurred between 1973 and 1986 (first impoundment), and an additional 18% occurred between 1987 and 1995 (following the Amarti river diversion). According to the key informants the number of evicted households in Walda was suggested to be higher than the 5% estimate from the survey.

Table 3.3. Number of relocated households during the first and second impoundment in three sub-watersheds, Fincha'a watershed western Ethiopia.

Sub-watershed	Number of respondents	Relocated households		Relocation period (%)	
		(No)	(%)	1973/86	1987/95
Balabala	40	8	20	100	0
Hulluqa	38	7	18	57	43
Walda	40	2	5	100	0

An attempt was made to count the number of homes that would have been inundated by the water reservoir from the 1957 aerial photos. However, the resolution of the photos was too low to do so. The absence of a reliable secondary data also limited us to get the actual number of households relocated due to inundation. Taking the 14% of relocated households (Table

3.3), and the average household size of 8 people (Table 3.1) as the averages for entire Fincha'a watershed, we can estimate the number of relocated households in the entire watershed. The total population of Fincha'a is 178,000 people, making 22,250 households in total of which 14% were relocated in the watershed. This makes an estimated 3115 households.

What ever the magnitude of eviction would be, migration appeared to be "short-distance" which means the majority of the households had self-resettled in the hilly areas of the watershed. A few numbers of relocated families have been involved in lumbering, wildlife hunting and honey gathering in the Fincha'a River Valley downstream of the dam site (Taye, 2003).

Information showed that a few number of landlords had received a limited amount of compensation for the loss of physical property such as land, houses and trees. The majority of landlords were not able to get appropriate compensation because the process was aborted due to the land reform of 1975, which had converted private land ownership to the state. Before the land reform there were two forms of compensation proposed. The first was a financial compensation that was often reported from Balbala and Hulluqa that included perennial plantations, houses and total land owned. The second was a straight land-for-land compensation that was reported by two farmers in Walda. According to these farmers land-for-land compensation was proposed in a place far away from these sub-watersheds and was not preferred by the displaced people in this watershed. In spite of this segregating proposal, land redistribution was made for both landlords and tenants based on family size in 1975.

In general it was not possible to determine the number of households who received compensation in the entire watershed. There are two main reasons for the difficulty in obtaining a reliable answer. Firstly, since the event had occurred 30 years ago, many relocated farmers are not any longer alive. Secondly, many households did not like to disclose this information, complaining about the very limited scope of compensation given and due to lack of transparency in the dam construction procedures. According to the latter group the community was not consulted, but merely informed about compensation through a few 'representative' landlords. Unfortunately, many of the promises were not kept. The example below shows the dynamics of household and farm size, land fragmentation and compensation payments, based on one key informant.

A household leader named Wodajo had seven children and owned one Qalad (= 40 hectares) of "undivided" and fertile land in the downstream part of Hulluqa sub-watershed (Onnonnee village) before most of his land and his village was inundated due to the construction of Fincha'a dam. After inundation he was forced to resettle in the upstream part of this sub-watershed. His holding became smaller in size and less fertile compared to the lands inundated. He had received compensation amounting about 200 Birr in 1973 (1 USD = 8.6 Birr, current value) for the properties left behind, which according to his elder son (Kebede) was very low. According to Kebede, Wodajo was one of the most prosperous farmers in the area who became poor after his properties were flooded. He passed away because of old age. Kebede is currently 70 years old, has given birth to 23 children and is currently a leader of a poor household of 5 people (other children have established their own *families), holds 4 plots of land (2.5 ha), 5 cattle and 1 horse. He complains about the poor land he holds and the unfavourable situations caused by the water reservoir. Source: Kebede Wodajo (2003).*

3.3.4 Land use changes

Land use can contribute to diverse cultural landscapes of outstanding aesthetic, economic and ecological value, but it may equally result in land degradation, soil loss and impoverished ecosystems (Haberl et al., 2004). Hence land use is shaped by processes of society–nature interaction. In Fincha'a watershed cropland has expanded from 31% in 1957 to 36% in 1980 and 46% in 2001 (Table 3.4).

Table 3.4. The sizes of the major land use types in 1957, 1980 and 2001 in Fincha'a watershed, western Ethiopia.

Land use	1957		1980		2001	
	km^2	%	km^2	%	km^2	%
Cropland	403	31	479	36	607	46
Grazing land	555	42	273	21	332	25
Forest	71	5	34	3	38	3.3
Town	3	0.3	4	0.3	5.6	0.7
Swamp	286	22	377*	29	96*	7
Waterbody	0	0	151	12	239	18

Source: Bezuayehu and Sterk (2006a). *Note: The swamp area was large in 1980 because of high rainfall, and much smaller in 2001 because of drought.

Grazing land has shown a sharp decline between 1957 and 1980 due to inundation but slightly increased between 1980 and 2001 due to a recent reduction in the annual rainfall amounts. Depending on moisture regime in the floodplain area, grazing land can be divided into permanent grazing land (well drained and available the whole year round) and seasonal grazing land (only being grazed during the dry season). For example, out of the 332 km^2 grazing land in 2001, 145 km^2 was permanent grazing land and 187 km^2 was seasonal grazing land. However, due to a shortage of grazing land farmers were forced to let animals graze the wetlands that resulted in drowning of animals.

On the other hand the size of swamp has declined from 377 km^2 in 1980 to 96 km^2 in 2001 due to the recent reduction in the annual rainfall amount in the watershed area. The areas from which swamp was receded became seasonal grazing land (used for grazing during dry season). Generally, land that was potentially available for crop production, grazing and forestry has changed from 1032 km^2 (78%) in 1957 (before the dam) to 790 km^2 (60%) following construction of the dam. This means that 40% of the watershed was either inundated or became swamp and could not be used for crop production, permanent grazing, forestry and settlement.

3.3.5 Soil erosion and sedimentation

People displaced from the inundated area of the reservoir, or those whose movement is facilitated by the reservoir and dam construction activities, have resettled in the upstream parts of the watershed. Their cultivation practices may have created additional erosion, leading to increased sedimentation reducing storage capacity of the reservoir. Sediment also affects water quality for drinking and irrigation.

Virtually all of the surveyed households mentioned the erosion threat to their land and its effect on agricultural production. Hence 73%, 24% and 3% of the surveyed households evaluated the soil erosion level as severe, moderate and low, respectively. Farmers listed three main harmful effects of erosion: loss of soil (70%), loss of seeds and fertilizers (80%) and loss of water (22%). Nevertheless an insignificant number of households have implemented soil conservation measures such as soil bunds, cut-off drains and tree planting. However, the terraces and cut-off drains constructed were hardly visible in the sub-watersheds. The two major reasons for this were deliberate removal by the farmers (43% of the respondents) and lack of maintenance (57% of the respondents). The deliberate removal occurred when the current government replaced the *Derg* regime, which can be interpreted as a reaction to the lack of community participation during implementation. On the other hand 68% of the surveyed households practice tree planting in the homestead and along farm boundaries for different community needs. In general accelerated soil erosion has become a concern for the farmers, local leaders and the hydropower scheme due to its on-site and off-site effects. This in turn may affect crop and livestock production.

3.3.6 Crop and livestock production

Due to the poor yield records by farmers we show only the crop production of the major crops for the years 1992, 2001, 2002 and 2003 (Table 3.5). The year 1992 was selected because it was a year that could easily be recognized by farmers due to the political change that occurred in the country at that time, but 2001 to 2003 were the most recent years for which the farmer could remember the magnitude of production obtained in those years. Crop yields of the year 1992 were generally low compared to the year 2001 due to low provision of chemical fertilizers. Crop yields of the year 2003 were also low for most crops due to poor rainfall distribution. The farmers in the study sub-watersheds obtained weighted average crop yields of 1.1 t ha^{-1} while the farmers in the neighbouring districts got 1.7 t ha^{-1} in 2002 (Table 3.6). Problems of obtaining chemical fertilizers and a lack of agricultural extension services were some of the major reasons for reduced crop productivity in the sub-watersheds.

Table 3.5. Average crop yields of Balbala, Hulluqa and Walda Fincha'a watershed, western Ethiopia.

Year	Crop yield (t ha^{-1})				
	Maize	Tef	Wheat	Niger seed	Horse bean
1992	0.8	0.5	0.7	0.3	0.6
2001	2.4	0.4	0.8	0.2	0.7
2002	2.3	0.5	1.0	0.2	0.6
2003	1.3	0.3	0.7	0.2	0.4

Table 3.6. Average crop yield in the five neighbouring districts and the study sub-watersheds in Fincha'a watershed, western Ethiopia.

Crop	General distribution of cropland (%)	Crop yield in 2002 ($t\ ha^{-1}$)	
		Neighbouring districts ($t\ ha^{-1}$)	Study sub-watersheds ($t\ ha^{-1}$)
Maize	25	3.3	2.3
Tef	30	1.2	0.5
Wheat	20	1.7	1.0
Niger seed	15	0.3	0.2
Horse bean	10	1.3	0.6
Weighted average		1.7	1.1

Note: Yield per hectare of the major crops in the neighbouring districts was taken from the Central Agricultural Census Commission, Part II (2002) and that of the sub-watersheds was from the own survey. Average cropland size in the neighbouring districts was 2.74 ha but that of the survey sub-watersheds was 2.5 ha.

Livestock is an integral part of the rural economy in this watershed. On average 12.3 Tropical Livestock Units (TLU) were kept per household with a slight variation between the sub-watersheds (Table 3.7). Oxen are the sole draught power sources for crop production activities in these areas. Lack of oxen, therefore, determines the economic as well as social status of the households in the community. However, 24% of the survey households were without any ox. The farmers without oxen get their plots ploughed by exchanging human labour for oxen and by sharecropping. According to this survey the number of horses, that was thought to be high in the area, has turned out to be low. Only 9% of the survey households keep a total of 26 horses. An increase in the incidence of waterborne diseases and fodder shortage could have caused the reduction of the number of horses in this watershed. On the other hand, farmers increasingly keep donkeys as pack animals because they believe donkeys are less susceptible to diseases and can be easily fed on locally available fodder.

Table 3.7. Livestock numbers and TLU owned by the surveyed households in Balbala, Hulluqa and Walda, Fincha'a watershed, western Ethiopia.

	Ox	Other cattle	Goat & sheep	Horse, mule & donkey
Respondents (no)	90	102	66	87
Total animals (no)	221	718	157	131
Animals per household (no)	2.5	7.0	5.3	4.2
TLU per household	2.8	5.6	0.4	3.5

The information gathered based on key informants and checklists show that there has been an overall increase in the livestock number in the area but the number of animals per household decreased. For instance, there were several families who held more than 100 cattle before the dam and who identified themselves from those with less cattle by 'wearing' a stomach of a cow in public, a so-called "*garaacha uffachuu*". This tradition has become nonexistent because no household owns such a large number of animals these days. During this research only one household reported as many as 47 cattle. Communities believe that inundation of the vast areas of grassland was the major cause for the reduction of livestock numbers and their productivity. The remaining communal grasslands are situated in depression areas adjacent to the water reservoir but as water in the dam reservoir recedes during the dry season many animals get drowned while grazing along the edges of the reservoir. Others die as a result of waterborne diseases. Besides, milk production, which was estimated to be 1.0 and 1.5 litres per cow per day during dry and wet seasons respectively, before the dam, has been reduced by 50% in these days. Agriculturalists suggest that the poorly developed rural infrastructure, including access road, marketing and other social services, affects social and economic activities in the areas.

3.3.7 Rural infrastructure

The construction of the dam and the formation of a large reservoir have "encircled" more than 10,000 people in this watershed (OADB, 1996). There are many small islands locally known as *cittuu* surrounded by the water reservoir. The communities living in the *cittuu* use traditional boats and floating grasses known as *saalmalee* for transportation (Figure 3.3). Both forms of transportation are not safe at all since the wind induced waves often divert travel direction and the methods are constrained by low loading capacity and speed.

Figure 3.3. Floating grass (*Saalmalee*) as a means of transport in Fincha'a watershed, western Ethiopia. (Photo: February 2003).

The farmers in these sub-watersheds (mainly Hulluqa) as well as those in the islands are deprived from information and advice, among others from extension services and research results. For instance, many affected farmers do not follow the fertilizer application rate recommended but go for the amount they can afford. In general, lower crop and livestock prices due to poor marketing, led to poor credit repayments. As a result, communities encircled by the lake receive 15% lower prices for their crop and livestock production, compared to the non-affected communities. This situation was clearly evident in 2001, when a relatively better crop production was achieved but the lowest prices were obtained, leading to poor credit repayments (Dechassa, 2003). Consequently farmers hesitated to use production-enhancing inputs.

Some of the saving practices are to store the own farm produce until prices increase (85% of the respondents), purchase grains and animals (25% of the respondents) and *iqubi* (30% of the respondents). *Iqubi* is a social organization in which people organize themselves for money contribution that can be paid for all members turn-by-turn depending on the bylaws. None of the respondents save money in the bank because the available banks are too far to be used. In spite of this, most subsistence farmers sell their produce when crop prices are low in order to pay back credit on fertilizers and to pay land taxes. Hence savings are low. On the other hand, the foundation of Fincha'a town and the construction of an all-weather road that connects the town to several other towns in the area have attracted more job opportunities, improved transportation and marketing at least for part of the watershed.

Besides, according to the health offices, people dwelling within and around the water reservoir are often exposed to a variety of diseases such as dysentery and internal and external parasites. The spatial distribution of schools and health centres in the districts is highly skewed towards roads and towns, hence, areas impounded by the dam reservoir and those with a poor road network are less favoured in this regard. For example, sub-watersheds such as Hulluqa are inaccessible by all weather roads and constrained by poor infrastructure development and social services.

3.4 Discussion

In the previous sections various interrelated factors have been discussed that greatly affect the livelihood in the watershed after the construction of dam. In this section we summarize some of the major social and economic situations in Fincha'a watershed and the adjacent districts (Table 3.8).

Table 3.8. The major social and economic situations in Fincha'a watershed compared to that of the neighbouring districts.

Area	Relative size of potentially available land to the community* (%)			Resulting land size in 2003 (ha/family)	Relative crop production in 2002 (%)	Family size in 2003	Population density (person km^{-2})
	1957	1980	2001				
Fincha'a watershed	78	60	60	2.5	65	8	98
Neighbouring districts	100	100	100	2.7	100	7	90

*Excludes areas that are not potentially used for crop production, grazing and forestry such as swamp, waterbody and towns.

The potentially available land for different community utilization has been reduced from 78% in 1957 (before the dam) to 60% of the entire watershed between 1980 and 2001 due to inundation. Therefore the reduction in the potentially available land to the community due to the dam was really high compared to areas where such losses did not occur. Moreover those parts of the watershed that have been submerged or became swamp were relatively flat land

and would have been more suitable for grazing and crop production. Those community members who were displaced from the currently inundated parts of the watershed (as many as 3100 families) have been self-resettled in more steep and probably less fertile lands. Compared to the other land utilization types the reduction that was caused on grazing land was immense and severely affected the traditional grazing pattern. The traditional grazing pattern involved alteration of grazing between the currently flooded areas during the dry season and the upper parts of the watershed during the wet season and was known to be effective in breaking diseases' cycles. Though statistical data was not available to substantiate the argument, the key informants indicated that communities in this watershed used to own a higher number of livestock than the neighbouring districts. Following the dam, however, the opposite occurred: they own 23% less TLU than the neighbouring districts (OADB, 1996).

It appeared that while the farmers in this watershed on average hold about 2.5 hectares of cropland those in the neighbouring districts hold 2.7 hectares (Table 3.8). The production per hectare of the major crops in this watershed was 35% lower than that of the neighbouring districts due to less cropland area and low crop productivity. Crop productivity was low due to less use of chemical fertilizers and improved seeds because of bad access to markets and lack of extension services created due to the water reservoir. Moreover following inundation of the relatively flat lands in this watershed cropping has been practiced on very steep land leading to severe soil erosion problems, hence loss of crop productivity.

On the other hand the family size of eight is higher than that of the neighbouring areas. This is probably caused by a lack of family planning knowledge and services in the sub-watersheds. The creation of water reservoir has created accessibility problems to most of the sub-watersheds. It was not only the family size, which was high in this watershed but also the population density. The forced migration that was caused by inundation of the downstream parts of the watershed has added more people into the upstream parts of the watershed. The higher population density in the upstream parts of the watershed was caused by both the normal population growth and the forced migration. Therefore, the average land holding size of 2.5 hectare per family is perhaps low to support the cereal-based and extensive agricultural production needs of an average family size of eight.

On the other hand cropland has expanded to the extent that there are few possibilities remaining for further expansion, to accommodate the increasing population pressure. There are already more than 25% of the families in this watershed who became landless (OADB, 1996). The demand for cropland and grazing becomes more pressing when the reservoir and swamp area are expanding and new families are created. The traditional farming system was not any longer able to become sufficient to reduce soil erosion in steep areas. Reduced fallowing and continuous cropping became common practices in the watershed. Free grazing of croplands cannot provide sufficient livestock fodder but on the other hand caused soil degradation and became a potential hindrance for soil and water conservation adoption.

3.5 Conclusions

When a development project requires that people be relocated, it is necessary to ensure that the productive base and income-earning ability of those affected are improved, so that they share the benefits of the new development and they are compensated for the transitional hardships. The displaced people should regain at least their previous standard of living and, at the relocation site, they should be assisted to become socially and economically integrated into the host communities. In many parts of the world (Dixon et al., 1989; WCD, 2000) and also in Ethiopia (Desslegn, 1999) dams were planned and implemented politically without involving indigenous communities.

The attempt of comparing the social and economic changes as a result of creation of water reservoir in the watershed was difficult due to lack of baseline data and documentation. The fact that the dam was constructed before 30 years and local communities did not participate in the planning and implementation process made extremely difficult to obtain social and economic data such as livestock number and land size of earlier time. The few households who received compensation in Fincha'a watershed believed that the amount was very low compared to the economic and environmental damage caused.

Attempts were made to compensate a few landlords for the loss of their physical resources, such as land, house and perennial trees but the majority of the population was not taken into account. Addressing only the few landlords and disregarding the majority of the population should have emanated from the land tenure policy of that time. First of all the project did not recognize that the majority of the population, who at that time were tenants, were the original inhabitants of the area, while the few landlords were new settlers. Secondly the project gave emphasis to valuing physical assets only disregarding the social cost of the dam. This showed that the planning and implementation of the hydropower dam was not participatory, and implemented based on a political decision. The rural community does not benefit from the electricity generated. Infrastructure that includes roads, health services, schools, marketing, etc. were not well developed.

Nevertheless, the dam plays a significant role in supporting the national economy through electric power generation, supplying water for sugar factory downstream and introducing fisheries in the area. The reconsideration of compensating the loss of physical resources after 30 years is, however, not any longer a sensible strategy to pursue. Instead, implementation of soil and water conservation, agricultural intensification, promotion of family planning, improvement of health and education services and infrastructure development need to be addressed. Conversely, allowing the community problems to persist will intensify the ubiquitous social and economic activities in the upstream part of the watershed leading to increased food insecurity and reservoir sedimentation. The allocation of a certain portion of the revenues obtained from the electric power generation into the above-mentioned social and economic endeavours would be justifiable in terms of property rights and equity. Since the watershed is located in the Blue Nile river basin the social and economic changes due to this dam may have local and regional impacts. This calls for cooperation at local level and beyond.

Chapter 4

Erosion and sedimentation modelling in Fincha'a watershed, western Ethiopia

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Submitted to: CATENA.

Erosion and sedimentation modelling in Fincha'a watershed, western Ethiopia

Abstract

In 1973, a hydropower reservoir was constructed in Fincha'a watershed, western Ethiopia, which caused serious land use changes in the watershed. Especially an increase in cropland on steep slopes has occurred, which potentially has increased erosion and sedimentation problems in the area. The purpose of this study was to test the Morgan, Morgan and Finney (MMF) model for estimation of spatial erosion rates and sediment delivery ratios (SDR) in Fincha'a watershed. Erosion data was collected from 19 crop fields and used for calibration and validation of the model. Erosion rates predicted by the model were compared with annual soil losses observed at these 19 fields. This resulted in a coefficient of efficiency of 0.86 for calibration, and 0.79 for validation. Erosion classes of the major land uses types were described qualitatively and the classes were compared with the model predictions. Apart from grazing land, the model predictions were comparable with the observations. After calibration and validation results, the model was run for two sub-watersheds using land use data of 1957, 1980 and 2001, to evaluate the impact of land use changes on erosion and sediment delivery. The model was also run for the entire Fincha'a watershed based on the 2001 land use data to determine spatial erosion patterns. Erosion rates have shown an increasing trend with expansion of cropland on steep slopes between 1957 and 2001. Also SDR's have increased in the same period, indicating increasing sedimentation in the hydropower reservoir. In general, given limited data and financial resources, the model predictions showed quite reasonable erosion patterns across the watershed, which can be used for SWC planning.

4.1 Introduction

Soil erosion results from the combined influence of factors such as climate, topography, soil type and land use (Le Bissonnais, 1996; Molnar and Julien, 1998). It causes decreased soil fertility, a loss of viable agricultural land, pollution of surface waters, and sedimentation in reservoirs and rivers (Lu and Higgitt, 1998; Theurer et al., 1998; Le Bissonnais et al., 2001). In Ethiopia, soil erosion is a serious problem, which threatens the agricultural sector (Alemneh, 2003), and causes increased sedimentation of reservoirs and lakes (Sileshi, 2001; Michael, 2004). Hurni (1993) estimated the nation's annual soil loss on cropland at 42 t ha^{-1}. This erosion has reduced crop productivity by an estimated 0.12 to 2% (Kappel, 1996), while sedimentation has resulted in a decline of more than 30% of the storage volume of the Koka hydropower reservoir and blocked the flow of water to the powerhouse intakes (Michael, 2004). Improper land use, which is essentially a function of human activities and soil and agro-climatic characteristics, intensifies reservoir sedimentation (Sileshi, 2001).

The lack of reliable soil erosion and sediment yield data affect the planning of a watershed-based soil and water conservation (SWC) programme and the design of water reservoirs. In Ethiopia, the Soil Conservation Research Programme (SCRP) was started in 1981 (Hassen et al., 2004). This programme aims at providing basic data on soil erosion and to assess the effectiveness of SWC projects. The SCRP has monitored surface runoff and soil erosion by installing six gauging stations in different agro-climatic zones in Ethiopia. However, monitoring those gauging stations is expensive and it was not possible to extrapolate the obtained data to ungauged watersheds (Hassen et al., 2004).

In principle, effective soil conservation measures can be designed to prevent erosion or to minimize the surface runoff and sediment that leave the watershed. This requires an understanding of sources, movement and delivery of sediment at the watershed scale. The watershed-based planning has the advantage that the watershed is the natural geomorphological unit for water erosion, in which risks at any point can be understood in relation to its topographic position and the effects this has on local hydrology and sediment production (Morgan, 2005). Therefore, both on-site and off-site effects of erosion can be appreciated within a watershed.

So far no tools were developed for soil erosion prediction and sediment yield assessment at watershed scale in Ethiopia. In some instances, estimation of soil loss has been based on the Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1978). But, this model was not designed for soil loss estimation at watershed level. When the USLE is applied for the modelling of erosion in grid cells, no account is taken of the variability of surface runoff from upslope areas, which is unrealistic (Kinnell, 2001). Moreover, the model does not account for sediment delivery and deposition (Cox and Madramootoo, 1998; Morgan 2005).

Most watershed-scale erosion models are deterministic models, created since the 1960s to evaluate off-site risks of soil erosion and surface runoff (Morgan, 1995). Even though they are based on physical laws, they retain a high level of empiricism in their equations (Morgan, 2005) and require much data for input, calibration and validation (Morgan, 1995; De Vente and Poesen, 2005). They proved generally ineffective in reproducing spatial patterns of erosion unless a high level of detail in the input data was provided (Takken et al., 1999). The main problems of the application of deterministic models at watershed scale are the large data requirements (Shrestha, 1997) and the insufficient system knowledge to incorporate all different erosion processes (e.g., gully erosion), interactions and feedbacks between these processes that are active at the watershed scale (De Vente et al., 2005). Application of deterministic models is still in question whether it can better predict soil erosion than the existing empirical models (Vigiak and Sterk, 2001).

Compared to the deterministic models, empirical water erosion models generally are straightforward, require few input data and can be useful in pinpointing areas exposed to high erosion risk (Vigiak and Sterk, 2001). A good model should satisfy the requirements of reliability, universal applicability, easy use with a minimum of data, comprehensiveness in terms of the factors and erosion processes included, and the ability to take account of change in climate, land use and conservation practices (Morgan, 2005).

Among the empirical models, the Morgan, Morgan and Finney (MMF) model was created for tropical conditions to predict annual soil loss from field-sized areas on hill-slopes (Morgan et al., 1984). The MMF model uses the concepts proposed in the USLE but provides a stronger physical base (Morgan, 2005). It retains advantages of an empirical approach regarding ease of understanding and availability of data (Morgan, 2001; 2005). The model was recently revised and adapted for application at watershed scale (Morgan, 2001), and was successfully applied in two watersheds in the East African highlands (Vigiak et al., 2005). The model can be incorporated into a geographical information system (GIS) with basic input data to predict spatial distribution of surface runoff, soil erosion and sediment yield. The objective of this study was to apply the revised MMF model for estimation of soil erosion and sediment delivery ratios (SDR) in an Ethiopian Highland watershed with a hydropower reservoir. In particular, the effects of land use changes on erosion and sediment delivery into the reservoir were evaluated.

4.2 Materials and methods

4.2.1 The Morgan, Morgan and Finney model

The MMF model separates the soil erosion process into a water phase and a sediment phase. It considers soil erosion to result from the detachment of soil particles by raindrop impact and surface runoff, and the transport of those particles by surface runoff. The process of transport by rain splash is ignored. The model compares the predictions of total detachment with the transport capacity of the surface runoff, and assigns the lower of the two values as the annual rate of soil loss, thereby denoting whether detachment or transport is the limiting factor. The predictions obtained by the model are most sensitive to changes in annual rainfall and soil parameters when erosion is transport-limited, and to changes in rainfall interception and annual rainfall when erosion is detachment-limited (Morgan, 2005).

The following summarizes the main MMF equations used to calculate annual soil erosion at field-scale as described by Morgan (2001; 2005). This field scale description is followed by the description of surface runoff routing and sediment yield calculation for small watersheds.

The rainfall kinetic energy (KE, J m^{-2}) is a function of the effective rainfall (ER, mm), i.e. the fraction of mean annual rainfall (R, mm) that is not intercepted by the vegetation canopy (A, fraction between 0 and 1):

$$ER = R(1 - A) \quad (1)$$

The effective rainfall is split into direct throughfall (DT), which directly reaches the soil, and leaf drainage (LD), which is intercepted by the canopy and reaches the surface by stemflow or dripping from leaves. LD is a function of the canopy cover (CC, fraction between 0 and 1):

$$LD = ER\ CC \quad (2)$$

And the remaining part of the effective rainfall is thus direct throughfall:

$$DT = ER - LD \quad (3)$$

The kinetic energy of the direct throughfall (KE(DT); J m^{-2}) is determined as a function of rainfall intensity (I: mm h^{-1}), using a typical value for the erosive rain of the climatic region.

For the Ethiopian Highlands the equation of Wischmeier and Smith (1958) was selected, because of its good performance in Ethiopia (Hurni, 1993; Gete, 2000).

$$KE(DT) = DT\ (11.9 + 8.7 \log I) \quad (4)$$

The kinetic energy of the leaf drainage (KE(LD); J m^{-2}) is a function of plant canopy height (PH, m) as proposed by Brandt (1990):

$$KE(LD) = [(15.80\ PH^{0.5}) - 5.875]\ LD \quad (5)$$

Therefore, the total energy of the effective rainfall (KE; J m^{-2}) is obtained from:

$$KE = KE(DT) + KE(LD) \quad (6)$$

The annual surface runoff (Q; mm) is obtained from:

$$Q = R \exp(-R_c/R_o) \quad (7)$$

where R = mean annual rainfall (mm), R_o = the mean rain per rain day (mm) (i.e., mean annual rainfall R divided by the number of rainy days per year, n) and R_c = the soil moisture storage capacity and estimated as:

$$R_c = 1000\ MS\ BD\ EHD\ (ET_a/ET_p)^{0.5} \quad (8)$$

where MS = the gravimetric soil moisture content at field capacity (%), BD = the bulk density of the soil (Mg m^{-3}), EHD = the effective hydrological depth of soil (m) and ET_a/ET_p = the ratio of actual to potential evapo-transpiration. The EHD indicates the depth of soil within which the moisture storage capacity controls generation of surface runoff. It is a function of plant cover, which influences the depth and density of roots, and, in some instances, the effective soil depth, for example on soils shallower than 0.1 m or where a surface seal or crust has formed (Morgan, 2001). There are some guide values for EHD for use with the revised MMF model. Values range from 0.05 for bare and shallow soils on steep slopes, to 0.20 for forest soils. The larger EHD, the more water can be stored in the soil, and less surface runoff is produced. At present, the effect of different types of tillage practices on EHD has not been evaluated. Morgan (2001) recommended that tillage be accounted for by adjusting the crop cover factor (C_f) value, which is used to calculate transport capacity (Equation 11).

The next step in the model is the calculation of soil particle detachment by rainfall and runoff. Soil particle detachment by raindrops (F; kg m^{-2}) is a function of total KE and soil detachability:

$$F = 10^{-3}\ K\ KE \quad (9)$$

where K = soil detachability index (g J^{-1}), defined as the weight of soil detached from the soil mass per unit of rainfall energy. Guide values for K have been revised and now cover a wider range of soil textures (Morgan, 2001). Soil particle detachment by surface runoff (H; kg m^{-2}) is estimated as:

$$H = 10^{-3}\,(0.5COH)^{-1}\,Q^{1.5}\,\sin(S)\,(1-GC) \qquad (10)$$

where COH = cohesion of the soil surface (kPa), Q = volume of surface runoff (mm), S = slope (°) and GC = fraction of vegetation ground cover (0-1). The equation assumes that soil particle detachment by surface runoff occurs only where the soil is not fully protected by ground cover. As a first approximation, this seems reasonable since a dense ground cover will dissipate most shear stress from surface runoff.

Transport capacity is the maximum amount of sediment that a given surface runoff amount can carry without net deposition occurring. The transport capacity of surface runoff (TC; kg m^{-2}) is a function of slope angle, surface runoff amount, and the crop cover factor C_f:

$$TC = 10^{-3}\,C_f\,Q^2\,\sin(S) \qquad (11)$$

where C_f = crop or plant cover factor, which is an index of soil loss at a given vegetation cover compared with the soil loss at bare soil, taken as equal to the product of the C and P factors of the USLE (Wischmeier and Smith, 1978). The C_f factor can be adjusted to take account of different tillage practices and levels of crop residue retention.

Eventually, the estimates of soil particle detachment by raindrop impact and by surface runoff are added together to give a total annual detachment rate. This is then compared with the annual transport capacity of the surface runoff, and the lesser of the two values is the annual erosion rate (E; kg m^{-2}):

$$E = \min[(F + H), TC] \qquad (12)$$

The model can be used to predict soil loss from small watersheds by dividing the watershed into land units (elements) of similar soils, slopes and land cover. Routing the annual surface runoff and sediment production over the land surface from one unit to another, gives the erosion and deposition in the watershed and the sediment delivery from the watershed (Morgan, 2005). The surface runoff for each unit is calculated as the summation of the surface runoff generated on that unit and the surface runoff flowing into it from upslope. The transport capacity is calculated for this combined surface runoff. Similarly, the total sediment available for transport is the summation of that detached on that unit and the material transported into the unit from upslope, and this is compared to the transport capacity of the land unit. When operated in this way, the model is able to identify the major source areas of sediment and the locations of deposition within a watershed. This procedure provides the information for the SDR (Morgan, 2001).

Morgan (2001) did not make clear how to take into consideration the relative importance of the area of the different elements, and how this would affect the accumulation of surface runoff along the slope. This problem became clear when Vigiak et al. (2005) applied the model in two East African Highland watersheds. They developed equations that accounted for the contribution of surface runoff and sediment from upslope areas in the routing procedure at watershed level. The total surface runoff of the element i (Q_{ti}) was considered as the sum of the surface runoff generated within the element i (Q_i; Equation 7), plus the surface runoff received from the immediate upslope area (Q_{up}) weighted by the ratio between the area of the upslope element (S_{up}) and the area of the element i (S_i):

$$Q_{ti} = Q_i + Q_{up} (S_{up}/S_i) \quad (13)$$

The total surface runoff Q_{ti} (mm) is then used to calculate the detachment rate by surface runoff and the transport capacity of the element i. Hence, soil particle detachment by surface runoff (H_i; kg m^{-2}) is estimated as:

$$H_i = 10^{-3} (0.5COH_i)^{-1} Q_{ti}^{1.5} \sin(S_i) (1-GC_i) \quad (14)$$

The transport capacity of runoff (TC_i; kg m^{-2}) is the function of slope angle, surface runoff amount, and crop cover factor:

$$TC_i = 10^{-3} C_{fi} Q_{ti}^2 \sin(S_i) \quad (15)$$

The mean annual soil loss rate of the element i (E_i; kg m^{-2}) is estimated as the minimum of sediment available and transport capacity:

$$E_i = \min[(F_i + H_i + E_{up}), TC_i] \quad (16)$$

where E_{up} = influx of sediment from the immediate upslope area.

Sedimentation occurs where the influx of sediment from upslope (E_{up}) is larger than the transport capacity out of the element (TC_i), with net sedimentation (SED_i; kg m^{-2}) equal to:

$$\begin{aligned} SED_i &= E_{up} - TC_i && \text{for } E_{up} > TC_i \\ SED_i &= 0 && \text{for } E_{up} \leq TC_i \end{aligned} \quad (17)$$

A sediment delivery ratio (SDR) is defined as the ratio of sediment delivered at the watershed outlet to gross detachment (Walling, 1983). It is a dimensionless scalar (Lu et al., 2005) and has vale between 0 and 1. Factors that influence SDR are hydrological inputs (mainly rainfall), landscape properties (e.g. vegetation, topography, and soils) and their complex interactions (Walling, 1983). In this study, it was assumed that the sum of all sediment output of the land units directly draining into the river system was equal to the sediment delivery of the watershed. Hence, once the detached soil enters the river system it was assumed to find its way to the watershed outlet. In reality sediment may be permanently of temporarily stored in the river system, but this was not taken into account in the MMF model.

4.2.2 The study watershed

The study area is Fincha'a watershed, which is located approximately 200 km WNW of the Ethiopian capital Addis Ababa. It is a representative watershed for the western Highlands of Ethiopia with mixed crop and livestock agricultural systems. The watershed covers an area of 1318 km^2 (Bezuayehu and Sterk, 2006a), and has a total population of about 178,000 people (Bezuayehu and De Graaff, 2006). At Fincha'a a hydropower reservoir was created in 1973, which covers approximately one third of the watershed area (Bezuayehu and Sterk, 2006a).

Elevation in the watershed ranges from 2200 m to 3100 m. Most of the area (80%) can be described as a wide rolling plateau, and is within the altitude range between 2200 m and 2400 m. About 51% of the watershed is flat (0 to 3% slope steepness), which is mainly under the water reservoir and swamp. The gently sloping (3 to 8% slope steepness) to sloping (8 to 15% slope steepness) areas cover about 34% of the watershed. Steep (15 to 30% slope steepness) to very steep (> 30% slope steepness) cover about 15% of the watershed area. The higher parts near the watershed boundaries, as well as the higher parts in the middle of the watershed, which exist as an isolated outcrop, are made of Quaternary volcanics. A small part of the watershed at the north-eastern part is covered by the Adigrat sandstone formation. This formation is composed of alternating beds of sandstones and shales, which have been deposited unconformably upon the eroded surfaces of the Basement Complex. The dominant soils in the watershed have a texture of clay-loam, clay and loam. Soils are deep (> 150 cm) on flat lands, but on steep slopes (>30%) soil depths are shallow (< 25 cm).

Due to its high elevation, Fincha'a watershed falls into a temperate humid climate. The yearly average rainfall in the watershed is 1823 mm and about 80% of the annual amount occurs between June and September. The mean monthly temperature varies from 14.9°C to 17.5°C. The average annual reference evapo-transpiration (based on Penman-Monteith) is 1320 mm, with low monthly variations.

A dam was constructed in this watershed in 1973 and created a water reservoir with an area of 151 km^2 in 1980. Later, in 1987, a diversion from Amarti river entered into this scheme and the reservoir area has subsequently increased to 239 km^2 in 2001. The reservoir is used for hydropower production, irrigation and fishery. The major land use types in the watershed are cropland, grazing land, waterbody, swamp, forest and town (Bezuayehu and Sterk, 2006a). Forested areas are with a well-developed understory that provide good protection against raindrop impact and influence infiltration capacity of the soil. Grazing land is a land use type whereby trees, shrubs and grasses cover the soil. Much of the grazing land is situated on steep slopes, where overgrazing may result in erosion problems. In towns, houses are sparse and no proper drainage is in place to safely dispose surface runoff. Hence runoff from the roofs and that from the direct throughfall may cause rills and gullies. On the other hand, areas under swamp and reservoir do not suffer from soil erosion.

Major crops grown in the area are maize (*Zea mays*), bean (*Vicia faba*), Niger seed (*Guizotia abyssinica*), tef (*Eragrostis tef*), barley (*Hordeum vulgare*) and wheat (*Triticum species*). Tillage is practiced using the ard or single-tined plough known as *maresha*. Tillage operation for planting most crops is often done 2 to 7 times, depending on the crop and soil type. The plough breaks up dried topsoil (Goe, 1999) and creates fine tilth, which makes the soil susceptible to erosion and crust formation. Tillage depth is shallow (maximum depth is

20 cm). Generally, the agricultural practices leave the soil bare and loose at the onset of rains, when rainfall intensities are often high, and may result in severe erosion.

Cattle production is practiced for draught power, food, soil fertility enhancement, cash income, levelling of tef fields and threshing of crops. Natural pasture is a major source of fodder for livestock but crop residues are used to supplement this during the dry season.

4.2.3 Data collection and analysis

Two sub-watersheds namely Qoricha (165 ha) and Hadocha (1155 ha) were selected for data collection and calibration and validation of the MMF model. Data that include slope, soil texture and land use were collected from farm fields in both sub-watersheds using the Assessment of Current Erosion Damage (ACED) method as described by Herweg (1996). The Arc View GIS software package version 3.2 was used to aggregate spatial data, and to create the homogeneous land units or elements. Calculations were performed using the Microsoft excel spreadsheet utility.

Slope information was extracted from a topographic contour map at a scale of 1:50,000 with an original vertical interval of 20 m, which was available from the Ethiopian Mapping Agency (edition 1982). From the contour map a triangulated irregular network (TIN) was processed to create a digital terrain model (DTM). The DTM was used to produce a slope map of the entire watershed. The grid size of the DEM and other maps were 20 m.

A soil texture map that covers Fincha'a watershed at 1:250,000 scale was available from Oromiya Agriculture Development Bureau (OADB, 1996). This map was digitised into Arc View GIS. The moisture content at field capacity of clay loam, silt clay and loam soil types was obtained from the feasibility study database of Gembo irrigation project, which was situated in this watershed (OIDA, 2002). The other soil parameters, namely, bulk density, erodibility factor, soil cohesion and EHD were taken from literature (Morgan, 2001; 2005).

Bezuayehu and Sterk (2006a) derived land use maps of the watershed for the years 1957, 1980 and 2001 from aerial photographs and an ASTER satellite remote sensing image. The land use classes identified were cropland, grazing land, forest, town, swamp, and waterbody. There was no waterbody in this watershed before the impoundment period (i.e. 1973). In 1980, a reservoir with an area of 151 km^2 (11.5%) existed, which increased to 239 km^2 (18.2%) in 2001. Cropland has increased from 403.3 km^2 in 1957 to 478.8 km^2 in 1980 and 607.1 km^2 in 2001; a net increase of 50.6% during a period of 44 years. The area of grazing land has decreased by 50.8% between 1957 and 1980 but increased by 21.7% between 1980 and 2001, i.e., a net decrease of 40.1% between 1957 and 2001.

Climatic data were obtained from Shambu metrological station located at the middle part of the watershed. Average rainfall and temperature data were computed from 34 years of mean monthly data (1970-2003). According to the climatic and agro-climatic classification of Ethiopia, Fincha'a watershed falls into a temperate rainy climate (NMSA, 1996). For that reason, the temperate typical value of 10 mm h^{-1} was used for intensity of erosive rain (I) in the MMF model calculations (Morgan, 2005). Rainfall erosivity index (EI_{30}) of the year 1980, 2001, 2002 and 2003 was computed for all rainstorms (Wischmeier and Smith, 1958). The average of this value was used for estimating the USLE cover and management factor (C) of the major crops in the area, again based on the procedures described by Wischmeier and

Smith (1978). In Fincha'a watershed contour ploughing is dominantly practiced for erosion control. Other SWC measures are non-existing in the area. Hence, the effect of contour ploughing as it varies with slope steepness was used to estimate the P-factor (Wischismeier and Smith, 1978; Morgan, 2005).

CropWat version 4.3 (Smith et al., 1998) was used to compute the ratio of actual to potential evapo-transpiration (ET_a/ET_p) for the main crops in the area. Since the crop coefficient K_c of the local crops (i.e. tef and Niger seed) were not available in CropWat, the default K_c value of small grains was used for tef and the K_c of pulses was used for Niger seed. CC, GC and PH parameters of the major crops were determined taking into consideration the crop diversity and possible crop rotations in the area. Six fields for the respective major crops were selected for monitoring of crop cover development stages in both sub-watersheds. Four fields (2m by 2m) were randomly selected within each field for the collection of CC and GC, and the average of the four data were taken. The CC and GC were collected using visual assessment in comparison with different cover percentages as illustrated in Herweg (1996). The same fields were also used for the measurement of the PH in which three plants were randomly selected from each field and the average of the 12 data was taken. Data were collected every 15 days during the long rainy season (June to August) in 2004, which according to farmers in the study area was a normal rainfall year.

CC, GC and PH values for grazing land, forest and swamp were determined during this study based on field measurements. Six representative sites were used to estimate the PH, GC and CC values of each of these three land use/cover types. The other land cover parameters such as vegetation interception (A) of grazing land, forest and swamp were obtained from literature (Morgan et al., 1984; De Jong and Riezebos, 1992; Morgan, 2001; 2005; Vigiak, 2005).

The ACED method as described by Herweg (1996) was used during surveys to assess the visible erosion features such as rills and gullies of recent origin. During three transect walks through both sub-watersheds, qualitative assessments of erosion extent, management practices, percentage ground cover and topography (slopes) were made. Quantitative ACED measurements covered 19 crop fields (8 in Qoricha and 11 in Hadocha). The number of rills, their length and dimensions in each field were monitored every 15 days during the rainy season of 2004. Soil loss was determined by calculating the volume of the soil that has been washed away during rill erosion. The calculated volume of soil loss was then converted to weight by multiplying the volume with the bulk density of the respective soils. Estimation of erosion by sheet erosion was neglected since this is difficult to determine and, according to Herweg (1996), could be very small as compared to rill erosion.

4.2.4 Model calibration, validation and application

The quantitative soil loss data from the ACED survey were used for the calibration and validation of the MMF model. For this purpose, the ACED soil loss data were considered to represent the annual soil loss amount in the study watershed. This is justified by the fact that more than 80% of the annual rainfall occurs during the months of June to August, and thus most of the annual erosion is expected in this period. The entire dataset of soil losses from the 19 fields was sorted in increasing order and split in two parts. The fields with odd numbers (ten in total) were used for calibration and the remaining nine fields were used for validation. Calibration was applied for the EHD for two reasons: 1) EHD is difficult to determine in the field, and 2) EHD was expected to have a strong effect on runoff volume and thus on erosion.

The model was run for the two sub-watersheds, including the routing procedure. After the run, the grid cells corresponding to the erosion survey fields were selected, and the average erosion value was compared with the observed soil loss value. The coefficient of efficiency (CE) as defined by Nash and Sutcliffe (1970) was used for evaluation of model performance:

$$CE = 1- \frac{\sum_{i=1}^{n}(O_i - M_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2} \quad (18)$$

where, O_i is the observed erosion value, M_i the calculated erosion value, $\overline{O}$ the mean observed erosion value and n is the number of observations. The maximum value for CE is one, which means that the model calculations and observations have a perfect match. Low values of CE represent high deviations between observed and modelled values. If CE is negative, the model performance is very poor.

Model performance was further evaluated by comparing qualitative erosion classes for the other land use types than the cropland of the 19 fields used for the ACED surveys. After calibration and validation, the model was run for the 1957, 1980 and 2001 land use data for both Qoricha and Hadocha sub-watersheds. This was done to evaluate the impact of land use change on soil erosion and sediment yield in the sub-watersheds. The model was also run for the entire Fincha’a watershed using only the 2001 land use data.

4.3 Results and discussion

4.3.1 Soil erosion assessment

The transect walks for qualitative erosion assessment with ACED covered cropland, grazing land, fallow land, forest and town. Different erosion features such as sheet erosion, rills and gullies were observed in both sub-watersheds. Sheet and rill erosion features predominate in croplands but gullies were abundant in grazing lands and fallow lands. Generally, soil erosion was observed on land with steep slopes, while sediment deposition was observed on footslopes and farm boundaries. The poorly laid out roadside drains and cattle trampling have been the major causes for the gullies. In towns erosion caused destruction of roads and footpaths and exposed buried pipelines. The surface runoff released from urban areas and roads threatened downstream farmlands and grazing lands. Contour ploughing and limited tree plantation were practiced but other SWC measures were lacking in both sub-watersheds. Erosion classes of the major land uses types were described qualitatively and the classes are shown in Table 4.1.

Table 4.1. Qualitative erosion classes of the major land use types in Hadocha and Qoricha, Fincha'a watershed, western Ethiopia.

Land use	Erosion class
Cropland	High
Grazing land	Moderate
Forestland	Low
Swampland	Very low

General information of the farm fields used for detailed ACED surveys and the observed, rill density and calculated soil loss are shown in Table 4.2. A higher rill density and more soil loss were measured in Hadocha sub-watershed due to its steeper slopes. Typical rill erosion features in Hadocha sub-watershed on crop field of Niger seed that was planted two weeks ago was exhibited in Figure 4.1.

Figure 4.1. Rill erosion in a field with Niger seed, Fincha'a watershed, western Ethiopia. The field has an average slope of 35% and a clay-loam soil.

The rill density in tef fields was higher than in the other crop types in both sub-watersheds. On the other hand the average length, width and depth of rills in tef fields were smaller than on other cropland. This high rill density and small dimensions of rills in tef fields is attributable to the difference in the management practices. As opposed to other crops, tef needs fine soil tilth and during planting the soils should be compacted by letting cattle walk in the fields. Soil compaction reduces infiltration, but also resists incision by concentrated flow. In the other crop fields the rills were very wide and in some instances comparable with ephemeral gullies. Those large rills or ephemeral gullies are usually removed by tillage operations, but during subsequent storms they may reappear due to erosion by concentrated flow.

Some management practices made it difficult to monitor the rill development on maize and tef fields. Maize fields were ploughed about two months after planting for reducing weeds and thinning plant population. This practice destroyed existing rills. Noticing this problem the owners of the selected maize fields were asked to halt this management activity until the survey was completed. The tef fields were repeatedly ploughed in almost half of the rainy season. This created problems in monitoring the development of rills before tef planting time (middle of rainy season). Hence the erosion survey on tef fields was done only after the crops were planted, thus the numbers in Table 4.2 for tef fields probably underestimate the real erosion of those fields.

4.3.2 MMF model inputs

Crop cover parameters for individual crops and land use parameters in the sub-watersheds are shown in Table 4.3. The values of crop cover parameters were averaged, taking into consideration the crop diversity and possible crop rotations in the area. These average values were used as land crop cover parameters of cropland at watershed level.

Table 4.2. The observed rill density and soil loss from 19 fields in Hadocha and Qoricha, Fincha'a watershed, western Ethiopia.

*Site	Crop	Soil Texture	Field area (m^2)	Slope (^{o})	Rill density (rill ha^{-1})	Soil loss (kg m^{-2})
Q1	Bean	Clay loam	1974	6	61	2.39
Q2	Maize	Clay loam	915	7	98	2.62
Q3	Tef	Clay loam	2190	7	137	3.15
Q4	Niger seed	Clay loam	3438	10	46	3.90
H5	Tef	Clay loam	4231	9	191	3.92
Q6	Niger seed	Loam	1999	14	90	3.99
H7	Bean	Clay loam	3906	10	92	4.36
Q8	Maize	Clay loam	9177	14	29	5.58
H9	Bean	Clay loam	3939	17	148	5.62
H10	Niger seed	Clay loam	2801	17	186	5.82
Q11	Niger seed	Loam	641	11	125	5.83
H12	Tef	Clay loam	4096	14	654	7.02
H13	Barley	Clay loam	1679	9	226	7.19
Q14	Niger seed	Clay loam	1531	7	65	7.81
H15	Niger seed	Clay loam	3683	17	209	10.6
H16	Wheat	Clay loam	1087	10	258	11.8
H17	Barley	Clay loam	4052	14	111	12.8
H18	Maize	Clay loam	447	14	125	16.0
H19	Wheat	Clay loam	2987	19	60	16.9

*Note: Q is site in Qoricha and H is site in Hadocha.

The average rainfall interception A ranged from 0.20 to 0.35, canopy cover CC from 0.64 to 1.0 and ground cover GC from 0.14-1.0. These values indicate that the different land uses and crop types generally provide good soil cover and reduce the raindrop impacts and shear stress of surface runoff. As compared to other land use types, however, soils under crop are generally less protected against raindrop impacts and shear stress of surface runoff. Cropland does not provide a good soil cover against erosion mainly at the onset of rainfall. There was no significant difference in the model land use parameters between the two sub-watersheds.

Table 4.3. Land cover input parameters for the MMF model applied at Fincha'a watershed, western Ethiopia.

Land use	A	CC	GC	PH (m)	EHD (m)	ET_a/ET_p	C
Crop land:							
Niger seed	0.20	0.64	0.14	0.70	0.09	0.83	0.250
Wheat	0.31	0.65	0.13	0.60	0.09	0.83	0.250
Tef	0.25	0.58	0.13	0.60	0.09	0.75	0.230
Maize	0.25	0.61	0.21	1.80	0.09	0.74	0.280
Bean	0.20	0.63	0.11	0.70	0.09	0.78	0.250
Barley	0.30	0.85	0.09	0.80	0.09	0.59	0.170
Average	0.26	0.64	0.14	0.87	0.09	0.78	0.250
Grazing land	0.33	0.85	0.85	1.50	0.12	0.80	0.010
Forest	0.35	0.86	0.90	2.00	0.20	0.90	0.001
Swamp	0.35	1.00	1.00	0.40	0.20	1.00	0.001

Typical values of soil parameter for the major soil types in the watershed are given in Table 4.4. Swamp is wetland located at low-lying parts of the watershed and covered with perennial grasses and organic muck. Values of soil parameters used for this land use class was estimated based on the assumption that there will be no erosion in areas under swamp.

Table 4.4. Typical values for soil parameters used in the MMF model prediction, Fincha'a watershed, western Ethiopia

Topsoil texture	MS (%)	BD ($Mg\ m^{-3}$)	K ($g\ J^{-1}$)	COH (kPa)
Silt clay	0.45	1.1	0.5	10
Clay loam	0.36	1.3	0.7	10
Loam	0.34	1.3	0.8	3
Swamp	0.80	1.0	0.0	2

Sources: MS (OIDA, 2002); BD, K and COH (Morgan, 2001 & 2005).

4.3.3 Calibration and validation

We used one single EHD per land use class for simplicity (Table 4,.3). Calibration and validation was done for croplands only, using the 19 fields for quantitative assessment in Hadocha and Qoricha. The value of effective hydraulic depth (EHD) recommended for croplands without surface crusting is 0.09 m (Morgan, 2001 & 2005). Initially the model was run for the two sub-watersheds using this value assuming that there is no problem of soil crusting in the area. However, the resulting model coefficient of efficiency (CE) using the

EHD value of 0.09 m was poor (-1.03). The model was then calibrated by altering EHD from 0.01 to 0.10 m (in steps of 0.01). The CE was calculated for each EHD value (Figure 4.2). At low EHD values, the model over predicts soil loss because the infiltration capacity of the soil is largely underestimated, resulting in an overestimation of surface runoff and soil loss. On the other hand when EHD is too high, the model under predicts soil loss because surface runoff volume and transport capacity of surface runoff is underestimated. An optimal value of CE (0.86) was obtained at EHD of 0.05 m. This shows that the local tillage system, that is often shallow and breaks soil clods into pieces (Goe, 1999), might have caused impermeable soil layers within 0.15 m of the surface (Morgan, 2005).

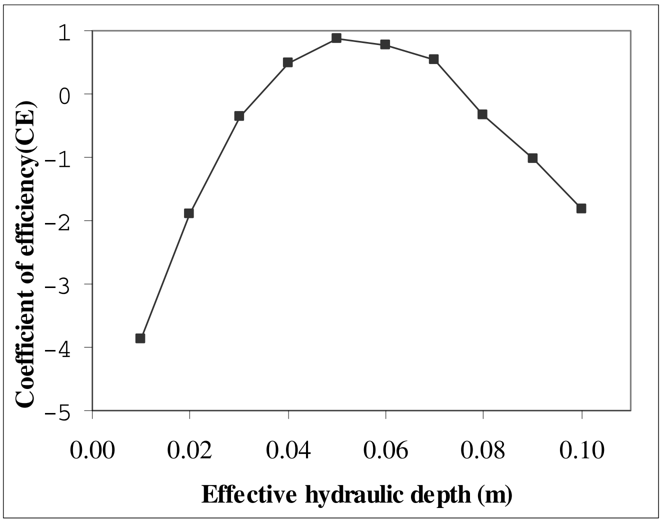

Figure 4.2. Calibration of MMF model for Fincha'a watershed, western Ethiopia; effect of effective hydraulic depth (EHD) on model performance.

The model was then validated using this optimum EHD value of 0.05 m. The obtained CE value was 0.79. The model calibration and validation results are shown in Figure 4.3 and Figure 4.4, respectively.

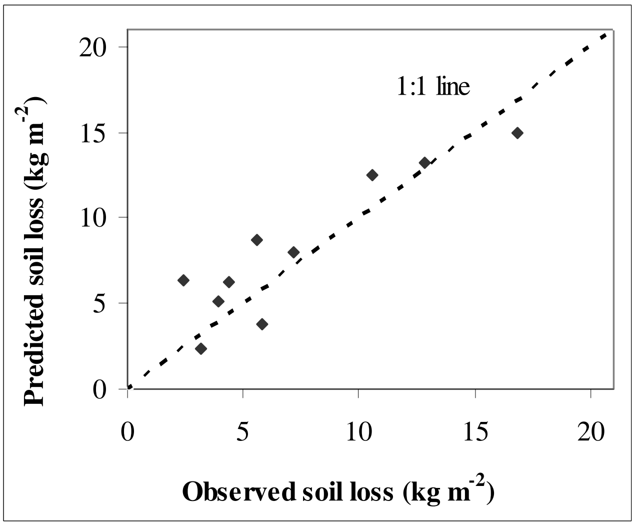

Figure 4.3. Calibration of the MMF model; comparison of observed and predicted soil losses for 10 fields in Fincha'a watershed, western Ethiopia.

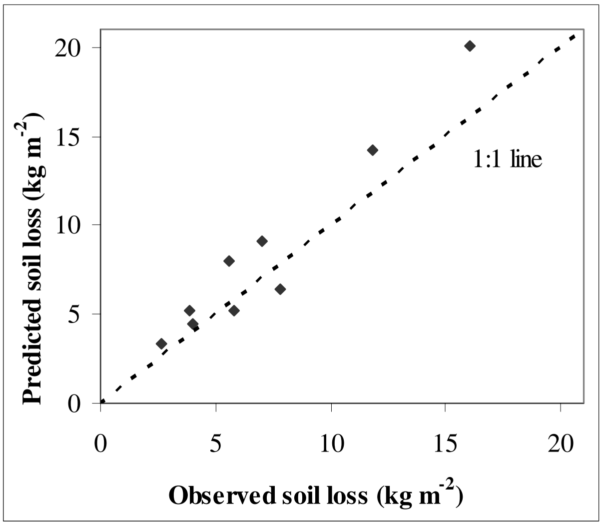

Figure 4.4. Validation of the MMF model; comparison of observed and predicted soil losses for 9 fields in Fincha'a watershed, western Ethiopia.

The calibration and validation procedure only included cropland, which accounts for 60% in Hadocha, and 71% in Qoricha. No quantitative evaluation of the other land use types could be done, as quantitative soil loss data were not available. But to get an idea of the model performance, the qualitative erosion classification (Table 4.1) during transect walks were compared against the erosion prediction results of MMF model on 10 arbitrarily chosen fields per land use class. The obtained erosion values were classified into four classes: low erosion ($E \leq 1$ kg m^{-2} yr^{-1}), moderate erosion ($1 < E \leq 5$), high erosion ($5 < E \leq 10$), and very high erosion ($E > 10$ kg m^{-2} yr^{-1}). According to this erosion classification, erosion rates were high on cropland and low on grazing land, forestland and swamp. Compared with the qualitative erosion classification, the model results for grazing land were rather different. Grazing lands were described as moderate erosion in the qualitative classification (Table 4.1) but low erosion using the MMF model. During the transect walks gully erosion features were observed in grazing lands which is not accounted for in MMF. But, most of the gullies in grazing lands have been caused by the runoff generated from the upstream areas such as from footpaths and roads. This kind of information is not included in the MMF model, resulting in predictions of relatively low erosion on grazing lands. Except for grazing land the model prediction and qualitative ACED survey showed fair agreement in describing soil loss rates across the sub-watersheds. The MMF model, therefore, was considered appropriate to calculate soil erosion rates at Fincha'a watershed.

4.3.4 Soil erosion in the sub-watersheds

Following the calibration and validation, the MMF model was run for both sub-watersheds, using the three land use maps of 1957, 1980 and 2001. The results are shown in Figure 4.5 (Hadocha) and Figure 4.6 (Qoricha). The predicted erosion values were classified into five classes: no erosion ($E \leq 0.1$ kg m^{-2} yr^{-1}), low erosion ($0.1 < E \leq 1$), moderate erosion ($1 < E \leq 5$), high erosion ($5 < E \leq 10$), and very high erosion ($E > 10$ kg m^{-2} yr^{-1}).

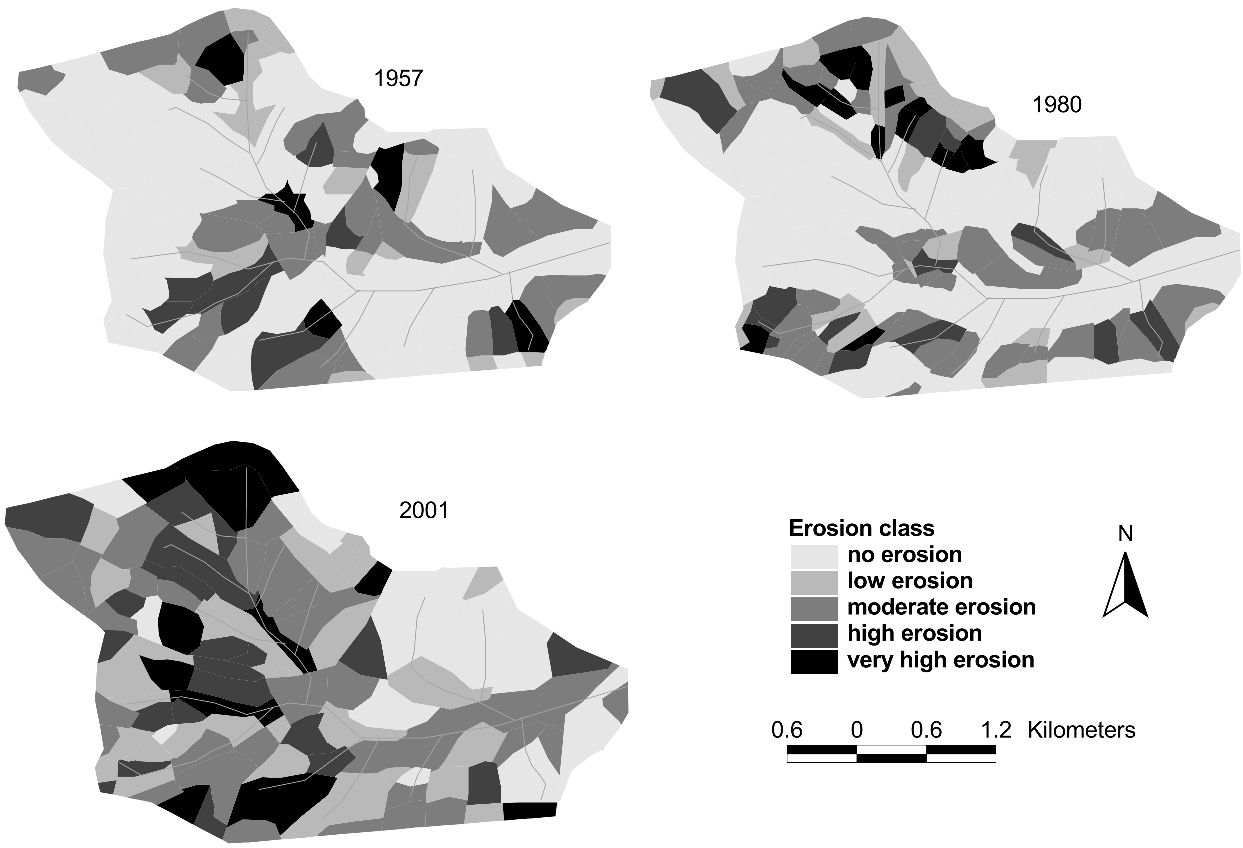

Figure 4.5. MMF erosion maps of Hadocha in 1957, 1980 and 2001, Fincha'a watershed, western Ethiopia

In Hadocha, mean erosion on cropland has increased from 4.6 kg m^{-2} yr^{-1} in 1957 to 4.8 kg m^{-2} yr^{-1} in 1980 and 5.5 kg m^{-2} yr^{-1} in 2001. Mean erosion on grazing lands varied from 0.04 kg m^{-2} yr^{-1}in 1957 to 0.15 kg m^{-2} yr^{-1}in 1980 and 0.81 kg m^{-2} yr^{-1} in 2001. Mean erosion on forestlands was 0.03 kg m^{-2} yr^{-1} throughout. Swamps have generated no runoff and hence no erosion rates were predicted. This is because swamps are situated on flatlands and have a good vegetation cover. Conversion of natural vegetation into cropland has increased erosion rates in the sub-watershed. The modelling results show that erosion rates on grazing lands and forest were generally low compared to cropland. There was not much difference in erosion rates between grazing land and forestland. The forestlands are also used for grazing and this probably accounts for small differences in erosion rates between these two land use types. This situation was taken into account in the modelling while collecting vegetation cover parameters in the field. Compared to the years 1957 and 1980, in 2001 erosion rates along drainage lines have increased mainly due to the reduction in the ground cover percentage (Figure 4.5).

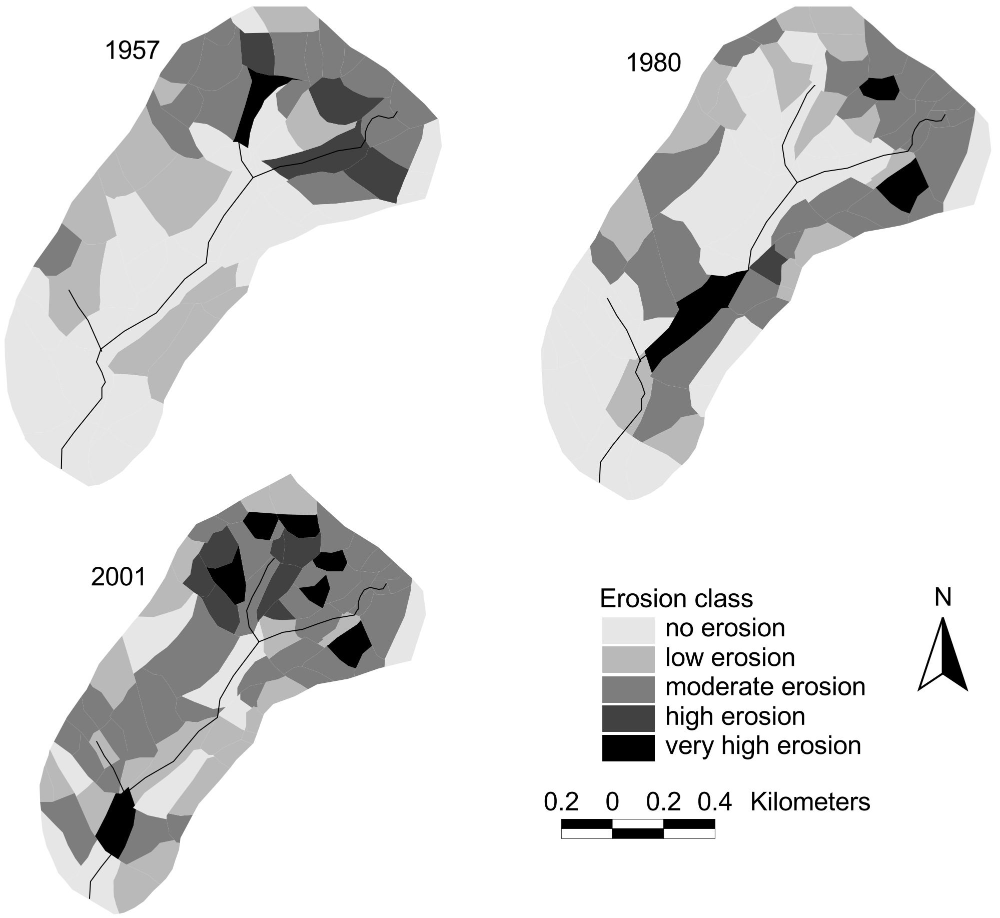

Figure 4.6. MMF erosion maps of Qoricha in 1957, 1980 and 2001, Fincha'a watershed, western Ethiopia

In Qoricha, mean erosion on cropland has increased from 2.9 kg m^{-2} yr^{-1} in 1957 to 3.1 kg m^{-2} yr^{-1} in 1980 and 6.6 kg m^{-2} yr^{-1} in 2001. On grazing lands, mean erosion varied from 0.23 kg m^{-2} yr^{-1} in 1957 to 0.21 kg m^{-2} yr^{-1} in 1980 and 1.7 kg m^{-2} yr^{-1} in 2001. Major conversion of natural vegetation to cropland has caused high erosion rates in 2001. Grazing lands currently remain only at steep slopes and along river courses. Surface runoff generated from croplands, roadsides and gullies are directed into grazing lands. This runoff concentration into grazing land could have caused increased erosion rates on grazing lands. Croplands are also expanding to the river courses at the expenses of riparian vegetation leading to increased sediment influxes into the streams.

The model predictions showed that erosion on cropland was far greater than on the other land use types. This is mainly because of the lower percentage of ground cover and smaller effective hydraulic depth on croplands compared to on the other land use types. High erosion rates were predicted on the foot slopes where more than two elements drained their surface runoff into one element. Vigiak et al. (2005) have reported similar results whereby the predictions increased from ridge to valley bottom. This shows that with downslope accumulation of runoff, the erosion potential of runoff increases.

The predicted average erosion rates on cropland of 5.5 kg m^{-2} yr^{-1} in Hadocha and 6.6 kg m^{-2} yr^{-1} in Qoricha in 2001 are higher than the estimated national average of 4.2 kg m^{-2} yr^{-1} (Hurni, 1993), and in the same range as the estimated soil losses (1.8 to 7.9 kg m^{-2} yr^{-1}) in Chemoga watershed, north-western Ethiopia (Woldeamlak and Sterk, 2003). These erosion rates also exceed the rates of soil formation in the Ethiopian highlands, which was estimated at 0.2 to 2.2 kg m^{-2} yr^{-1} (Hurni, 1983). The average erosion rate of 0.3 t ha^{-1}yr^{-1}on forestlands in Hadocha is within a range of the erosion rates of the world's undisturbed forests that vary between 0.004 to 0.5 t ha^{-1}yr^{-1} (Pimentel et al., 1998).

A comparison of the mean erosion rates by country or watershed or land use type could be misleading because average erosion rates obscure the high degree of variability within each country or watershed or land use type (Bezuayehu et al., 2002). For example, in Hadocha the MMF predicted erosion rates on cropland in 2001 varied between 0.0 to 24.7 kg m^{-2} yr^{-1} and the average was about 5.5 kg m^{-2} yr^{-1}. Hagmann (1991) has also reported erosion rates that varied between 10 and 20 kg m^{-2} yr^{-1} on croplands of Illubabor area, western Ethiopia. Therefore, determination of spatial erosion patterns gives better information about erosion problems in an area compared to the mean erosion values (Vigiak and Sterk, 2001).

4.3.5 Sedimentation

Sedimentation occurred in about 25% of Hadocha and 30% of Qoricha. This shows that areas that benefit from the transported sediments are relatively small compared to those from which it was detached. In Hadocha, mean sedimentation increased from 4.8 kg m^{-2} yr^{-1} in 1957 to 4.9 kg m^{-2} yr^{-1} in 1980 and 8.5 kg m^{-2} yr^{-1}in 2001. In Qoriccha, mean sedimentation varied from 1.9 kg m^{-2} yr^{-1} in 1957 to 1.8 kg m^{-2} yr^{-1} in 1980 and 6.7 kg m^{-2} yr^{-1}in 2001. Sedimentation occurred where much influx of sediments from upslope (E_{up}) was available and where sudden changes in slope steepness or vegetation cover reduced the transport capacity (TC) of surface runoff in the downslope element. In Hadocha, sedimentation was controlled by vegetation cover and topography. In Qoricha, sedimentation was controlled mainly by topography. Field observation during transect walks showed that sedimentation occurred along field boundaries and footpaths. It was also observed that vegetation cover of the landscape was generally low and there were several gullies across the sub-watersheds, which will further reduce the deposition of transported material.

4.3.6 Sediment delivery

Erosion prediction showed that the amount of sediment detached and that actually leave the sub-watersheds have increased between 1957 and 2001 (Table 4.5). In Hadocha, the sediment delivery ratio (SDR) has increased from 0.18 in 1957 to 0.20 in 1980 and 0.40 in 2001 (Table 4.5). In Qoricha, it has increased from 0.23 in 1957 to 0.37 in 1980 and 0.56 in 2001. A high SDR does not necessarily mean that many types of sediment are transported into the reservoir. The amount of sediments directly entering the reservoir depends on topography, soils and vegetation cover of the river systems. Compared to the year 1957, SDR in 2001 had increased by 120% in Hadocha and 140% in Qoricha due to major land use changes across the sub-watersheds.

SDR's are scale-dependent. For example Edward (1988) and Lu et al. (2005) estimated a SDR of 0.10 for a watershed of 50 km^2 and 0.05 for a basin of 1.1 million km^2, respectively. Moreover, watersheds with little relief and high clay content of soils have a low potential to transport eroded sediments (Lu et al., 2005). Also studies made by Walling (1983), Erskine et al. (2002) and De Vente and Poesen (2005) showed that SDR's are inversely related with watershed area. When the size of the watershed increases sediment yield becomes dominated by sediment transport and sediment deposition rather than by active erosion processes. This could be the major reason for a higher SDR prediction in Qoricha (165 ha) than Hadocha (1155 ha) in all respective prediction years.

Field observation in both sub-watersheds have shown deposition of high sediment loads at the points where the streams and water reservoir meet. Relatively coarser sediment loads have been deposited before reaching the reservoir where sudden slope changes occurred. Fine particles did probably directly enter into the water reservoir reducing the water storage capacity of the dam. The increased sediment delivery in the reservoir may reduce power production capacity of the dam and could increase the level of water pollution. In spite of these problems SWC is lacking and haphazard land use changes are taking place in both sub-watersheds (Bezuayehu and Sterk, 2006a).

Table 4.5. Sediment delivery ratios predicted with the MMF model in Hadocha and Qoricha in 1957, 1980 and 2001, Fincha'a watershed, western Ethiopia.

Year	Qoricha			Hadocha		
	Sediment detached (Mg)	Soil loss (Mg)	SDR	Sediment detached (Mg)	Soil loss (Mg)	SDR
2001	3322.3	1876.7	0.56	46605.6	18397.4	0.40
1980	3040.2	1130.9	0.37	42025.0	8344.4	0.20
1957	2975.8	674.8	0.23	39120.4	7420.7	0.18

4.3.7 Erosion prediction in Fincha'a watershed

For erosion prediction in Fincha'a watershed, 110 sub-watersheds ranging from 0.40 to 33.0 km^2 (average = 8.38 km^2) were delineated. The waterbody was excluded from the modelling. About 6000 elements were formed to run the MMF model for the entire watershed based on the 2001 land use data. The predicted erosion map is shown in Figure 4.7. The reservoir, which is a sink for runoff and sediment loads, is overlaid on the erosion map.

In 24% of the 922 km^2 there is no erosion problem while 10% of the area experiences low erosion rates. Fifty-one percent of the 922 km^2 has moderate erosion rates and 15% has high to very high erosion rates. Compared to the other land use types the highest erosion rates were predicted on croplands that ranged from 0.0 to 45.4 kg m^{-2} yr^{-1} (mean = 6.3 kg m^{-2} yr^{-1}). Average erosion rates were 0.56 kg m^{-2} yr^{-1} on grazing land and 0.04 kg m^{-2} yr^{-1} on forest land. No erosion was predicted in swamps. Very high erosion rates were predicted on steep slopes that have been converted to cropland. These parts of the watershed have lost much of their soils due to increased erosion.

Today, ridges as steep as 40° are used for crop production without applying appropriate

SWC measures (Bezuayehu and Sterk, 2006a). Numerous streams and rivers originate from hills and ridges and run to the water reservoir and swamps from all directions. The SDR's predicted for Hadocha (0.40) and Qoricha (0.56) show that large amounts of sediment could enter the reservoir and swamps. Those rivers and streams, therefore, facilitate sediment influx into the reservoir from their respective sub-watersheds. The removal of vegetation cover on steep slopes should have reduced rainfall infiltration and probably ground water recharge. Consequently, some farmers who hold cropland on steep slopes reported that they often face crop failure due to moisture stress as a result of the reduced moisture storage capacities of the soils. Gullies and streams often transport boulders and stones to downstream areas. Runoff often burst their courses and flood crops and sometimes villages during heavy rains. Most perennial springs have dried up exposing the community to the problem of water shortage (Assefa, 1994; Dechassa, 2003). Despite these problems the entire watershed has not been treated with SWC measures. There are not any meaningful policies in place that prevent unwise land use changes in the watershed (Bezuayehu and Sterk, 2006a).

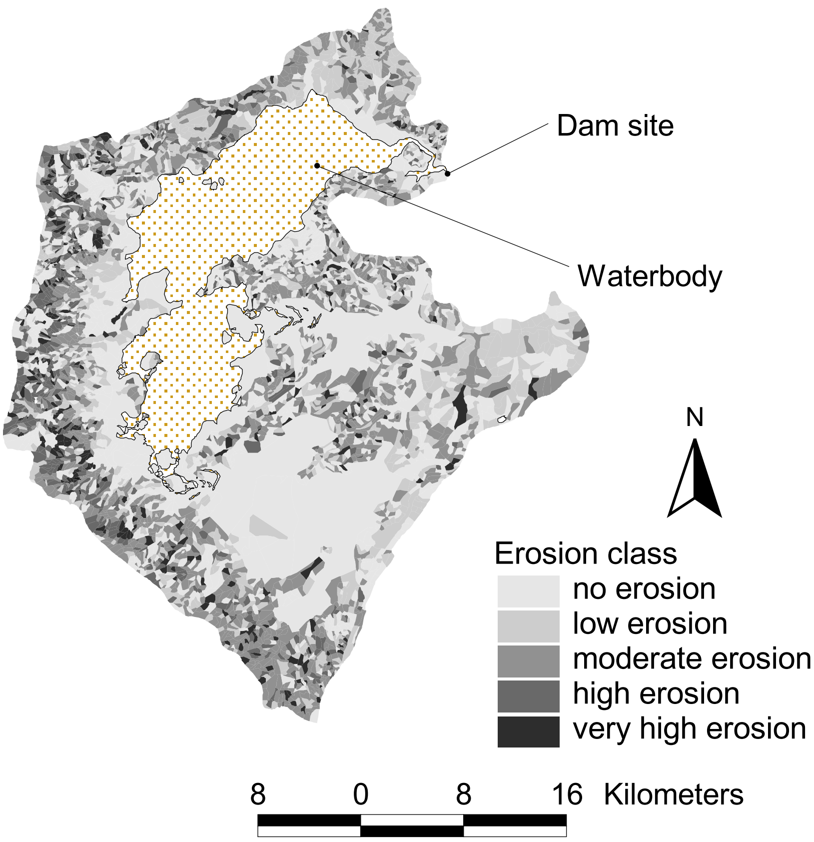

Figure 4.7. MMF erosion map for Fincha'a watershed, western Ethiopia, based on the 2001 land use map.

4.4 Conclusions

The monitoring of erosion rates in Hadocha and Qoricha using the MMF model show that the severity of erosion has been increased as a result of mainly land use changes. In the MMF model prediction the contribution of gully erosion to the annual soil loss was not accounted for. Thus the actual erosion in the study watershed is probably higher than the prediction rates reported. On most steep parts of the watershed soil depth has become shallow, which means that any further soil loss could severely and affect food security situation in the watershed and increases offsite reservoir sedimentation. SWC should, therefore, aim at reducing overland flow volume and velocity across the watershed.

Land use is one of the major factors determining soil erosion and reservoir sedimentation in Fincha'a watershed. The mean annual soil losses from grazing land and forestland are much lower than losses from cropland. Therefore, croplands are major sources of sediment in Fincha'a watershed and should be targeted by on-site SWC to reduce sediment supply to rivers and the reservoir. This is generally not done yet.

Sedimentation occurred in only 25% of Hadocha and 30% of Qoricha, where it remains in temporary storage (Walling, 1983; Sonneveld and Keyzer, 2003; Morgan, 2005). Sedimentation was caused by sudden changes in slope steepness and vegetation cover percentage. However, quite enormous amounts of detached soil material (i.e. SDR between 0.40 and 0.56) could find its way to the watersheds outlets or the reservoir. SDR had increased by 120% in Hadocha and 140% in Qoricha between 1957 and 2001. The increased SDR could increase reservoir sedimentation and reduce power production capacity of the dam. At the time when the Fincha'a hydropower project was initiated the planners had assumed that the sediment load of the watershed was not a significant concern (HARZA, 1966). This might have been true prior to the project, when there was better vegetation cover across the watershed which was also revealed by a relatively low erosion rate and SDR prior the dam. Concurrent with the construction of the dam, however, increasing population pressure promoted hillside farming, increased soil erosion and SDR. The resultant clearing of vegetation on hillsides will further increase soil erosion and reservoir sedimentation. Improper construction and maintenance of roads have also been important contributors of rills and gully erosion as well as sedimentation.

The semi-empirical MMF model provided good estimates of soil erosion on croplands, and reasonable estimates for other land use types. It can be used to identify areas with high erosion rates leading to land degradation where conservation measures are required, identify sediment source areas and calculate sediment delivery ratios. In countries like Ethiopia where limited information or limited funds are available to develop or apply detailed models, semi-empirical models such as the MMF can be used to identify areas with high erosion rates and reservoir sedimentation where conservation measures are required. However, the MMF model tends to over predict erosion rates at foot slopes and under predict at water-divide lines (ridges) because the spatial pattern of erosion prediction by the model is driven by accumulation of runoff in which the possibility of re-infiltration along slopes was not taken into account (Vigiak et al., 2005). Besides, the model does not take into account the erosion contributions made by gully erosion, which can be as high as 10-94% of total water erosion (Poesen et al., 2003). Therefore provided that the possibility of re-infiltration of runoff along slopes and gully erosion contribution to the total soil loss are taken into account the MMF model gives fairly good erosion predictions at the watershed level.

Chapter 5

Factors affecting soil and water conservation adoption in Fincha'a watershed, western Ethiopia

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Submitted to: Land Degradation & Development

Factors affecting soil and water conservation adoption in Fincha'a watershed, western Ethiopia

Abstract

The knowledge of soil erosion processes, attitude towards rational use of resources and institutional support affect the capability of farmers to implement soil and water conservation (SWC) measures. This research was conducted to determine the factors that affect adoption of SWC measures in Fincha'a watershed, western Ethiopia. A total of 50 farmers were interviewed using a semi-structured questionnaire, and two group discussions were held with 20 farmers. Moreover, transects were walked to classify erosion features, and a quantitative erosion survey was made on 19 farm plots during the rainy season of 2004. The results showed that crop fields are affected by annual soil losses ranging from 24 to 160 t ha^{-1}. Farmers are well aware of these erosion problems, and related the soil loss to steep slopes and a decline in soil fertility. However, they did not invest much in SWC measures, but apply soil management practices to sustain crop yields. The wealth status of farmers, land tenure arrangements and degree of access the farmers have to information are the major factors affecting SWC adoption. High labour demand of SWC measures, lack of short-term benefits and free grazing has negatively affected SWC adoption. Soil erosion problems in Fincha'a watershed have both on-site and off-site effects that require integrated SWC adoption at watershed scale.

5.1 Introduction

Depletion of soil resources due to erosion has important implications for developing countries like Ethiopia (Barbier and Bishop, 1995; Lal, 2001). It has been threatening the agricultural sector of the country and has become one of the culprits of the current drought and famine (Alemneh, 2003). After the massive famine and starvation in the 1970s the Ethiopian government initiated a soil and water conservation (SWC) programme, which was operational on ad hoc basis until 1980 (Kebede, 1991; Betru, 2002; Alemneh, 2003). Later the human and financial resources were concentrated in hydrological units in order to achieve better soil erosion control. This so-called watershed approach has been adopted in the 1980s. Over the years this approach has promoted various SWC measures such as soil bunds, stone bunds, *fanya juu* terraces, bench terraces, cutoff drains, waterways, check dams, grass strips and plantations. The efforts made so far using the watershed approach have restored degraded farmlands, improved soil water holding capacities, increased woodlots, and improved the productivity of pasturelands (Kebede, 1991; WFP, 2002; Betru, 2002; Sonneveld and Keyzer, 2003; WFP, 2004). Incentives such as food-for-work, hand tools, and farmers' and staff trainings were the key stimulants during implementation of SWC in the country.

Despite the successes, some studies claimed that the SWC programme in Ethiopia did not succeed in triggering voluntary adoption of conservation practices outside the project area (Admassie, 1995). Reasons for failed adoption by farmers are the poor extension approaches, lack of incorporating indigenous SWC techniques (Herweg, 1993; Million, 2001), land tenure insecurity (Shiferaw and Holden, 2000; Selamyihun, 2004) and the inability to make SWC productive (Betru, 2002). Moreover, in areas where the SWC programme operated for a long period of time (eastern and northern parts of the country) the use of incentives (e.g. food-for-work) in implementing SWC has to some extent distorted farmers' perceptions regarding the environmental consequences of soil erosion (Daba, 2003). On the other hand a survey result of Bekele and Drake (2003) showed that the use of incentives has positively influenced SWC adoption in the eastern part of the country.

Several studies have emphasized that SWC adoption by farmers will gain more acceptance when (1) capacities for learning and action are enhanced (Baidu-Forson, 1999; Hellin and Haigh, 2002; Daba, 2003; Tenge et al., 2004), (2) the causes of soil erosion rather than merely the symptoms are addressed (Pretty and Chambers, 1994), and (3) SWC technologies that give immediate benefits by improving yield are introduced (Shiferaw and Holden, 1998). Furthermore, policy changes that provide increased land security (Besley, 1995; Pretty, 1995; Gavian and Fafchamps, 1996; Tiffen, 1996) and greater access to markets will motivate farmers to improve soil quality via the use of conservation-effective and productivity-enhancing technologies (Hellin and Haigh, 2002). When farmers have secured land tenure, they have been shown to invest a considerable capital in conservation methods, without external assistance or intervention, when benefits of increased production are demonstrated (Tiffen, 1996). The high labour costs involved in establishment and maintenance of SWC technologies (Stocking, 1995) and the potential loss of land to measures (Lucila et al., 1999), however, will negatively influence SWC adoption.

The Ethiopian ministry of agriculture and rural development has a strong commitment to the promotion of SWC extension programmes into different parts of the country. The ministry together with the U.N. World Food Programme has developed a community-based participatory watershed development guideline in 2005. This guideline promotes the community-based problem identification, planning, implementation and governance of the SWC activities. To make the guideline more effective, it is necessary to better understand the factors that influence the adoption of SWC. The existing studies on those factors that determine SWC adoption are scanty in the country in general and non-existing in the western part of Ethiopia. The objective of this research was, therefore, to evaluate the major factors that determine the adoption of SWC measures in a watershed in western Ethiopia, and to give recommendation that might contribute to improved policies and programmes for SWC in Ethiopia and elsewhere.

5.2 Materials and methods

5.2.1 Study area

The study area is Fincha'a watershed, which is a representative watershed for the western highlands of Ethiopia. Typical for these highland areas are the mixed crop and livestock agricultural systems. The watershed covers 1318 km^2 and its approximate location is shown in Figure 5.1.

Elevation in the watershed ranges between 2200 m to 3100 m. Due to its high altitude, Fincha'a watershed falls into a temperate humid climate. The yearly average rainfall in the watershed is 1823 mm and about 80% of the annual amount occurs between June to September. The mean monthly temperature varies from 14.9°C to 17.5°C. The average annual reference evapo-transpiration (based on Penman-Monteith) is 1320 mm, with low monthly variations.

The dominant soils in the watershed have a texture of clay, loam and clay-loam. The soil bulk densities range from 1.1 Mg m^{-3} for clay, to 1.3 Mg m^{-3} for loam and clay-loam. Soils are deep (> 150 cm) on flat lands but on steep slopes (>30%) soil depths are shallow (< 25 cm). Shallow soils are constrained by incidences of crop failure due to moisture stress at times when there is a long duration between consecutive rain storms.

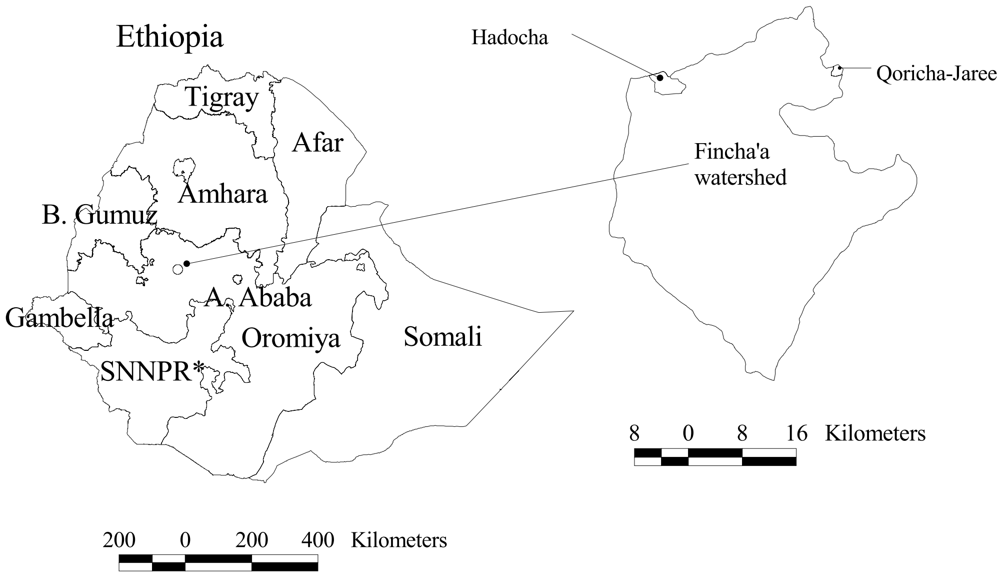

Figure 5.1. Location of Fincha'a watershed in the country and that of Hadocha and Qoricha-Jaree sub-watersheds, western Ethiopia. *SNNPR- Southern Nation, Nationalities and Peoples' Region.

Population density was 98 people per km^2 in 2003. State ownership of land persisted since the 1975 land reform. Land redistribution by the state was used as a means for providing land for landless people. The last land redistribution was done in 1975, when all farm households were given a piece of land. Today, however, 20-30% of the families in the watershed is landless. They entirely rely on sharecropping and selling of family labour (OADB, 1996).

A dam was constructed in this watershed in 1973 and created a water reservoir of 239 km^2 (Bezuayehu and Sterk, 2006a). The reservoir is mainly for hydropower production, but has caused major land use changes in the watershed by inundating swamp, grazing land, cropland and forestland. The inundation and population increase has induced the conversion of steep lands for crop production and grazing.

The research was conducted in two sub-watersheds, namely Hadocha (1155 ha) and Qoricha-Jaree (437 ha), representing the upper and lower parts of Fincha'a watershed, respectively (Figure 5.1). While Hadocha sub-watershed is situated in Horro district, Qoricha-Jaree is in Abbayyii Coomman district. The number of inhabitants in Hadocha was 980 from 176 households. In Qoricha-Jaree 565 people live in 87 households. The economy of the local population is mainly based on farming, which involves crop-livestock production systems.

Major crops grown are maize (*Zea mays*), bean (*Vicia faba*), Niger seed (*Guizotia abyssinica*), tef (*Eragrostis tef*), barley (*Hordeum vulgare*) and wheat (*Triticum species*). Cattle rearing is practiced for draught power, food, soil fertility enhancement, cash income, levelling of tef fields and threshing of crops. In order to enhance the soil fertility level, those farmers who have cattle herds apply a soil fertility management practice known as *ciicata* (a practice of overnight kraaling of cattle on farm fields to collect their droppings for growing high value crops). Farmers form several working groups or teams locally known as *daboo* or *jigii* to accomplish different agricultural tasks such as ploughing, planting, weeding, harvesting and threshing.

Natural pasture is a major source of fodder for livestock but crop residues are used to supplement this during the dry season. Tillage is practiced using the ard or single-tined plough known as *marasha*. Tillage operation for planting most crops is often done 2 to 7 times, depending on the crop and soil type. The plough breaks up dried topsoil (Goe, 1999) and creates fine tilth, which makes the soil susceptible to erosion and crust formation. Generally, the agricultural practices leave the soil bare and loose at the onset of rains, when rainfall intensities are often high, and may result in severe erosion.

5.2.2 Methodology

Field research was carried out based on formal and informal survey methods (Conway and Barbier, 1990; de Graaff, 1996) and comprised three stages: group discussions, interviews, and transect walks with quantitative erosion assessments. The first stage involved discussions with 20 farm households (10 from each sub-watershed) that hold land. Two informal group discussions were held, one in each sub-watershed. These discussions were held during the dry season (February 2004), and lasted for about three hours. Only the household leaders participated in the discussions. The purposes of these discussions were to identify and prioritise the major agricultural problems in the sub-watersheds, using a checklist.

The second stage was conducted to collect specific and quantitative data related to household characteristics, labour availability, land tenure, soil quality and management, agricultural problems and perceptions, factors for adoption and non-adoption of SWC measures, and soil erosion and soil fertility statuses. A total of 50 farmers (25 from each sub-watershed) were randomly selected across the sub-watersheds out of a population of 263 registered farmers. The used questionnaire was semi-structured, with a mixture of open-ended questions and questions with codified answers. The open-ended questions were designed in such a way that interviews were continued based on the reply of the farmer to the previous question. The codified questions were used while farmers were asked to evaluate their plots of cropland that were situated on different slope classes in terms of erosion extent using three classes, i.e., 1 = high, 2 = medium and 3 = low. Similarly soil fertility level was valued as 1 = poor, 2 = medium and 3 = fertile. The survey included measurements of plot sizes and slope steepness using the slope classes defined for Ethiopia by Escobedo (1988): flat (0-3%), gentle slope (3-8%), sloping (8-15%), moderately steep (15-30%), steep (30-50%) and very steep (>50%). The total number of plots used for these analyses were 157. Interviews were held at the farmers' compounds, during the dry season of 2004, and lasted usually halve a day for a single farmer.

The third stage involved the assessment of soil erosion on different slopes and its relation with soil type and crop type. This was done to determine the extent of soil erosion in the two sub-watersheds, and relate the soil erosion problems to reasons for adoption or non-adoption of SWC. The Assessment of Current Erosion Damage (ACED) method as described by Herweg (1996) was applied. The erosion assessment included both qualitative transect walks and quantitative monitoring of the dimensions of visible rills in the major crop fields during the rainy season (July to August) of 2004. The quantitative assessment was carried out every two weeks during the rainy season on 19 plots distributed over the two sub-watersheds. The volume of soil loss that was calculated based on the dimensions of the rills was then converted to weight unit by multiplying the volume of soil loss with the respective bulk densities of the soil types in the area.

In addition, discussions were held with local agricultural offices and development agents working at the study sub-watersheds. The purposes of the discussion at the agriculture offices were to gather information on general agricultural and SWC problems, past SWC extension methods, success and failure of the past extension programme and current extension approaches. The development agents were interviewed about the specific agricultural problems in the sub-watersheds, their extension approaches and technical and financial assistance they get from the district agricultural offices. Periodical reports from the same agriculture offices were reviewed for complementing the information obtained during this survey.

5.3 Results

5.3.1 Household characteristics

The farm families that reside in the study sub-watersheds are characterised as indicated in Table 5.1. On average the interviewed farming families consisted of 6.9 persons, and had about 3 ha. This farming land was divided over 7-8 fields (on average 6.8 fields in Qoricha-Jaree and 8.5 fields in Hadocha), which were spatially scattered across different slope classes, soil types and at varying distances from homesteads. The majority of the family heads (47 in number) were men and only three were women. Women-headed farms are constrained by family labour, because those women have lost their husband and are responsible for both farming and household activities. Three sub-groups of farmers were identified based on age: young (< 30 years), middle (31-55 years) and old (over 55 years). Several farmers (10 respondents) were young and generally had small farms (2.3 ha on average). The average land holding of the middle-aged groups of farmers was 3.1 ha, while the group of old farmers (13 in number) had an average farm size of 4.1 ha. The old farmers tend to stick to the traditional practices, and have a high labour shortage because they are not as strong as when they were younger, and most of the children have left the farm. On the other hand, the group of young farmers have sufficient labour available, but are constrained by small farm sizes, and lack options to increase the farm size due to land shortage in the area.

Table 5.1. Characteristics of selected farming household heads in Qoricha-Jaree and Hadocha, Fincha'a watershed, western Ethiopia.

Characteristic	Description	Qoricha-Jaree n = 25	Hadocha n = 25
Sex	Male	24	23
	Female	1	2
Age	Young (18-30 yr)	8	2
	Middle (31-55 yr)	12	15
	Old (> 55 yr)	8	5
Education	No enrolment	16	17
	Primary (1-6 yr)	9	3
	J/secondary (7-8 yr)	0	2
	Secondary (9-12 yr)	0	3
Farm size	0-2 ha	5	8
	2-3 ha	6	9
	>3 ha	14	8
Number of oxen	0-1 ox	8	9
	2 oxen	13	11
	≥ 3 oxen	4	5

A majority of the farmers (33 in number) were without any formal education but 12 farmers got primary education, while five farmers got both junior secondary and secondary education. Hadocha sub-watershed has a higher proportion of farmers with junior-secondary and secondary education. The recent improvement in education facilities in the area had created better education opportunities for young farmers to attend school before being a farmer. However, many people with secondary-school education do not want to stay in rural areas because of limited social and economic services.

Farmers also differed based on their wealth level. Land size and soil quality, number of oxen, family labour and off-farm income were the major criteria for determining the wealth status of the farmers in the sub-watersheds. The off-farm income was limited and was not considered as such. Instead, farm size and number of oxen became the practical parameters to be used in analysing wealth ranks. Thus, households operating less than two hectares of land and owning less than a pair of oxen were categorized as poor farmers but households with more than three hectares of land and owning more than a pair of oxen were categorized as rich farmers. It was observed that those farmers who are economically better off tended to dominate over less favoured farmers during the group discussions.

The rich farmers combine food and cash crop production activities and attain food security through own production. Since they own cattle herds, they have the opportunity to apply manure onto their fields. They often establish woodlots for energy sources and construction. However, the production system of the economically medium households is usually subsistent and less diversified. They devote the entire land area for food crop production, mainly tef. The poor households are self-insufficient and supplement livelihood by selling family labour. Hence, family members are less privileged to attend education.

5.3.2 Land tenure

Since the 1975 land reform, land belongs to the state and farmers have use rights only. However, they make (informal) land exchange (mainly cropland), which included sharecropping and gifting or bequest. The survey households were interviewed regarding the mode of acquisition of the plots of land they operate and the rights they have on those plots. About 62% of the croplands that were operated by the sample households were allocated by the government (Table 5.2).

Table 5.2. The size of croplands under different tenure arrangement in Qoricha-Jaree and Hadocha, Fincha'a watershed, western Ethiopia.

Land tenure type	Qoricha-Jaree		Hadocha	
	Cropland (ha)	Cropland (%)	Cropland (ha)	Cropland (%)
Allocated	46.6	52.6	68.8	72.2
Gifted or bequest	16.1	18.2	1.2	1.2
Sharecropped in	17.8	20.1	5.3	5.6
Sharecropped out	8.1	9.1	20.0	21.0

About 50% of the farmers make sharecropping arrangements to fulfil their cropland shortage. At the time of the survey, the sharecropped areas covered 28% of the total cropland in Qoricha-Jaree sub-watershed, and 27% in Hadocha sub-watershed. The arrangements usually last for a few production seasons only (mostly one or two). Farmers who do not have sufficient land to till (mainly young families), draught oxen or labour make sharecropping in arrangements. Old farmers who lack family labour usually make sharecropping out arrangements.

Land management and investment practices were different from field to field, depending on land tenure arrangements. For example farmers do not apply soil fertility enhancement practices and tree planting on those plots of land under sharecropping arrangements. Moreover, a landholder prefers to sharecrop out plots of land far away from his home because it is believed that those plots are less secured (fear of land redistribution by the state), less fertile (due to less fertility management practices) and demand more travel time to execute agricultural activities. On the other hand many farmers have planted trees on fields they own and are located nearby their homesteads.

Since 1975 no land redistribution has been made in Fincha'a, and there has not been any official declaration. Despite this, most farmers remembered the 1975 experiences, and holders of a relatively big farm feared loss of some plots of land through redistribution. However, already before the survey, the possible land redistribution in the area was relinquished by the Rural Land Use and Administration Proclamation of the regional state (Magalata Oromiya, 2002). The new proclamation allows land renting and land certificates that assure land holding right and security for at least three years can be issued. The farmers apparently did not yet know this, or they lack confidence in the official proclamation.

5.3.3 Soil quality and management

The 50 households were interviewed to identify the major soil types in their area. They were also interviewed to characterize their own plots, based on the major soil types identified, in terms of soil fertility level, response to application of chemical fertilizers, sensitivity to erosion, workability and drainage level. In general three major soil types, namely *diimolee* (red soil, Nitosol), *gurracha* (black soil, Mollisol) and *kooticha* (heavy clay soil, Vertisol) were distinguished (Table 5.3). The spatial distribution of *diimolee* is on excessively drained steep slopes. The *gurracha* are generally situated on the well drained rolling plateaus and the *kooticha* are predominant at the foothills and along the water reservoir. The *diimolee* has covered a wider area in Qoricha-Jaree but *gurracha* soil is abundant in Hadocha sub-watershed.

Table 5.3. Major soil types and their inherent qualities in Qoricha-Jaree and Hadocha, Fincha'a watershed, western Ethiopia.

Inherent quality	Soil type		
	Diimolee (Nitosol)	*Gurracha* (Mollisol)	*Kooticha* (Vertisol)
Fertility level	low	high	medium
Response to fertilizer application	high	medium	low
Resistance to erosion	high	medium	low
Workability	high	medium	low
Drainage	high	medium	low

The inherent fertility status of *gurracha* is considered to be better than those of *kooticha* and *diimolee*, the latter being least fertile. The *diimolee* soil responds better to the application of chemical fertilizers as compared to *gurracha* and *kooticha.* The areas where *diimolee* soil is predominant have been used for crop production for a long period of time due to its better drainage and workability as compared to *gurracha* and *kooticha*.

There are several soil management practices applied in the sub-watersheds. The most notable practice is the use of runoff disposal trenches known as *yaa'a.* These trenches are made using a local plough that is drawn by a pair of oxen just before seeding. The trenches have a triangular cross-section with about 35-40 cm (upper) width and 15-20 cm depth. Spacing between the trenches is determined depending on soil type, crop type and slope steepness. The typical spacing between the trenches is about 7 to 15 m on *diimolee* soils and 5 to 10 m on *gurracha* soils. The type of trench applied on *kooticha* soil is, however, different form the other soil types. On *kooticha* soil a series of ridge-and-furrow systems that are closely spaced to each other are formed to drain excess water from the field.

The gradient of the trenches, which is defined as the ratio of change in vertical height to horizontal distance (m/m), varies depending on the slope steepness of the farm fields. When slope of the field is 0-15% the trenches are given a gradient of about 0-0.10. When the slope of the farm is 16-38% the gradient of the trench will be about 0.11-0.26. Moreover, when crop fields are steeper than 20%, trenches are often established across each other to increase runoff disposal efficiency. Even though different adjustments are made in spacing and gradient of the trenches, scouring and overtopping of the trenches were commonly observed on steep slopes.

Traditionally the trenches have been developed for tef fields because compared to the other crops, tef planting requires soil compaction which is done by letting cattle walk on the field when soils are moist. Soil compaction is believed to increase the germination rate of tef seeds and/or to suppress growth of weeds. On the other hand, when a tef field is levelled by compacting the soil, the overland flow generated on a relatively smooth surface washes out the tef seeds and fertilizers. This runoff, therefore, should be disposed from the field through the trenches before it gets concentrated. Today, nevertheless, the trenches are increasingly applied for all crops. The trenches that are applied for other crop types, however, are relatively far apart and the gradients are very low. For example, spacing between the trenches on wheat and barley fields varies between 10 to 20 m and those trenches are laid out along the contour.

Tillage is applied on all soil types and for all crops. Tillage direction is usually variable, with some tillage operations conducted along the contour, others across the contour, and also intermediate directions are used. These multiple directions are believed to make a good seedbed. In order to reduce the effect of surface runoff on soil erosion, farmers apply contour ploughing during the rainy season and seeding time.

Fallowing is one of the soil management practices that is believed to improve the productivity of impoverished lands. When crop yields from a plot of land decreases farmers put the plot under fallow for a period of time ranging from three to five years before it is cultivated again. Some farmers indicated that when a plot of land is severely degraded, fallowing can last up to ten years before satisfactory result would be achieved. While a plot of land is under fallowing it is often used for grazing. However, due to land shortage and use of chemical fertilizers fallowing is less practiced in the sub-watersheds. During this study only eight farmers replied that they apply fallowing.

In order to enhance the soil fertility level, those farmers who own cattle herds apply a soil fertility management practice known as *ciicata.* This is a practice of overnight kraaling of cattle on farm fields in a rectangular fence-like structure known as *dalla* to collect their droppings for growing high value crops. The herd of cattle stays three to six nights on a piece of land and then the *dalla* is relocated to the next piece. The number of nights the cattle stay on the same piece of land is determined by rainfall situation and the soil fertility status of the field. During the rainy season the maximum number of nights at one place will be as low as three because the field will be muddy and it will not be suitable for the animals to stay on the same place for a long time. In the dry season, and especially when the fertility status of the field is low, the number of nights the cattle are kept in the same place will be as many as six nights. Generally farmers tend to give better care for more fertile plots that give better yields on long-term basis, even if no soil management practices are applied.

A recent soil management practice in the area is the application of chemical fertilizers. Today, the majority of farmers (41 in number) apply chemical fertilizers on non-leguminous crops. The farmers who applied chemical fertilizers reported that they get relatively good crop yields on the fertilized fields, even on severely degraded land. But, the price of chemical fertilizers has become very high in recent years, which limits the area on which fertilizers are applied.

5.3.4 Agricultural problems

Based on the group discussions five major agricultural problems of the community were identified and put in a priority order (Table 5.4). There wasn't much difference between the sub-watersheds in the type and order of the problems identified but quite a big difference was noticed between the problems and priority of the rich and poor farmers. For example, a high cost of chemical fertilizer was the foremost problem of the rich farmers. But for poor farmers, the decreased cropland area has become the most important problem. The grazing land shortage and increased livestock diseases has not concerned the poor farmers as much as it concerned the rich farmers, because the poor farmers own fewer animals. The poor farmers were highly concerned about fulfilling their immediate need of crop production, which is constrained by land shortage and declining soil fertility. The rich farmers apply the *ciicata* soil fertility enhancement practice and use chemical fertilizers to sustain crop production. But the poor farmers lack these options. The poor farmers underlined that, though rising costs of chemical fertilizers is a general community problem, its effect on the poor farmers is most severe.

Table 5.4. The major problems of the community in Qoricha-Jaree and Hadocha, Fincha'a watershed, western Ethiopia.

Priority order*	Major problem	
	Wealthy farmers	Poor farmers
1	Increased costs of chemical fertilizers	Decreased cropland area
2	Decreased grassland area and its productivity	Increased costs of chemical fertilizers
3	Increased livestock diseases	Decreased crop yield due to erratic rainfall and soil erosion
4	Decreased crop yield due to erratic rainfall and soil erosion	Decreased grassland area and its productivity
5	Decreased cropland area	Increased livestock diseases

*1= most important; 5 = least important.

From Table 5.4 it is clear that soil erosion is not the major concern to farmers. Despite this result, we continued to better understand erosion problems in the farming systems. During the dry season (March to May) of 2004, farmers were interviewed about the severity of soil erosion problems on their plots of lands and its impact on agricultural production. About 33 farmers replied that soil erosion is severe on their plots, and affects crop production (Table 5.5).

Table 5.5. Severity of soil erosion as perceived by households heads in Qoricha-Jaree and Hadocha, Fincha'a watershed, western Ethiopia.

Soil erosion severity	Qoricha-Jaree n = 25	Hadocha n = 25
High	15	18
Medium	7	5
Low	3	2

They expressed that increased soil erosion has become a serious constraint for crop production due to its effect on loss of seed, fertilizers, soil fertility and water. Soil erosion has reduced soil depth and several rills and gullies have been created in croplands and grasslands. Farmers mentioned that "in the past we were able to produce a sufficient amount of crop without application of chemical fertilizers, but today this is not possible at all". According to the survey, steep land farming was recently experienced in the area following increased land shortage due to population growth. Not only cropland has been affected but also grasslands. Where soil depths have reduced due to erosion, biomass production from grasslands has also reduced, leading to fodder shortage.

On the other hand five farmers replied that agricultural practices in the area do not face any problem yet. Detailed analysis of the characteristics of the farmers who didn't see any agriculture-related problems showed that they are from the rich group of farmers and their farmlands are generally situated at downstream parts of the sub-watersheds, where slopes are gentle, and less erosion problems are experienced.

The qualitative classification of erosion severity and soil fertility status by the farmers showed a clear relation between the occurrence of soil erosion and soil fertility status. The majority of the farmers did perceive an increased erosion problem on their lands and associated it to high rainfall and overland flow, steep slopes and reduced vegetation cover. According to their perception, soil erosion and slope steepness were strongly related, as were the decline in soil fertility status and soil erosion severity. In their perception, slope is the most important factor for the occurrence of erosion. Soil types did not really matter.

5.3.5 Soil and water conservation

Information from the agriculture offices showed that when SWC was introduced into the limited areas of Fincha'a watershed between 1983 and 1991, communities were mobilized to construct soil bunds, cut-off drains and waterways through the Peasant Associations. However, following the government change in 1991, most of the terraces were either intentionally removed or decayed out due to lack of maintenance. There were two major reasons given for the failure of the extension programme. The first and most important problem was that the approaches followed were top-down and coercive in nature. The second problem was related to lack of appropriate technology selection and design considerations. For example, the determination of spacing between two terraces was done based on 1 m vertical interval (regardless of the variation in slope steepness and farming systems). This uniform vertical interval between terraces had created narrow spaces between terraces on steep slopes and caused problems on the traditional oxen ploughing activities. Moreover, the dimensions of the terraces were generally low so that they lacked the capacity to sustain the increased overland flow volume and velocity generated between adjacent terraces. Free grazing was also one of the major problems that put more pressure on vegetation that was established for SWC purposes.

Almost all farmers have applied runoff disposal trenches and contour ploughing in their crop fields as a SWC measure. About five farmers applied a limited amount of soil bunds in both sub-watersheds. The bunds were poorly maintained indicating that the farmers lacked interest in them. Farmers mentioned various reasons for not adopting SWC measures. The major reasons given were: (1) the SWC measures take a large area of land (10 to 15%) out of crop production (48 of the respondents), (2) terraces become an obstacle to tillage operations (46 of the respondents), and (3) lack of short-term benefits (40 of the respondent). Moreover, about 38 farmers replied that the establishment of the measures requires a high labour input. Only 19 farmers replied that land tenure insecurity is a problem in adopting SWC technologies. Some 20 respondents (14 from Hadocha sub-watershed) indicated that the structures harbour weeds and rats that affect field crops.

The past SWC extension programme was resumed in 2002 after being halted for a decade. In general, the development agents working in the sub-watersheds were less trained on SWC skills, and lacked field equipment and transport. They did not get sufficient technical backstopping from the SWC experts at district level. The SWC experts at district level reported that they did not give sufficient technical support to the development agents due to lack of transport means and finance.

Field observations in the sub-watersheds during the 2004 rainy season have shown that the technical shortcomings of the earlier approaches have not improved yet. The soil bunds were not designed taking into consideration the varying bio-physical situations and farming systems in the area. This time, although participatory planning was well token, the traditional top-down planning approach persisted. Yet many farmers hesitate having terraces on their plots.

The majority of the farmers (41 in number) had a good contact with the development agents regarding fertilizer usage. Since crop production is hardly possible without the use of chemical fertilizers, these farmers consult development agents on the techniques of fertilizer application. Besides, the introduction of high yielding maize and wheat varieties into the area has encouraged 36 farmers to consult the development agents and they now use improved seeds. On the other hand only eight farmers had communicated with development agents on soil erosion problems and conservation methods. These eight farmers indicated that the terraces are good in conserving soils but they did not improve crop yields. They stressed that, "SWC officers at district level do not often come to our area and explain to us the problem of soil erosion. Only the development agents in our area have explained the problems of soil erosion." In addition, they mentioned "we only will adopt the terraces, like we did for chemical fertilizers and improved seeds, if the terraces increase crop yields". The farmers who showed strong interest in SWC were mostly having small land sizes and own very few cattle. But given the lack of confidence whether or not SWC can increase crop yields, these farmers had not yet started implementing terraces on their plots.

5.3.6 Erosion survey

The qualitative transect walks carried out in the 2004 rainy season showed that sheet, rill and gully erosion features affected cropland, grazing land and fallow lands in both sub-watersheds. Sheet and rill erosion features predominate in croplands but gullies were abundant in grazing lands and fallow lands. In a plot of land where one or a combination of soil management practices is applied the prevalence of soil erosion features is low. However, since plots of lands are fragmented and owned by different farmers, the soil management practices may not be systematically planned and implemented to reduce the effects of soil erosion.

Table 5.6. Rill density and soil loss based on ACED method in Qoricha-Jaree and Hadocha, Fincha'a watershed, western Ethiopia.

Sub-watershed	Crop type	Plot area (ha)	Slope (°)	Soil texture	Rill density (rills ha^{-1})	Soil loss (kg m^{-2})
Qoricha-Jaree	Bean	0.20	6	Clay-loam	61	2.4
	Maize	1.01	7-14	Clay-loam	35	4.1
	Tef	0.22	7	Clay	137	3.9
	Niger seed	0.76	7-14	Loam	68	5.3
Hadocha	Bean	0.78	10-17	Clay-loam	116	4.9
	Maize	0.04	10	Clay	125	16.0
	Tef	0.83	9-14	Clay-loam	419	7.5
	Niger seed	0.65	17	Clay	198	8.2
	Wheat	0.41	10-19	Clay	113	14.3
	Barley	0.58	9-14	Clay	144	10.0

The quantitative soil erosion assessment with the ACED method (Table 5.6) showed that crop fields were affected by soil losses of 2.4 to 16.0 kg m^{-2} (average ≈ 7.2 kg m^{-2}). Visible erosion damage of about 35 to 419 rills per hectare was observed in the major crop fields. In both sub-watersheds the highest rill densities were observed in tef fields compared to the other fields, due to the different management practices used for this crop. In the majority of plots, run-on contributed from upstream plots had aggravated the soil erosion problems. A higher rill density and more soil loss were observed in Hadocha sub-watershed, probably due to the higher slope steepness in this area.

5.4 Discussion and recommendations

The observed soil losses in the sub-watersheds are higher than the national estimate of average annual soil loss of 4.2 kg m^{-2} (Hurni, 1993). The actual soil loss in the study area is probably even higher because the ACED method does not account for the amount of soil loss contributed by inter-rill erosion. The most likely reasons for the high soil losses in the study area are past land use changes (Bezuayehu and Sterk, 2006a), increased use of steep slopes, and lack of sufficient SWC measures. Especially steep slopes have been converted to agricultural land due to population increases and the construction of a hydropower reservoir in

Fincha'a watershed (Bezuayehu and Sterk, 2006a). Much of the previously existing vegetation cover was removed on the slopes, which enhanced the erosion susceptibility.

Runoff trenches are not adequate to control soil erosion problems, especially on steep slopes. Scouring of the embankments and overtopping have undermined their performances leading to rill formation and seed and fertilizer losses. Therefore there is a need for additional SWC measures. The trenches can be combined with other SWC measures if their gradients are low. But if the gradients of trenches are larger than the gradients of conventional SWC measures there will be a possibility for the trenches to cross the other measures that may reduce soil erosion control.

From the interviews it has become clear that farmers are well aware of erosion problems. The majority of the farmers did perceive increased erosion rates on their land and associated it to high rainfall and overland flow, steep slopes and reduced vegetation cover. Their qualitative evaluation of factors of soil erosion showed that they clearly link the erosion problem to the slope of their land and a decline in soil fertility. Most farmers were worried about crop production levels, but despite this, they have not invested in adequate soil and water conservation on those slopes. They merely try to mask erosion effects on crop yield by soil fertility management, mainly by applying *ciicata* and fertilizers. The presence of a good soil depth in flat areas could, to some extent, also mask the effect of erosion. But on steep lands where soils tend to be shallow the application of fertilizers seems to be the only real option to sustain yield levels without implementing SWC. Obviously, the soil may be entirely lost in the long term if nothing is done to control erosion on those steep sloping lands.

The results of the group discussions showed that decreased areas of crop and grazing land, increased fertilizer costs, decline in crop yields, and livestock diseases are the major community problems in the sub-watersheds (Table 5.4). Increased population growth and the creation of the hydropower reservoir in Fincha'a watershed were indicated to be the major reasons for decreased crop and grazing lands. As a result the traditional way of cropland expansion is not possible anymore, because most of the sub-watershed areas have already been converted to cropland. Farmers have showed interest in doing something that will enable them to get out of these multifaceted problems. From the group discussions, however, soil erosion was not given a high rank because more emphasis was given to immediate needs for sufficient crop and livestock production.

Trying to maintain high crop production levels despite the loss of fertile topsoil by erosion has increased the demand for chemical fertilizers. Previously farmers relied more on the use of *ciicata*, but this practice is less applied nowadays. The number of cattle per household has reduced in the area due to shortage of grazing land and more frequent livestock diseases (Bezuayehu and De Graaff, 2006). *Ciicata* is only meaningful when a sufficient number of cattle can be kraaled at night. Typical numbers are 10-20 cattle. Only few farmers have herds of such size and can continue with *ciicata*.

The high concern farmers showed about escalating costs of fertilizer indicates an interesting option for the promotion of erosion reducing measures that prevent nutrient losses. If farmers can be convinced about the stabilizing effects of those measures on crop yields, they may become more interested in adoption of the measures. Implementation of the measures requires high initial investments, but in the long term the SWC measures may reduce the cost for fertilizers, and thus making the land more profitable (Tenge, 2005).

The wealth status of the farmer, land tenure arrangements and degree of access the farmers have to information are the major factors affecting SWC adoption. Wealthy farmers grow cash crops (nitrogen fixers), apply *ciicata*, practice fallowing, plant trees and grow alternating both cash and food crops. These farmers clearly have more options to invest in the farm and their land. Poor farmers are constrained by land security and low livestock numbers. They barely exercise management practices that sustain or enhance the crop production levels. Hence, the practices of the poor farmers may lead to soil mining and threaten the family's future food security. However, the few farmers that had a clear interest in SWC measures were from the group of poor farmers. But they lacked confidence in the positive effects of the recommended measures on their crop yields, and had not started implementing any of the measures.

If farmers are uncertain how long they will be permitted to farm a piece of land they operate, they will have few incentives to invest in practices that only payoff in the long term, such as SWC measures. The fact that tree plantation activities and the traditional soil fertility management activities have been practiced on the government allocated lands but not on sharecropped lands has revealed this situation. Old and female farmers usually sharecrop out some pieces of land due to lack of family labour. Sharecropping is, therefore, one of the methods that have been used to overcome the problems of land shortage among the young and poor farmers, and supports the livelihood of the old and female farmers. But, the practice of sharecropping may lead to natural resource degradation and poor SWC adoption because it has become clear that neither the sharecropper nor the land holder is committed to invest in the sharecropped lands. Hence, only when land holding rights are secured, farmers are more likely to spend family labour as well as finance in SWC. This assertion is similar to results of studies in other parts of Ethiopia (Shiferaw and Holden, 2000; Hagos et al., 2002; Selamyihun, 2004) and other parts of the world (Besley, 1995; Gavian and Fafchamps, 1996; Tiffen, 1996). Given the already high number of landless farmers in the area, who depend on sharecropping and selling labour, the regional government may at some point in time decide to redistribute the land again in the future. This threat discourages most farmers to invest much in their land.

In general the farmers that participated in the surveys had good contacts with the extension services on agricultural inputs (improved seed and fertilizer), but the number of farmers who had contacted the SWC professionals and development agents were extremely low. There are two possible explanations for this: (1) farmers are not convinced about the foreseeable economic benefit of applying SWC, and (2) the past extension methods followed could have discouraged their motivation. Discussions with SWC professionals, development agents and farmers showed that the past SWC extension methods were not participatory in problem analysis, technology selection, design and construction. This may have created aversion by farmers against SWC.

The reasons indicated for not adopting SWC are generally similar to the situations in the central (Shiferaw and Holden, 1998) and eastern (Daba, 2003; Bekele and Drake, 2003) Highlands of Ethiopia and West Usambara Highlands of Tanzania (Tenge et al., 2004). The construction and maintenance of SWC measures generally demand a high labour investment. Old and female farmers in particular are constrained by shortage of family labour, which makes the adoption of SWC more difficult for them. The loss of 10 to 15% of cropland by construction of SWC measures is a severe constraint to farmers in general and small farmers in particular. This loss of productive land makes the implementation of these measures economically unjustifiable at least in the short run. Moreover, some farmers believe that terraces may harbour rodents (moles and rats), which are destroying part of the crops, and the browsing of vegetation established for SWC by the free grazing livestock make farmers reluctant to adopt measures.

For better promotion and adoption of SWC, the focal point of any SWC programme should be betterment of the people and sustenance of the resource base. For farmers what is important is production, and for subsistent farmers it is mainly the production of the current season that guarantees the mere survival of their families (Herweg and Ludi, 1999). SWC, however, unfortunately involves short-term costs, while benefits can only be expected in the long-run (Hurni, 1988), and often shows a negative net present value (Kappel, 1996). In the studied sub-watersheds, poor farmers had a clear interest in SWC adoption but they still needed to get confidence in the positive effects of SWC measures on their crop yields. If soil erosion problems in the sub-watersheds are not controlled, it will affect the livelihood of the present farmers and will have social costs in the long-run. Moreover, increased soil erosion in the entire Fincha'a watershed will affect the national economy due to its off-site effect (sedimentation and pollution) on the hydropower generation.

Based on the results of this study, the following recommendations are given for enhancing SWC adoption in the area:

(1) Introduce land tenure security for plots of land with erosion risk where SWC measures have been implemented and are well maintained. This may stimulate farmers to adopt recommended SWC measures to control the erosion problems on their land and in return get a certificate that guarantees the land holding right in the future.
(2) Introduce incentives, like provision of planting materials, hand tools, fertilizers on credit basis and travel to areas where SWC adoption showed good results. Incentives for SWC implementation may overcome the problem of unforeseeable financial benefits of measures. Also, as erosion is not just a problem to the farmers, society will benefit from better SWC adoption through reduced off-site impacts like reservoir sedimentation.
(3) Keep the SWC costs low by introducing agronomic and biological measures. These measures can have added advantages of increasing soil fertility and crop productivity. But it should be noted that unless biological SWC measures are integrated with mechanical measures their performance will be low on steep slopes and at onset of intensive rainfall (Herweg and Ludi, 1999).
(4) To make spaces occupied by SWC measures productive by establishing grasses and leguminous species. The grasses can be used for animal fodder, while the leguminous plants can be used for soil fertility enhancement, animal fodder and as food for families (e.g. Pigeon pea, *Cajanus cajan*).
(5) Improve extension services and institutional support. While extending SWC technologies the role of professionals should be contribution of arguments and dissemination of

information about the pros and cons of SWC measures, their costs and benefits, and about technical details. The professionals should also stimulate farmer-to-farmer learning processes.

Chapter 6

Integrated watershed management: a planning methodology for new dams in Ethiopia

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Integrated watershed management: a planning methodology for new dams in Ethiopia

Abstract

Integrated watershed management (IWM) is emerging as an alternative to the centrally planned and sectoral approaches during dam planning across the world. This paper reviews the concept of IWM and discusses the major social, environmental and economic problems caused by dams in Ethiopia and elsewhere. The effects of dam creation on land use changes, erosion and sediment yield in Fincha'a watershed, western Ethiopia, were assessed. In Ethiopia, dams are planned top-down, relocate people against their will, cause haphazard land use changes and increase soil erosion and reservoir sedimentation. Communities have not been sufficiently recognized, compensated and environmental protection measures such as land use planning and soil and water conservation (SWC) have not been adopted in watersheds where dams have been implemented. Revenues generated from hydropower and water supplies often benefit urban dwellers or the national economy at the cost of rural inhabitants. Creation of a multi-stakeholders platform, integration of soft system methodologies with hard system tools in the analysis of the effects of land use change, soil erosion, sedimentation and community relocation, and completion of environmental protection measures are some of the major components of an improved planning methodology for new dams in Ethiopia. This means that an environment should be created where science and knowledge help people to develop a diversity of locally appropriate resource management solutions. Effective implementation of environmental policies and strategies may improve the quality of watershed-based developments. The conclusion is that the IWM approach is the most promising alternative for effectively addressing the social, environmental and economic problems during the planning of new dams in Ethiopia.

6.1 Introduction

The watershed has been promoted as a useful unit for integrating conservation and development planning since the early 1980s. Sometimes water management efforts (e.g. construction of dams) have been unsuccessful because they have focussed on water only, rather than on other environmental components such as sediment, air, or biological issue (Heathcote, 1998; WCD, 2000). They have failed to incorporate the full range of values and perspectives present among water users or agencies. Consequently, besides their advantages, construction of dams has caused social, environmental and economic problems (Dixon et al., 1989; De Wet, 1999; WCD, 2000). Although integration at watershed level is increasingly possible, integration at larger scales is conspicuously absent (McDonald and Kay, 1988; Johnson and Baltodano, 2004; Attwater et al., 2005). When small-scale watersheds are considered, the planning tools have commonly focussed on participatory development and livelihood systems. However, when regional watersheds or river basins are considered a mismatch between the existing administrative hierarchies and the physical and societal boundaries could be contestable and could affect stakeholders' participation (Voinov and Costanza, 1999; Attwater et al., 2005). Under such circumstances, appropriate institutions that would allow communication between many administrative entities such as towns, districts and regions are required.

Population density and a limited resource base make integrated watershed management (IWM) essential for sustainable natural resource management. As global concerns about the need for integrated management grows, it may now be social and economic forces, rather than technical considerations, that determine the success of an IWM planning effort (Heathcote, 1998). IWM approaches have, therefore, shifted from an engineering focus, to a rational comprehensive, and more recently to a participatory approach (Attwater et al., 2005). Stakeholders' participation is expected to make IWM more successful and sustainable (Johnson et al., 2001). This is one of the lessons coming out of decades of failures of centrally planned watershed development projects through which local people have been either coerced or paid to participate (Pretty, 1995; Pretty and Ward, 2001).

IWM is a relatively new a practice in Ethiopia. This concept was introduced to Ethiopia by the soil and water conservation (SWC) programme of the country in the 1980s. The aim of this IWM approach was to concentrate the human and financial resources in hydrological units in order to achieve better soil erosion control (Bezuayehu and Sterk, 2006b). Over the years this approach has promoted various SWC measures, restored degraded farmlands, improved soil water holding capacities, increased woodlots, and improved the productivity of pasture lands (Kebede, 1991; WFP, 2002; Betru, 2002; WFP, 2004). On the other hand, construction of dam projects were planned and implemented without recognizing people as partners and caused community relocation against their will (Dessalegn, 1999). Most dams were planned as a single purpose project by the public power or water supply utility (Michael, 2004), and options assessment has been typically limited in scope and confined primarily to technical cost-benefit analysis (Yonas, 1997). Integration of dam construction with land use change and SWC are seldom practiced in Ethiopia. As a result, sedimentation and the consequent long-term loss of storage of dams is a serious concern (MoWR, 1997; Sileshi, 2001; Michael, 2004).

In order to meet its food security, electrification and water supply objectives, the Ethiopian Government envisages construction of new dams, implementation of SWC, *in situ* water harvesting and reforestation. To achieve these objectives the government has formed various organizations, which have different duties and responsibilities and endorsed various policies and acts. To make the implementation of these policies and acts more effective, it is necessary to better understand the factors that influence the adoption of IWM. The existing studies on planning and implementation of IWM are scanty in Ethiopia. The objective of this paper is, therefore, to develop an IWM planning methodology for new dams in Ethiopia. The concepts of IWM will be clarified, the major problems caused by dams in Ethiopia and elsewhere will be reviewed and relevant remarks for planning new dams will be made.

6.2 Integrated watershed management

Although a strategy that is increasingly advocated in the literature, IWM is still a relatively new concept (Heathcote, 1998). Therefore it is important to clarify this concept. In this paper a watershed is defined as the drainage basin: an area of land within which all waters flow to a single river system. Today there is a clear global consensus that the watershed is an appropriate unit for water and natural resources management (Goodman and Edwards, 1992; Heathcote, 1998; Lixian, 2002). Watersheds have been promoted as useful integrating units for land use planning, SWC and linking upstream and downstream effects. It is also useful for considering the temporal and spatial social organizational structures which overlap the landscape patterns in an open and complex way (Attwater et al., 2005). Watershed management is, therefore, the protection, improvement and rational use of water, land and other renewable natural resources in a watershed, in order to reach the optimal goals of ecological, economic and social benefits (Lixian, 2002). The watershed based planning has the advantage that the watershed is the natural geomorphological unit for water erosion, in which risks at any point can be understood in relation to its topographic position and the effects this has on local hydrology and sediment production (Morgan, 2005). Therefore, both on-site and off-site effects of erosion can be appreciated within a watershed.

IWM involves a comprehensive multi-resource management planning process, in which all stakeholders within the watershed jointly negotiate how they will define their interests, set priorities, evaluate alternatives, and implement and monitor outcomes (Heathcote, 1998; Johnson et al., 2001; Sims, 2001). The IWM planning process strives to understand the needs and impacts of stakeholders on the natural functions of a watershed and provides a blueprint for making decisions regarding resource management and sustainable development. Community developed IWM plans are often most effective (Sharma, 1997; Heathcote, 1998). Participation in IWM becomes high when the direct and visible benefits of the programme are in congruence with the interest of the people or community.

There are generally two schools of thought on inducing stakeholders' participation: incentive proponents and opponents. The incentive proponents such as the 'Green Water Credits' argue that the downstream users of water should pay the upstream 'producers' (Dent, 2005). The rationale for this idea is that the upstream producers are generally poor to invest in SWC and benefit accrues mostly on long-run. SWC techniques increase the supply of clean water and reduce sedimentation. Consequently, compared to the often limited and retarded onsite economic benefits, the offsite economic benefits will be huge and immediate for the downstream users (e.g. hydropower companies, water supply utilities and breweries). Therefore credits should be transferred from downstream beneficiaries to the upstream managers of land and water resources. The opponents of provision of direct incentives argue that payment for the construction of SWC practices makes farmers think that they are unable to implement these practices without external help (Bunch, 1999; Sanders and Cahill, 1999). Another argument is that developing countries have severe financial constraints to pay incentives. In a situation where a direct incentive is paid the farmer is not motivated to experiment with and adapt the practices to his own circumstances. Programmes also use incentives to achieve quick results, without paying much time- and energy-consuming attention to sustainable effects of a programme. This latter school underlines that a well-designed and executed education and extension campaign should suffice to convince most farmers to join such a programme.

6.3 Problems caused by dam construction

Dams as a means for storing water for electricity, irrigation, domestic water supply and flood control have been constructed for more than a century (WCD, 2000; Bird and Wallace, 2001). At the start of the 21st century, one-third of the countries in the world rely on hydropower for more than half their electricity supply (dams generate 19% of electricity overall) and some 30-40% of the 271 million hectares irrigated worldwide rely on dams (WCD, 2000). Dams may create income from export earnings from direct sales of, for instance electricity or by selling cash crops or processed products from electricity. The ever-increasing population and a higher standard of living require the construction of new dams and maintenance of the existing dams (Dixon et al., 1989; Van Duivendijk, 1995). In spite of the substantial benefits derived from dams there are social, environmental and economic and integration problems caused by dam construction. These problems are discussed in the following sub sections.

6.3.1 Social problems

Dams often cause involuntary resettlement of people and the disruption of their productive systems and lifestyles, inequity in sharing of costs and benefits (De Wet, 1999; WCD, 2000), and affect the livelihood of the host population (Dixon et al., 1989). Problems such as low amounts of compensation, delays of payment and lack of participation in the resettlement process cause dissatisfaction and hence affect the sustainability of the projects (Rooder, 1994; De Wet, 1999; Fujikura et al., 2003). The construction of the Kariba dam in the late 1950s, for instance, had flooded 4,000 km^2 of prime agricultural land and relocated about 50,000 people, disrupting their cultural systems and traditions (WCD 2000). The construction of the world's largest dam (the Three Gorges Dam) in China may displace up to 1.9 million people, adding to an enormous global population uprooted by this human effort to harness nature (Sims, 2001). Among affected communities, gender gaps have widened and women have frequently borne a disproportionate share of the social costs and were often discriminated against sharing of the benefits (WCD, 2000). Today, community displacement has emerged as a political issue in some countries (e.g. India) but not yet sufficiently in other countries (e.g. China) (Sims, 2001). In India, the combined efforts of displaced people, middle-class activists and a free press and judiciary increased awareness about the social effects of dams (Sims, 2001).

Along a dam project cycle, the World Commission on Dams (WCD) identifies five key stages in the decision-making process (WCD, 2000): (1) need assessment, (2) selection of alternatives, (3) project preparation, (4) project implementation, and (5) project operation. Decisions in the first two stages are related to the planning phase before the project and made at country and often political level (Fujikura et al., 2003). On the other hand, a relevant government department and/or dam developer will make decisions at the latter three stages. This means that the possibility for the watershed community to participate in all five key decision stages is low. The lack of community participation on their own affaires will have negative consequence on the effective implementation of dam projects.

6.3.2 Environmental problems

Watershed services can be considered as the subset of environmental services concerned with the impact of land use change on hydrological function (Johnson and Baltodano, 2004). This include water quality functions such as sedimentation and contamination as well as water quantity functions relating to annual water yield, seasonal flow, or ground water levels. Hence, the physical environmental effects of dams comprise changes in water quantity and quality, degradation of the upstream part of the watershed and sedimentation (Dixon et al., 1989; Terry, 1995). The loss of forests, wildlife habitat, species populations (biodiversity) and emitting greenhouse gases (due to rotten vegetation) are other forms of environmental effects of dams. Irrigation dams could result in the spread of diseases (e.g. malaria, bilharzias) through the increase of their vectors and create physical problems such as declining soil fertility and soil quality arising from water logging, salinisation and hardpan formation (Terry, 1995; WCD, 2000). In order to reduce the environmental impacts of large dams, the WCD recommends that alternatives to large dams (e.g. small dams and coal-fired thermal power plant) should also be considered. On the other hand, Fujikura and Nakayama (2002) argue that such alternative development projects (including smaller dams as an alternative to large dams) cannot be exempted from environmental scrutiny. Moreover a coal-fired thermal power plant (an alternative to multi-purpose dams) would increase various other environmental risks such as air pollution and acid rain, and does not function in flood control or drought prevention. Compared with nuclear power plants, hydropower plants generate no hazardous wastes (Bratrich et al., 2004). Thus any alternative options to dams should also be examined on the same grounds as dams.

6.3.2 Economic problems

In their cross-check survey, the WCD showed that the degree to which dams have delivered services and net benefits as planned varied substantially from one project to the other, with a considerable portion of dams falling short of physical and economic targets (Clarke, 2000). For instance, most dams designed to deliver irrigation services did not recover their costs and have been less profitable than expected. Irrigation dams fell short of targets in terms of development of command area (and infrastructure), area actually irrigated, and to a lesser extent the intensity with which areas are actually irrigated. With respect to the achievement of command area targets, the WCD cross-check survey demonstrated a general pattern of underachievement, with almost half of the 52 dams in the sub-sample falling short of the planned targets. Under-performance is most noticeable during the earlier periods of project life, as the average achievement of irrigated area targets compared with what was planned for each period increased over time from around 70% in year 5 to approximately 100% by year 30 (Figure 6.1). This slow rate of development contrasts with the 5 to 10-year horizon often used in project planning. Institutional failures that include over centralized systems of administration, divided management responsibility, and inadequate allocation of financing for tertiary level development were often the primary causes of under-achievement. Technical issues include delays in construction, inadequate surveys, poor drainage and high salinity and over-optimistic projections of cropping patterns, yields and irrigation efficiencies.

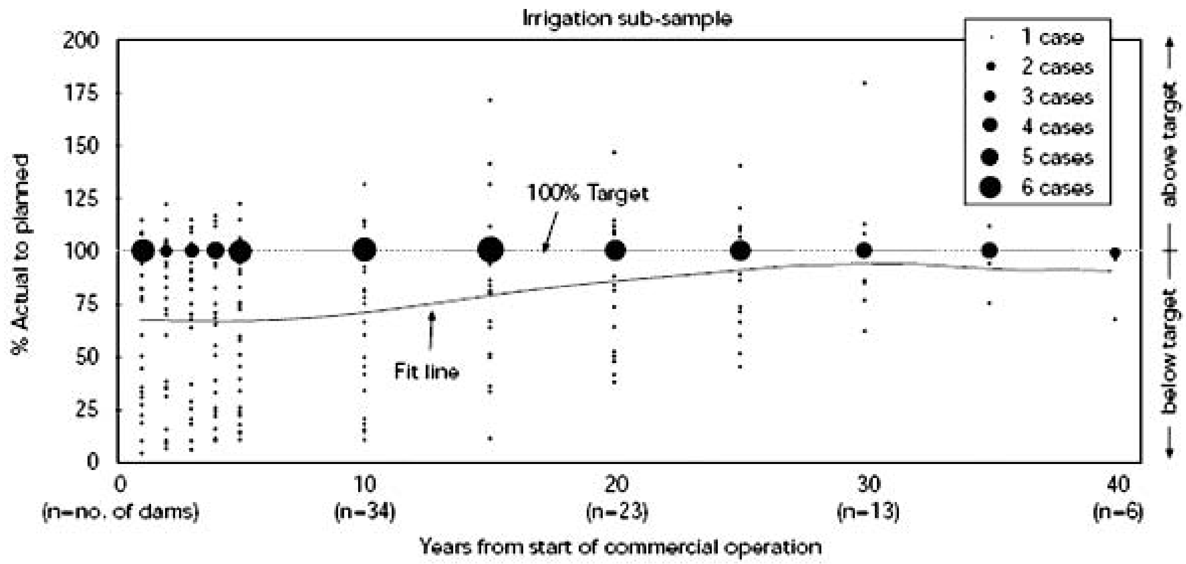

Figure 6.1. Actual irrigated area compared to planned targets over time. *Source:* WCD (2000).

In contrast to irrigation, the hydropower performance of 63 large dams in the WCD cross-check survey was on average closer to target but with considerable variability, much of it on the downside (Figure 6.2). Delivery of services and benefits were examined by assessing performance to targets for installed capacity and delivery of power. Hence a number of projects have far exceeded their technical, financial and economic targets, whereas others have fallen short. On average, almost half of the sample exceeded the set targets for power generation, with about 15% significantly exceeding targets. Thus average performance in the sample is sustained by a few over-performers and should not mask the variance in performance that is weighted towards shortfalls in power delivery. The higher-than-expected output in hydropower generation from almost half of the large dam projects in the cross-check survey is due to the addition of extra installed capacities prior to and since commissioning.

6.3.4 Lack of an integrated approach

As a development choice, large dams often become a focal point for the interests of politicians, centralized government agencies, international financing agencies and the dam-building industry (Van Duivendijk, 1995; WCD, 2000). When such decisions are taken an integrated approach to watershed development is often neglected and instead a sectoral or local approach is followed. The sectoral approach is not concerned about water mobility and user diversity. It puts greater emphasis on local-level water resource utilization. However a dam built at one point across a river course may affect the interests of domestic water users, farmers, livestock herders and fishermen downstream.

When a natural landscape is transferred into a cultural landscape (e.g. land use change) the watershed water balance is affected by increased surface runoff and evaporation, and reduced soil infiltration and groundwater recharge (Stroosnijder, 2003). High sediment loads delivered from watershed erosion are a major source of environmental problems throughout the world and has become a major issue in environmental policies of many countries (Verstraeten et al., 2003). Dams constructed may not meet their planned objectives unless the factors of soil erosion and reservoirs sedimentation are effectively addressed. Hence dam planning and water resource issues need to be seen from a wider perspective both in terms of space and livelihood.

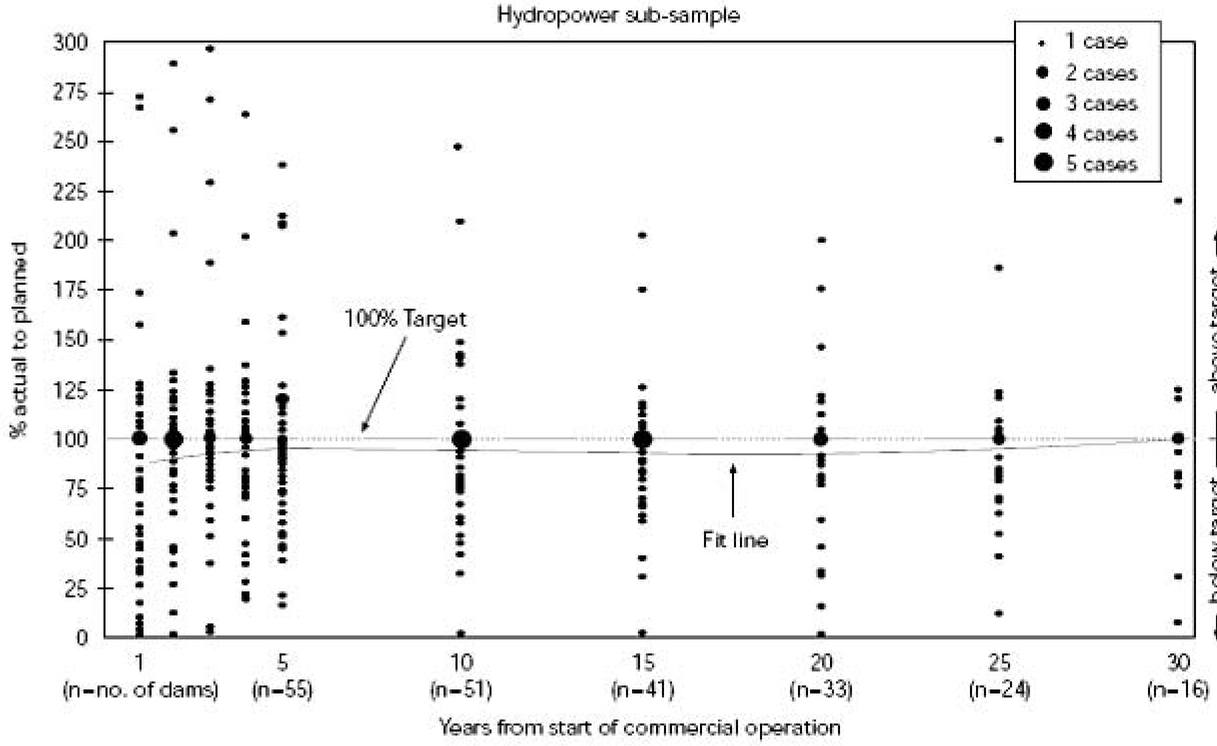

Figure 6.2. Actual versus planned hydropower generation over time. *Source:* WCD (2000).

In developing countries foreign assistance has accounted for about 15% of total funding in dam projects (WCD, 2000). The interest of the donors, therefore, could conflict with the interest of the fund receiving countries as well as the people residing in the watershed. In trans-boundary river basins, the lack of agreements on water use can create problem of integration, particularly as demands grow and decisions to build dams by one country alter water flows within the basin.

6.4 Ethiopian experience

Ethiopia owns abundant water resources but their utilization is low. Out of the hydroelectric potential of 30,000 MW only about 1% is being exploited (MoME, 1997). Out of the irrigation potential of 3.6 million hectares 5.5% is developed (Gedion, 2003). Only 31% of the total population has access to clean water while the rural water supply coverage is less than 23% (Gedion, 2003). There are nine medium and large dams, with a total capacity of about 3.5 km^3 (FAO, 2005). The major problems caused by water development projects in the country are: social, environmental, economical and lack of an integrated planning approach. These problems are discussed in the following sub sections.

6.4.1 Social problems

The failure to recognize people as partners in the planning process is a major characteristic of dam construction in Ethiopia (Dessalegn, 1999). Consequently the construction of dams has caused community relocation against their will. Examples are the Gilgel-Gibe hydropower dam that has relocated about 10,000 people (WRDA, 1994), and the Dirre dam water supply project that has evicted 765 people against their interest (WRDA, 1995). The evicted communities received limited monetary and land-by-land compensations. Since monetary compensation is not supporting the livelihood of rural households on a sustainable basis, it was not the preferred compensation option for those responsible for the construction of dams (WRDA, 1995). The land-by-land compensation was implemented through land redistribution in neighbouring areas and it has reduced the holding sizes of the communities that were living in the areas that were not directly affected by the created reservoirs.

The Fincha'a hydropower reservoir in western Ethiopia has caused major land use changes by inundating 100 km^2 grazing land, 120 km^2 swamp, 18 km^2 cropland and 1.2 km^2 forestland (Bezuayehu and Sterk, 2006a) and has relocated approximately 3100 families against their will (Bezuayehu and de Graaff, 2006). Those people who have been using the inundated parts of the watershed were forced to migrate from their villages and self-resettled in steep and fragile parts of this watershed. As more and more people seek to make a living in this watershed, they expand their cropland into forests and steep hillsides, farm their land in erosive ways and fail to replenish the soil nutrients that have been removed. The construction of the dam was decided by the central government and implemented without the participation of the inhabitants in 1973. A limited amount of monetary compensation was paid to a few landlords but nothing was paid to the majority of the tenants. Animals from the community have drowned in the reservoir and others are exposed to waterborne diseases. The rural people in the watershed do not benefit from the electricity generated. In spite of these the dam generate about 128 MW electric power, supply irrigation water for a sugar factory downstream and introduced fishery to the area.

In general communities in Ethiopia have been blamed for not taking an active part in irrigation development projects. This is attributed to a lack of technical expertise to run such projects and lack of ownership feeling. Community participation for effective utilization and management of irrigation schemes were reduced by lack of incorporating the traditional irrigation systems into the design and construction of improved irrigation schemes (Dessalegn, 1999). In stead, some of the traditional irrigation schemes were taken over and upgraded by the government without the consent of the communities and given to the producer co-operatives during 1980s. Those farmers who were unwilling to join the producers' co-operatives were denied access to water and relocated to elsewhere.

6.4.2 Environmental problems

In this section environmental problems caused by some dams will be explained based on case studies from different dam sites in Ethiopia. IWM to reduce soil erosion and reservoir sedimentation have been seldom practiced in Ethiopia. Failure to do this has increased soil erosion and reduced ground water recharge and base flows of rivers. Moreover, farming is practiced directly along water reservoirs increasing the connectivity of gullies and streams to the water reservoir. As a result, sedimentation and the consequent long-term loss of storage of dams is a serious concern in Ethiopia (MoWR, 1997; Sileshi, 2001; Michael, 2004). Four costly irrigation dams that were constructed in the 1980s had to be abandoned due to sedimentation (MoWR, 1997; Dessalegn, 1999). Examples are the Gode irrigation project (eastern Ethiopia) and Borkana dam (north-eastern Ethiopia). The Koka hydropower dam has lost more than 30% of its live storage capacity due to sedimentation (Michael, 2004).

In 1980s, thousands of hectares of irrigated land in the middle Awash had to be abandoned due to salinisation and waterlogging after less than five years of irrigation farming (Mahmud, 1997). Moreover, there is a growing concern about the use of water in the Awash basin because of the conflict between the environment and agriculture. Particularly in lowland rural areas, total base flows are diverted for irrigation without releasing water for ecological conservation (FAO, 2005) and indigenous communities.

The Alwero dam was constructed in 1997 to irrigate 10,000 ha of cotton fields for resettles in the Gambella region, western Ethiopia. However the irrigation scheme was not effective because during the rainy season it floods settlement sites and during the dry season the reservoir level drops and insufficient water reaches the fields (Woube, 1999). Moreover the dam has interfered with fish migration and the reservoir has become a breeding site for malaria mosquitoes. The increase in deforestation rates due to the influx of people from the drought stricken northern parts of Ethiopia has become the major cause for increased flood incidences in the downstream parts of the watershed (Woube, 1999). Before the dam the indigenous people were using the fine silts transported by the Alwero River to improve soil texture and to increase soil moisture.

Bezuayehu et al. (2006) have modelled the spatial erosion dynamics in Hadocha sub-watershed (1155 ha) of Fincha'a watershed. Predicted erosion maps are shown in Figure 6.3. The predicted erosion values were classified into five classes: no erosion ($E \leq 0.1$ kg m^{-2} yr^{-1}), low erosion ($0.1< E \leq 1$ kg m^{-2} yr^{-1}), moderate erosion ($1< E \leq 5$ kg m^{-2} yr^{-1}), high erosion ($5< E \leq 10$ kg m^{-2} yr^{-1}), and very high erosion ($E >10$ kg m^{-2} yr^{-1}). The calculated mean annual soil loss from cropland, for example, has increased from 4.6 kg m^{-2} yr^{-1}in 1957, to 4.8 kg m^{-2} yr^{-1} in 1980 and 5.5 kg m^{-2} yr^{-1} in 2001. This is mainly because of the conversion of natural vegetation into cropland. Poor vegetation cover on cropland provides insufficient protection from rainfall and runoff detachment. The predicted mean erosion rates are higher than the estimated national average of 4.2 kg m^{-2} yr^{-1} (Hurni, 1993), 1.8 to 7.9 kg m^{-2} yr^{-1} in Chemoga watershed, north-western Ethiopia (Woldeamlak and Sterk, 2003) and 1.1 kg m^{-2} yr^{-1} in Kwalei watershed, northeast Tanzania (Vigiak et al., 2005). These erosion rates also exceed the rates of soil formation in Ethiopian Highlands which were estimated at 0.2 to 2.2 kg m^{-2} yr^{-1} (Hurni, 1983).

The amount of sediment detached and that actually leave the sub-watershed have increased between 1957 and 2001 (Table 6.1). The sediment delivery ratio (SDR) has increased from 0.18 in 1957 to 0.20 in 1980 and 0.40 in 2001. Compared to the year 1957, SDR in 2001 has increased by 120% due to major land use changes that occurred across the sub-watershed mainly due to dam construction. Since there has been no buffer strip established between the reservoir and croplands the mobilized sediment load can easily find its way into the reservoir and could reduce the reservoir lifetime and increase the level of water pollution. Field observations showed deposition of high sediment loads at the point where the streams and water reservoir meet. Relatively coarser sediment loads have been deposited before reaching the reservoir where sudden slope changes occurred. Fine particles did probably directly enter into the water reservoir reducing the water storage capacity of the dam. A holistic long-term approach to minimizing the amount of sediments entering a reservoir is to reduce soil erosion in the watershed upstream through SWC (Saavedra, 2005). However, SWC is lacking in the Hadocha sub-watershed as it is in the entire Fincha'a watershed.

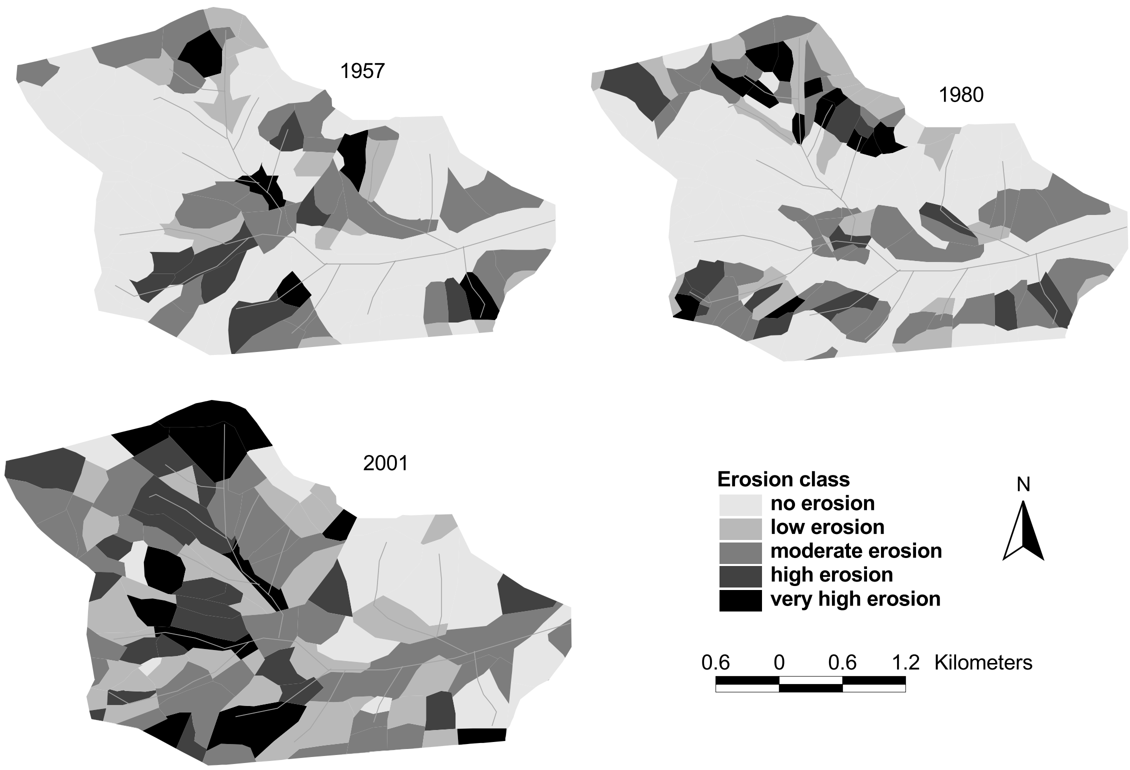

Figure 6.3. Erosion maps of Hadocha sub-watershed in 1957, 1980 and 2001, Fincha'a watershed, western Ethiopia.

Table 6.1. Sediment delivery ratios (SDR) predicted in Hadocha sub-watershed in 1957, 1980 and 2001, Fincha'a watershed, western Ethiopia.

Year	Sediment detached (Mg)	Soil loss (Mg)	SDR
2001	46606	18398	0.40
1980	42025	8344	0.20
1957	39120	7421	0.18

6.4.3 Economic problems

The Water Policy Act of Ethiopia recognizes water as an economic good for its substantive and significant contribution to the country's economy. However, lack of finance, uneven spatial and temporal distribution of water resources, and the trans-boundary nature of the major rivers have been some of the major factors for the insufficient utilization of water resources (Dessalegn, 1999; Gedion, 2003). In order to reduce financial constraints for irrigation development the central government has recently introduced cost recovery or cost sharing mechanisms. An example is the 15-year water sector development programme of Ethiopia that was presented in 2002. The programme envisaged cost sharing mechanisms for small-scale irrigation scheme development. Beneficiary farmers have to pay 20% of the total cost. The remaining costs were planned to be covered by the central government, donors, NGOs and private investors. Obviously, there is a long way to go to establish cost-sharing systems, because most beneficiaries have never contributed for operation and maintenance of the existing irrigation schemes, let alone for the construction of new ones.

Sharing water resources of trans-boundary rivers is very challenging, particularly the Nile tributaries with the downstream riparian countries Sudan and Egypt (Gedion, 2003; FAO, 2005). Recently, due to international law, which supports equitable utilization of the water resources, positive progress has been observed in that riparian countries are deciding on common water development programmes. The Nile Basin Initiative has been created in 1999. Projects are selected by individual riparian countries for implementation and submitted to the Council of Ministers of the Nile Basin Initiative for approval. The council has already accepted four hydropower and four irrigation development projects proposed by Ethiopia. Before this initiative, requests for funding IWM initiatives were not successful. Probably due to the fear that donors have on the possible negative impact of such initiatives on the neighbouring riparian countries.

6.4.4 Lack of an integrated planning approach

The development of water resources for irrigation, power sources and domestic supply was initiated in the 1950s in the Awash River basin. Aims were to develop agro-industrial enterprises, electricity generation and water supply (Dessalegn, 1999). The schemes were initiated by a Dutch company known as H.V.A. and managed by state or para-statatal enterprises. In the second half of the 1980s, as a result of the 1984 famine, however, many small-scale water management schemes were initiated in other parts of the country. Most large dam projects were planned and implemented as a single purpose project by the public power or water supply utility, which has reduced the economic viability of the dams (Michael, 2004). Options assessment has been typically limited in scope and confined primarily to technical cost-benefit analysis (Yonas, 1997). For example, the irrigation water requirement of the middle and lower Awash Valley was not considered during the planning phase of the Koka hydropower dam (Michael, 2004). Thus, the amount of water released from the Koka reservoir has been determined by the energy requirements. This has affected crop production and the economic viability of the lower Awash Valley agricultural farms (Michael, 2004). If the dam were designed for a multipurpose use, there would have been a cost sharing opportunity between irrigation development and power generation, which could have made both projects more viable.

6.5 A planning methodology for new dams in Ethiopia

Since quite a number of new dams are likely to be constructed in Ethiopia, certain changes need to be incorporated in the light of experience gained with existing dams. Hence we present some of the policy and technical issues that can be of paramount importance for the successful planning of new dams in Ethiopia.

6.5.1 Multi-stakeholders platform: a planning tool for integrated watershed management
In case of dam development, stakeholders are defined as individuals, organizations, public sector agencies and donors that are concerned with water resources and have interest in their developments (Le Moigne et al., 1994). It should be noted that the IWM approach assumes the management of the entire watershed or river basin, so also land is considered apart from the water resources. IWM, therefore, should address the interests of both the upstream and downstream communities. Since public goals by their nature are trans-disciplinary, the use of multi-disciplinary teams should be employed whereby each member contributes its professional perspective to the problem at hand. Major public institutions involved in water resources development in Ethiopia are:

1) The Environmental Protection Authority (EPA): The first environmental policy of Ethiopia was prepared by the EPA and endorsed in 1997 (FDRE, 1997). According to this policy all major water development and management projects are subjected to environmental impact assessment (EIA) processes. Moreover, while developing water projects, communities residing in the project area should be involved in the planning, design and implementation.
2) Ministry of Water Resources (MoWR): A comprehensive and integrated water resources management policy, prepared by MoWR, has been adopted in 2000 (FDRE, 2000). According to this policy the MoWR is responsible for the overall planning, development, management, utilization and protection of the country's water resources, as well as for supervising all water development activities carried out by other institutions. An EIA shall be an integral part of any watershed-based management project. Moreover, community participation will be the basis for any water management project.
3) Ministry of Agriculture and Rural Development is in charge of water management (irrigation extension), including water harvesting for smallholder irrigated and rainfed agriculture (FAO, 2005). The ministry, together with the U.N. World Food Programme have been promoting community-based IWM in Ethiopia. A detailed IWM guideline was prepared in 2005 and dispatched to the regional states.
4) Ethiopian Electric Power Corporation is responsible for providing an integrated and universal electrification scheme to meet the socio-economic developmental needs respecting the EPA rules. In 2004, the company has prepared an environmental guideline

for the hydropower sector in the country. This guideline indicates that any foreseeable hydropower project will be executed on the basis of the EIA guideline of the country.

5) Regional administrations are responsible for the implementation of the plans, policies and strategies developed at national revel within their jurisdiction. There are also a number of public sector agencies such as the NGOs that are concerned with water resources issues and activities.

Forming different state organizations that are responsible for planning, development and monitoring water resources and formulation of environmental policies is a major step foreward in Ethiopia. Effective implementation of these policies and strategies may improve the quality of future watershed based developments. For IWM to be effective, however, writing good policy statements alone is not sufficient. Policies need to be geared towards involving stakeholders (especially the watershed inhabitants) in the planning and management of watershed or water projects on the one hand, and on the other hand in the formulation of the rules and responsibilities governing the operation of such projects. When IWM programmes are initiated rural communities may not know their rights, duties and responsibilities. Therefore, they should get access to the policies and guidelines pertinent to IWM. A participatory decision making procedure does not require only gathering information and opinions from the stakeholders but should make them act as they were decision makers, who have to negotiate the final decision (Castelletti and Soncini-Sessa, 2005).

New developments in the field of operational research and management science have led for a number of new methodologies such as soft systems methodologies for dealing with unstructured watershed development situations (Bergvall-Kåreborn, 2002). These methods can assist in the development of hydro-informatic and decision support systems by aiding the analysis of organizational activities and information flows and by facilitating the communication between stakeholders (Amezaga and O'Connell, 1998). According to the soft systems methodology people in general want to solve their problems. In order to do this some kind of consensus or accommodation between stakeholders needs to be achieved. Furthermore, it is assumed that many problems and conflicting situations involve disagreements related to needs, objectives and measures of performance, and have their base in either misunderstandings or differences in interest or culture (Bergvall-Kåreborn, 2002). These misunderstandings and differences are usually due to lack of understanding or information. Either way, by understanding each other and these differences, it is possible to better solve, or at least improve many problematic situations. Hence, in the process of forging partnership between the government, dam builders and community to plan IWM bringing stakeholders to a common platform should be emphasised. Such platforms can discuss or negotiate on public policy, planning, implementation, monitoring and evaluation of the management initiatives based on say the soft system management approach.

6.5.2 Hard system tools for integrated watershed management

Technological tools such as Geographical Information System (GIS), which can operate within, or link with a 'soft systems' framework, for assisting with the development and implementation of IWM are now being developed. This means creating an environment where science and knowledge help people to develop a diversity of locally appropriate resource management solutions is essential (Sayer and Campbell, 2004). Understanding the effects of land use change due to dam construction on agriculture, soil erosion and sedimentation are some of the knowledge bases required to apply during planning IWM or planning new dams.

Erosion prediction models such as the revised MMF (Morgan, 2005) can be used to integrate remotely sensed data, topographic maps, satellite imagery, soils and climatic data in a GIS environment for predicting spatial erosion rates and sediment yields. These prediction results can be used for planning SWC measures or applying scenario analysis. The hard system tools have recently been applied in Fincha'a watershed to analyse the effect of dam construction on land use change, soil erosion and sediment yield (Bezuayehu and Sterk, 2006a; Bezuayehu et al., 2006). The results of these analyses showed that Fincha'a dam has caused major land use changes, which in turn have increased soil erosion rates, and sediment yields across the watershed. During this study, it has been learned that IWM should give emphasis to environmental sustainability because agriculture leads to the removal of biomass and nutrients, which are not or only partially returned (Smaling, 2005).

Environmental sustainability is also one of the U.N. Millennium Development Goals. IWM can increase offsite benefits including improved water quantity and quality, flood abatement and increasing river base flows that contribute to the sustainability of a dam project. This requires implementation of practices that increase water infiltration in the upstream parts of watersheds. Increasing the overall water use efficiency and biomass productivity at watershed-scale through institutional and technological change can be a critical first step in achieving more sustainable and poverty reduction development (Stroosnijder, 2003; Pender, 2004). These techniques have not been applied widely yet in Ethiopia because either there is no incentive (in terms of immediate reward or secure tenure) or there is lack of knowledge or resources.

6.5.3 Economic considerations

The notion of costs versus benefits has been a concern for public sector agencies in Ethiopia. Some of the concerns are: What criteria should be used to evaluate water development schemes? What should be the justification for promoting such schemes? The conventional approach of evaluation of water development schemes relies on economic arguments (Yonas, 1997). Dessalegn (1999), however, argues that greater weight should be given to social benefits as compared to economic benefits. For example in areas that are exposed to drought, where loss of life from food shortages is high, the evaluation of economic efficiency of irrigation schemes makes little sense. Under this situation, dam development projects should be judged successful if they promote food security, contribute to poverty alleviation and increase employment opportunities (Pender, 2004; Ruben and Pender, 2004). Implementation of IWM requires quite a large amount of finance. The sources of this finance can be the downstream users (electric company, water supply, breweries and eco-tourism) and local and international funding agencies.

Besides, huge public resources have been spent on existing dams in Ethiopia and many of them have not completed their economic life. Even after dams built for hydropower generation have completed their economic life and are abandoned there is a possibility to utilize them for fishery and irrigation (Michael, 2004). Opportunities exit to optimise benefits from many existing dams and this make the revisiting of the existing dams worthwhile. In Ethiopia, however focus is always given to the construction of new dams and little emphasis is given to the existing dams. The environmental and water policies of the country also give emphasis to the construction of new dams. This shows that there is still lack of understanding that dams, their use and the context they operate are dynamic.

6.5.4 Social issues

The WCD indicated that the social risks caused by dam development should be judged against the international framework of norms articulated in the UN Declaration of Human Rights in 1948. This provides an effective framework for integrating the economic, social and environmental dimensions of new dam constructions. For Ethiopia, this requires identifying stakeholders that should be entitled to participate in the formal consultative process. These stakeholders will participate during the eventual negotiation of the project specific agreements relating to resettlement or compensation, and benefit sharing. It is imperative that the community getting displaced from any dam project should form a partner in the dam venture, not only during construction but also throughout the life of the dam and its operation. They should have a share of the benefits from the project in terms of land or other permanent assets as well as annual financial returns from the project (e.g. revenue from power or water). Part of the benefits from a dam project should be used as a financial source for resettling people and compensating lost assets.

The execution and management of such IWM should not be done by government departments but by a corporation with representatives of various disciplines like dam builders, environmental specialists, representatives of the displaced and the beneficiaries. Such a set up should be made before starting the project. The government can plan and regulate such dam ventures and monitor their operation subsequently.

6.6 Conclusions

In Ethiopia, dams are planned top-down, relocate people against their will, cause haphazard land use changes and cause increased soil erosion and reservoir sedimentation. Communities have not been sufficiently recognized and compensated and environmental protection measures such as land use planning and SWC have not been adopted in watersheds where dams have been implemented. Revenues generated from hydropower and water supply dams often benefit urban dwellers or the national economy at the costs of rural inhabitants.

The creation of different state organizations responsible for planning, development and monitoring water resources and formulation of environmental policies is a major step foreward in Ethiopia. Effective implementation of these policies and strategies may improve the quality of future watershed based developments. However the question of how participation and integration are to be promoted in their implementation has not been adequately addressed. Since public goals by their nature are trans-disciplinary the use of multi-disciplinary teams should be employed whereby each member contributes its professional perspective to the problem at hand. In the process of forging partnership between the government, dam builders and community to plan new dams bringing stakeholders to a common platform is essential. The breakdown of traditional institutions and practices as a result of population pressure, dam construction and government policies in many parts of Ethiopia are causing natural resources degradation, food insecurity and leading to increased conflict. Thus a multi-stakeholders' platform that addresses these problems is vital. The platform should effectively interact on public policies, planning, implementation, monitoring, evaluation and conflict resolution.

Ethiopia needs to increase its construction of new dams to improve food security, water supply, electricity, and local employment and skills development. In too many cases in the past, an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms, by people displaced, by communities downstream and by the natural environment. The intensifying controversy surrounding dams is not about the technical designs themselves, but their social and environmental consequences and the decision-making processes that led to their construction. Therefore, full consideration has to be given whether or not a dam project is socially, environmentally and economically justified before implementation. The IWM approach, as it has evolved on recent years, should be employed to harmonize these comprehensive objectives.

The construction of new dams should proceed only after satisfactory recognition and compensation of the affected population and completion of environmental protection measures. Watershed soil erosion and reservoir sedimentation is the major environmental problem that reduces the functions of several dams in Ethiopia. The problem has been caused by the failure to include SWC during dam planning. For effective implementation of soil conservation and sediment control measures reliable information of the spatial variability in soil erosion and sediment production within the watershed is required. These spatial erosion and sediment yield information could be obtained by using hard system tools like GIS and erosion modelling such as the revised MMF model. This information will also help to reduce the risks of unnecessarily spreading the finances equally over the whole watershed and scenario analysis. In general creation of multi-stakeholders platforms and integration of soft system methodology and hard system tools (in the analysis of the effects of land use change, soil erosion, sedimentation and community relocation) and completion of environmental protection measures are some of the major planning methodologies to be followed during planning new dams in Ethiopia.

Implementation of IWM plans requires adequate funds. In cash-strapped developing countries like Ethiopia, however, funding IWM can be either difficult or the amount of funds allocated can be small compared to the amount of work to be done. In order to reduce funding problems the concept of payment for ecological services generated by specific land uses within watershed (Tognetti, 2000; Dent, 2005) should be introduced as key element of watershed intervention. Policies that aim at compensating land users for the environmental services they generate or charging them for the services they receive will increase both ecosystem function and overall social welfare (Johnson and Baltodano, 2004). This approach will generate resources from downstream users such as electric company, water supply and breweries that would support development interventions in the upstream parts of watersheds.

Chapter 7

Synthesis

Synthesis

7.1 Introduction

Very few accounts of participatory approaches to multi-sectoral and multi-objective programmes such as integrated watershed management (IWM) have been available or documented, particularly for mountainous watersheds. This is because they are very complex schemes, often dealing with conflicting objectives such as development and environment, maximisation of economic benefits and conservation of resources, and market economy and food security. The major impetus for this study, therefore, stemmed from the understanding that science needs to be linked to planning, and that decision-making should be based on stakeholder involvement. Fincha'a watershed was chosen for fieldwork because it is typical of the Highlands of western Ethiopia and there is a multipurpose dam in the watershed. In this chapter, the results of the previous chapters are brought together in the form of synthesis in order to address the research questions of this thesis. It will be recalled that there were five such questions:

1) How did the construction of the dam and the subsequent increase in the lake size affect land use changes in Fincha'a watershed?
2) What were the social and economic consequences of the creation of the dam for the people living in Fincha'a watershed?
3) If erosion is a problem, what was its magnitude before and after dam construction, and what have been the subsequent on-site and off-site effects?
4) What are the factors affecting the adoption of soil and water conservation?
5) Could an IWM methodology be developed and applied for planning new dams in Ethiopia and elsewhere?

This chapter has been divided into two sections. Section 7.2 will answer the research questions raised, and Section 7.3 presents the major institutional and policy implications of this thesis.

7.2 Integrated watershed management

Fincha'a dam is a multi-purpose dam that was completed in 1973 for electric power generation, irrigation, and fishery. The dam has caused major land use changes in the watershed (Chapter 2) and led to some 3100 households being displaced from their villages against their will (Chapter 3). The relocated rural population has resettled in steep and fragile parts of the watershed because no formal resettlement arrangements were made for them, nor were they paid appropriate compensation. The reservoir has inundated about 100 km^2 of grazing land, 120 km^2 swamp, 18 km^2 cropland and 1.2 km^2 forest. Elderly farmers described these parts of the watershed as very productive in terms of grass and crop production.

The major drivers of land use changes in Fincha'a watershed were the creation of the reservoir and the population pressure induced by forced migration due to the dam and normal growth. The 1975 land reform in Ethiopia should have contributed to some extent to land use changes in this watershed, because this reform opened up access to grazing lands and forests for the expansion of cropland and settlements. As more and more people seek to make a living in this watershed, they expand their cropland into forests and steep hillsides, farm their land in erosive ways, and fail to replenish the soil nutrients that have been removed**.** The factors of land use change in this watershed have therefore been interacting in a very complicated way. Consequently, the land use changes in the watershed have been more dynamic than in other watersheds in Ethiopia, such as Mettu (Solomon, 1994), Denbecha (Gete, 1997), and Chemoga (Woldeamlak, 2003). The observed land use changes in this watershed might have affected the livelihoods of the community and must have reduced the ability of the dam to deliver the planned economic benefits.

The widespread belief among the people in the watershed that the reservoir area expands from time to time seems to be unfounded, as the water reservoir and swamp have recently receded (Chapter 2). The reduction in annual rainfall since 2001 and the increased sediment influx into the reservoir could have affected the sizes of the reservoir and swamps (Chapters 2 and 4). The interface between swamp and grazing land easily fluctuates in response to rainfall, because the gradient between the dam site and the remotest part of the swamp (southern part of the watershed), about 60 km away, is low: 1:476 m/m. This could be why a large reservoir of 239 km^2 can be impounded by a dam only 20 m high with a crest 340 m long. Given this situation, the area of water body, swamp, and grazing land in the floodplain area could easily be affected by fluctuations in rainfall and sediment influxes. Because of the lack of long-term climatic data for the area, however, it was not possible to conclude that the recent reduction in annual rainfall is a general trend.

Besides generating electric power and providing water for irrigation and fishery, the Fincha'a dam project had planned to drain and reclaim the Coomman swamp, which is about 600 km^2, in order to provide the relocated people with substitute land for their inundated crop and grazing lands and to reduce the area of open water subject to evaporation losses. Though the project idea would have benefited both the community and the dam, it has not been implemented (Chapter 3). Thus a vast area of the watershed has not been made available for use by the community; furthermore, the objective of reducing evaporation losses has not been achieved. As a result, the reservoir has spread over a large area and is shallow (Chapter 2), and people have ascribed adverse social and environmental side-effects to it.

The creation of the reservoir and increased population growth were the major reasons for the decrease in crop and grazing land. As a result of this decrease, the relocated households owned 24% less livestock units and 23% less land area than households in the neighbouring areas (Chapter 3). They achieved only 65% of the crop production realised in neighbouring districts, because they made less use of chemical fertilisers, and because of poor extension services and smaller farms. The traditional way of expanding cropland is no longer an option, because 77% of the land potentially available for community use is already being used to grow crops (Chapter 2). Inundation has had the greatest effect on grazing land, however. Vast areas of grazing land have been inundated and this, coupled with cropland expansion, means that livestock production, which is as important as crop production, faces a serious challenge. The two major economic activities have entered a state of competition rather than complementing each other. Crop intensification is still lacking and improved sources of livestock fodder have not been developed in the area either. Today, over 25% of the people in Fincha'a watershed are believed to be landless. These people are relatively young, and have recently established their own families. Moreover, the rural population in the watershed is not benefiting from the electricity generated and animals have been drowned while grazing along the edges of swamps and the reservoir, while others are dying from waterborne diseases.

The land use changes in Fincha'a watershed have comprised expansion of cropland to steep slopes mainly at the expense of grazing land and forests (Chapter 2). As a result of the inundation of the vast area of flat land and the population growth, agricultural activities have been intensified on steep slopes, where farming without the application of SWC measures has increased soil erosion rates and sediment yields (Chapter 4). This assertion was confirmed when erosion rates were assessed in Hadocha and Qoricha sub-watersheds. For example, in Qoricha, erosion rates on cropland increased from 2.9 to 6.6 kg m^{-2} yr^{-1} between 1957 and 2001. In Hadocha, erosion rates increased from 4.6 to 5.5 kg m^{-2} yr^{-1} in the same period. In both sub-watersheds, the large-scale conversion of grazing land and forest on steep slopes to cropland between 1957 and 2001 has become the major factor for increased erosion rates. The mean erosion rate on cropland in Fincha'a watershed in 2001 was 6.3 kg m^{-2} yr^{-1}. This rate is higher than the estimated national average of 4.2 kg m^{-2} yr^{-1} (Hurni, 1993). The mean annual soil losses predicted for grazing land and forestland are much lower than for cropland. In Qoricha, for instance, mean erosion on grazing lands varied from 0.23 kg m^{-2} yr^{-1} in 1957 to 0.21 kg m^{-2} yr^{-1} in 1980 and 1.7 kg m^{-2} yr^{-1} in 2001. In Fincha'a watershed, average erosion rates in 2001 were 0.56 kg m^{-2} on grazing land and 0.04 kg m^{-2}on forestland. Therefore, croplands are the major sources of sediment load in Fincha'a watershed and should be targeted by onsite soil and water conservation (SWC) to reduce sediment supply to rivers and the reservoir. On most steep parts of the watershed the soil has become shallow (< 25 cm). Thus any further soil loss could decrease the productivity of soils and might directly affect the food security situation in the watershed.

The combination of severe erosion rates and high sediment delivery ratios (SDR) predicted in Hadocha (0.40) and Qoricha (0.56) show that large sediment loads could enter the reservoir and swamps (Chapter 4). Sediment delivery depends on slope steepness, vegetation cover, soil type, and climate. As no vegetated buffer strips have been established between Fincha'a reservoir and cropland the effects of a high SDR in the sub-watersheds on reservoir sedimentation are clearly a threat. Several gullies, rivers, and streams that flow into the reservoir from various parts of the watershed could, therefore, facilitate sediment influxes into the reservoir. It has also become clear that sediment delivery is scale-dependent. The SDR of Qoricha (165 ha) was higher than the SDR of Hadocha (1155 ha).

The removal of vegetation cover on steep slopes probably reduced rainfall infiltration and groundwater recharge. Consequently, some farmers with fields on steep slopes reported that their crops often fail because of moisture stress. Rivers and streams often transport debris and stones to downstream areas, often bursting their banks and flooding crops and sometimes villages during heavy rains. Nowadays, most perennial springs dry up, exposing the community to the problem of water shortage. Despite these problems, the entire watershed has not been subjected to SWC measures. Neither are any meaningful policies in place to prevent unwise land use changes in the watershed.

The group discussions held with poor and rich farmers in two sub-watersheds identified five major agricultural problems in the community (Chapter 5): 1) decreased cropland area, 2) increased costs of chemical fertilisers, 3) decreased crop yield due to erratic rainfall and soil erosion, 4) decreased grassland area and grassland productivity, and 5) increased livestock diseases. There was not much difference between the sub-watersheds in the type and ranking of the problems identified, but quite a big difference was noticed between the problems and priorities of the rich and poor farmers. The shortage of grazing land and increase in livestock disease has not concerned the poor farmers as much as it has concerned the rich farmers, because the poor farmers own fewer animals. The poor farmers were very concerned about meeting their immediate need for crop production, which is constrained by land shortage and declining soil fertility. The rich farmers apply the traditional soil fertility enhancement practice, known as *ciicata*, and chemical fertilisers to sustain crop production. The poor farmers stressed that though the rising costs of chemical fertilisers is a general community problem; the poor farmers are worst affected. For example, the high cost of chemical fertiliser was the foremost problem mentioned by the rich farmers, but the most important problem for the poor farmers has become the decline in cropland area.

The farmers expressed interest in doing something that would enable them to extricate themselves from these multifaceted problems. In the group discussions, soil erosion was not ranked highly because more emphasis was given to the immediate needs for sufficient crop and livestock production. From the interviews, however, it became clear that farmers are well aware of erosion problems (Chapter 5). The majority of the farmers did perceive increased erosion rates on their land and associated them with high rainfall and overland flow, steep slopes, and reduced vegetation cover. This situation was clearly reflected when the Morgan, Morgan and Finney (MMF) erosion model was applied in Hadocha and Qoricha sub-watersheds and the entire Fincha'a watershed (Chapter 4). The farmers' qualitative evaluation of factors causing soil erosion showed that they clearly link the erosion problems to the slope of their land and a decline in soil fertility. Most farmers were worried about crop yields, but despite this, they have not invested in adequate SWC on the slopes. They merely try to mask the effects of erosion on crop yield by soil fertility management, mainly by applying *ciicata* and fertilisers. The presence of a good depth of soil in flat areas could, to some extent, also mask the effect of erosion. But on steep land where soils tend to be shallow, the application of fertilisers seems to be the only real option for sustaining yield levels without implementing SWC. Trying to maintain high crop production levels despite the loss of fertile topsoil by erosion has increased the demand for chemical fertilisers. Previously, farmers relied more on the use of *ciicata*, but this practice is less widespread nowadays. Cattle numbers per household have fallen in the area due to the shortage of grazing land and more frequent livestock diseases (Chapters 3 and 5). *Ciicata* is only effective if a sufficient number of cattle – typically 10–20 head – can be kraaled at night.

In the past, farmers and agricultural extension officers believed that the traditional trenches for collecting runoff would be sufficient to protect fields against erosion. Recently, however, agriculture has been practised on steep slopes, where the runoff trenches are inadequate for controlling soil erosion (Chapter 5). Scouring of the embankments and overtopping have undermined their performance, leading to rill formation and losses of seed, fertiliser, and moisture. The trenches can be combined with other SWC measures if their gradients are low. But if the gradients of trenches exceed the gradients of conventional SWC measures, there is a risk that the trenches will counteract the other measures of soil erosion control. The possibility of improving the performance of the trenches on steep slopes needs to be studied, as does the mechanism of combining them with conventional terraces.

The high concern farmers showed about the escalating costs of fertiliser indicates an interesting option for the promotion of erosion-reducing measures that prevent nutrient losses. If farmers can be convinced about the stabilising effects of these measures on crop yields, they may become more interested in adopting the measures. Though the implementation of the SWC measures requires large initial investments, in the long-term they may reduce expenditure on fertilisers, thus making the land more profitable.

The major factors affecting SWC adoption are the farmer's wealth status, land tenure arrangements, and degree of access the farmers have to information. Wealthy farmers grow food and cash crops (nitrogen fixers), apply *ciicata*, practise fallowing, and plant trees. These farmers clearly have more options to invest in the farm and their land. Poor farmers are constrained by land insecurity and low livestock numbers. They rarely apply management practices that sustain or enhance the crop production levels. Hence, the practices of the poor farmers may lead to soil mining and erosion, and threaten the family's future food security. However, the few farmers that had a clear interest in SWC measures were from the group of poor farmers. But they were not yet convinced that the recommended measures would improve their crop yields, so had not yet implemented SWC measures.

The construction and maintenance of SWC measures generally demand a high labour investment. In particular it is the old farmers and female farmers who are constrained by the shortage of family labour, which makes it more difficult for them to adopt SWC. Losing 10 to 15% of cropland by installing SWC measures is a severe constraint to farmers in general and to small farmers in particular. This loss of productive land makes the implementation of these measures economically unjustifiable – at least in the short run. One way of reducing this drawback is to make the area occupied by the SWC measures productive, by establishing grasses and leguminous species. The grasses can be used for fodder, while the leguminous plants can be used to improve soil fertility, as fodder, and also as food for families (e.g. Pigeon pea, *Cajanus cajan*). Moreover, the introduction of incentives, such as the provision of planting materials, hand tools, and fertilisers on credit, and travel to areas where SWC adoption has shown good results, would improve SWC adoption. Incentives like these might reduce farmers' hesitation about the financial benefits of measures. Also, as erosion is not just a problem to the farmers, society as a whole will benefit from better SWC adoption, through reduced off-site impacts like reservoir sedimentation (Chapter 4).

Landless or sharecropper farmers are more willing to run the risk of land degradation, as they know they may not have access to the land in the future (Chapters 3 and 5). If there is no security of tenure, they are also less likely to invest in natural resources conservation, such as terracing, tree planting, and soil fertility management. This is borne out by the fact that tree planting and the traditional soil fertility management activities are practices on the government allocated lands but not on sharecropped lands (Chapter 5). Elderly farmers and female farmers usually sharecrop some of their land, due to a lack of family labour. Sharecropping is, therefore, one of the methods that has been used to overcome the problems of land shortage among the young and poor farmers, and to support the livelihood of the old and female farmers. But the practice of sharecropping may have led to natural resources degradation and poor SWC adoption, because neither the sharecropper nor the land holder is committed to invest in the sharecropped lands. Hence, only when landholding rights are secured are farmers more likely to invest family labour as well as finance in SWC. Given the already high number of landless farmers in the area, who depend on sharecropping and selling their labour, the regional government may at some point in the future decide to redistribute the land again. This threat discourages most farmers from investing much in their land.

Individual farmers have rights to use the cropland that they have been allocated. On the other hand, a large area of grazing land and woodland is common property. This common land is mainly on steep slopes. It is being encroached on by members of the farming community, which is creating hotspots of runoff generation and soil erosion (Chapters 2 and 4). In order to minimise land degradation problems on these land use types, the local government could perhaps give this land to users' groups on a long lease, giving the members of the group the right to own the benefits harvested from the lands. Moreover, the users' groups could be encouraged to practise joint forest management. Since such joint forest management can have significant offsite effects and the forest products may not give immediate economic benefit to the farmers, certain amounts of money could be allocated to encourage the management initiatives. The cost of seed could be split between the power company and the farmers.

The introduction of fishery to the area was considered to be one of the economic opportunities for the community in the watershed. However, few of the rural people in Fincha'a watershed eat fish, and fish marketing has not been developed. Improving market access for the fish resources could increase job opportunities and income generation.

It has become clear that the number of farmers who had contacted the SWC professionals and development agents was extremely low (Chapter 5). There are two possible explanations for this: (1) farmers are not convinced about the foreseeable economic benefits of applying SWC, and (2) the extension methods followed in the past could have demotivated them. The lack of community participation in problem analysis, technology selection, design, and construction may have fostered aversion to SWC among farmers. Local government institutions believe that farmers are often mismanagers of forests, soils, and water and must be advised and forced to adopt SWC technologies. On the other hand, farmers believe that their soil management practices are appropriate and they rely on their traditional practices. These differences in outlook have hampered smooth communication between government extension workers and farmers in Fincha'a watershed and probably elsewhere. To bridge these gaps, improved extension services and institutional support are required.

In many cases the farmers were very wise not to accept the unproven technologies that were on offer because their life is fraught with risks of crop failure that could be caused by poorly implemented SWC technologies. Farmers have to be cautious; they cannot afford to make mistakes. When a new technology does meet a real need, the rate of spontaneous adoption can be very rapid. This situation was clearly reflected when the number of farmers who adopted SWC was compared against those who applied chemical fertilisers and used improved seeds (Chapter 5). The soft systems methodology assumes that people in general want to solve their problems (Chapter 6). In order to do so there must be some kind of consensus or accommodation between stakeholders. Further, it is assumed that many problems and conflicting situations involve disagreements related to the needs, objectives, and measure of performance and are based either on misunderstandings and/or on differences in interest (Bergvall-Kåreborn, 2002). These misunderstandings and differences are usually due to lack of understanding or lack of information. For the design and implementation of appropriate erosion measures it is extremely important to localise erosion-prone areas and to quantitatively estimate soil loss rates with sufficient accuracy (Chapter 4). The MMF model could be used for this purpose. Farmers' knowledge of the spatial distribution of erosion could also be applied at watershed level and the result could be superimposed on the model's predictions of erosion. If the model's predictions of erosion agree with farmers' estimates of erosion rate, farmers will be motivated to adopt interventions in watershed management. While extending SWC technologies, the role of professionals should be to contribute to arguments about the pros and cons of SWC measures, their costs and benefits, and the technical details, and to disseminate information about all of these (Chapter 5). Therefore, integrating the applications of soft system methodology and hard system tools could improve the planning and implementation of IWM. To achieve this, an environment should be created in which science and knowledge help people to develop a diversity of locally appropriate resource management solutions.

For thousands of years, dams have been constructed as a means for storing water for electricity, irrigation, and domestic water supply, and for flood control (Chapters 3 and 6). In too many cases in the past, an unacceptable and often unnecessary price has been paid to secure those benefits, especially in social and environmental terms (by people displaced, by communities downstream, and by the natural environment). Most of the problems caused by dams are not about technical designs but about the social and environmental consequences of dams and the decision-making processes that led to their construction (Chapter 6). In many parts of the world, including Ethiopia, dam planning has been top–down, without involving the communities in the watershed area. As a result, the construction of dams adversely affects the livelihood of the communities and the benefits accrued from dams often go elsewhere.

The major problems caused by dams in Ethiopia are population relocation and natural resources degradation (Chapters 2, 3, and 6). The creation of a large water body in Fincha'a watershed has reduced the availability of some of the natural resources for community use and hence has helped reduce the resilience of the natural resources to community activities and uses. The problem has been aggravated by the diversion of much of the dam's output away from the rural community in this watershed and the lack of institutional support in the rehabilitation and development of the natural resources. Despite the problems, Ethiopia needs to increase its construction of new dams to improve food security, water supply, electricity, and local employment and skills development. In future, however, before a dam project is carried out, full consideration has to be given to whether or not it is socially, environmentally, and economically justified. The IWM approach, as it has evolved over recent years, should be employed in order to optimise these multi-faceted objectives. The construction of new dams should proceed only after the affected population has been satisfactorily recognised and compensated, and environmental protection measures have been completed.

7.3 Institutional and policy implications

The main conclusion from this research is that it is essential to establish public policies to encourage proper incentives for sustainable and efficient management of agriculture and natural resources. This requires removing the existing disincentives and putting in place new incentives. Policies that increase security of land tenure and support the intensification and diversification of agriculture are central for the success of IWM and to improve food security in Fincha'a watershed.

Experience from SWC pilot projects in different parts of Ethiopia has shown that the implementation of IWM plans requires large amounts of funds. In cash-strapped developing countries like Ethiopia, however, funding such IWM projects can create a budget deficit for the government. To reduce funding problems, the concept of payment for ecological services generated by specific land uses within watershed (Tognetti, 2000; Dent, 2005) should be introduced as a key element of watershed intervention. Policies that aim at compensating land users for the environmental services they generate or for charging them for the services they receive will increase both ecosystem function and overall social welfare (Johnson and Baltodano, 2004). This approach will generate resources from downstream users such as electric company, water supply, and breweries that would support development interventions in the upstream parts of watersheds.

Population pressure, dam construction, and certain government policies have affected the traditional institutions and practices in Fincha'a watershed and elsewhere in Ethiopia. The resulting effects of these breakdowns of traditional institutions and practices are natural resources degradation, increasing problems of conflict, and food insecurity. Thus a multi-stakeholder platform that addresses these problems is vital for implementing IWM. The platforms should effectively interact on public policies, dam planning, implementation, monitoring, evaluation, and conflict resolution. The formation of different state organisations that are responsible for planning, developing, and monitoring water resources and formulating environmental policies is a major step forward in Ethiopia. Effective implementation of these policies and strategies may improve the quality of future watershed-based developments. Since public goals are, by nature, trans-disciplinary, multi-disciplinary teams should be deployed, with each member contributing their professional perspective to the problem at hand.

In general, for better promotion and adoption of improved agriculture, the focal point of any programme of agricultural development should be betterment of the people and sustenance of the resource base. For farmers, what is important is production; what is most important for subsistence farmers is the production of the current season, as this guarantees the survival of their families (Herweg and Ludi, 1999). Therefore strong institutions are required to achieve the coordinated action necessary for involving stakeholders in sustaining agricultural production and resource conservation. When a development project requires that people be relocated, it is necessary to ensure that the productive base and income-earning ability of those affected are improved, so that they share the benefits of the new development and they are compensated for the transitional hardships. The displaced people should at least regain their previous standard of living and, at their relocation site, they should be assisted to become socially and economically integrated into the host communities.

Fincha'a dam plays a significant role in supporting the national economy through electric power generation, supplying water for a sugar factory downstream, and introducing fishery in the area. However, reviewing the possible compensation for the loss of physical resources after 30 years is no longer a sensible strategy to pursue. Instead, the issues that need to be addressed are the implementation of SWC, agricultural intensification, promotion of family planning, improvement of health and education services, and infrastructure development. Reclamation of the 600 km^2 Coomman swamp (Chapter 3) could still be an option to reduce land shortage and evaporation losses from the reservoir. If, instead, the community problems are allowed to persist, the ubiquitous social and economic activities in the upstream part of the watershed will intensify, leading to more food insecurity and reservoir sedimentation. It would be justifiable in terms of property rights and equity to allocate a certain portion of the revenue obtained from the electric power generation to the abovementioned social and economic endeavours. Since the watershed is located in the Blue Nile river basin, the social and economic changes attributable to this dam may have local and regional impacts. This calls for cooperation at local level and beyond.

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Summary

Summary

Chapter 1: Introduction

In Ethiopia, the construction of dams has caused social, environmental, and economic problems by increasing the relocation of communities against their will and inducing watershed land degradation. The failure to recognise people as partners in the planning and implementation processes is a major characteristic of watershed-based development projects. Soil erosion is a serious problem, threatening the agricultural sector and causing increased sedimentation of Ethiopian reservoirs and lakes. Unfortunately, there is very little reliable information on the spatial dynamics of the land use types, the factors driving the changes, and the implications of these changes in watersheds where a reservoir has been created. Such information is, however, very important for planning watershed-based development projects such as soil and water conservation (SWC) and dam construction. Studies have shown that despite some achievements, SWC programmes in Ethiopia have not triggered the voluntary adoption of conservation practices outside the project areas.

The area in which the research was done for this thesis is Fincha'a watershed, which is a representative watershed for the western highlands of Ethiopia. Typical of these highland areas are the mixed crop and livestock agricultural systems. Fincha'a is a special watershed, because of the hydropower dam and reservoir that was constructed in 1973. This reservoir has caused several effects on the local community, which is a different situation than in other watersheds in western Ethiopia. The research objectives were: 1) to analyse the impact of the dam in Fincha'a watershed on land use, social and economic situations and soil erosion, 2) to determine the factors affecting the adoption of SWC, and 3) to develop an integrated watershed management methodology for planning new dams in Ethiopia.

Chapter 2: Land use changes induced by a hydropower reservoir in Fincha'a watershed, western Ethiopia

This chapter analyses land use changes in Fincha'a watershed over a period of time and describes the possible causes and implications of these changes on the community at large and the dam itself. Before the dam was built there was no waterbody in this watershed. The interpretations of the 1980 aerial photos, however, revealed a waterbody, of 151 km^2; by 2001 it had increased to 239.3 km^2. The lake has inundated a total of 100 km^2 grazing land, 120 km^2 swamp, 18 km^2 cropland and 1.2 km^2 forest. Cropland has been expanded to steep and fragile parts of the watershed. Cropland now occupies 77% of the land potentially available for community use, indicating that there is hardly any possibility for further expansion to accommodate new families. The change in cropland area that has occurred in Fincha'a watershed is much greater than the changes found in the many studies done elsewhere in Ethiopia. The factors of land use change in this watershed have been interacting in a very complicated ways, with the overall repercussions being onsite environmental degradation and offsite sedimentation of the reservoir. The changes in the land use types in this watershed

could affect the livelihoods of the community and will affect the ability of the dam to deliver the planned economic benefits.

Chapter 3: Social and economic impacts of a hydropower reservoir on upland farming in Fincha'a watershed, western Ethiopia

This chapter analyses the social and economic changes brought about by the reservoir in Fincha'a watershed, and explains the possible causes and implications of these changes on the community and on the dam itself. Because of the reservoir, about 14% of the 120 survey households have been relocated against their will. They have been moved to the upstream parts of the watershed and have induced undesired land use changes. Land potentially available for community use has diminished from 78% before the dam to 60% after the dam. Currently, cropland has expanded to such an extent that there is little potential for further expansion to accommodate the increasing population pressure. The survey revealed that relocated households owned 23% less land and 24% less livestock units than other farmers in the neighbouring areas. They achieved only 65% of the crop production realised in neighbouring districts, because of less use of chemical fertilisers, poor extension services, and smaller farms. The rural population in the watershed does not benefit from the generated electricity and lose many of their animals – through drowning while grazing along the edges of swamps and the reservoir, or because of waterborne diseases.

Chapter 4: Erosion and sedimentation modelling in Fincha'a watershed, western Ethiopia

The Morgan, Morgan and Finney (MMF) model was used to predict the spatial soil erosion and sedimentation rates and the subsequent on-site and off-site effects in Fincha'a watershed. Erosion data collected from crop fields were used to calibrate and validate the model. This resulted in a coefficient of efficiency of 0.86 for calibration, and 0.79 for validation. After being calibrated and validated, the model was run for two sub-watersheds (Hadocha and Qoricha) using land use data from 1957, 1980, and 2001. It was found that soil erosion rates have increased to the extent that erosion could potentially undermine crop production in both sub-watersheds. Sediment delivery ratios have increased by 120% in Hadocha and 140% in Qoricha. The major drivers of the erosion and sedimentation problems are the land use changes that have been induced by Fincha'a dam, coupled with population growth. On most steep parts of the sub-watersheds as well as in Fincha'a watershed, the soil has become shallow, which means that any further soil loss might lead to reduced soil productivity, threaten farmers' food security, and increase offsite reservoir sedimentation. The removal of vegetation cover on steep slopes will have reduced rainfall infiltration and probably also groundwater recharge. Some of the major consequences of soil degradation in Fincha'a watershed are crop failure (due to reduced moisture storage capacities of the soil), inundation from overflowing rivers and streams, and the drying up of most perennial springs. Despite these problems, SWC measures have not been applied to the entire watershed. Neither are any meaningful policies in place to prevent the unwise use of land resources in the watershed.

Chapter 5: Factors affecting soil and water conservation adoption in Fincha'a watershed, western Ethiopia

Farmers' capability to implement SWC measures depends on knowledge of soil erosion processes, attitude towards rational use of resources, and institutional support. The research described in this chapter was conducted to determine the factors that affect adoption of SWC measures in Fincha'a watershed, western Ethiopia. The main survey methods employed were interviews, group discussions, and transect walks. The results show that crop fields are affected by annual soil losses ranging from 2.4 to 16 kg m^{-2} (mean = 7.2 kg m^{-2}). Farmers were well aware of these erosion problems, and related the soil loss to steep slopes and a decline in soil fertility. However, they did not invest much in SWC measures, but did apply soil management practices to sustain crop yields. The major factors affecting adoption of SWC are the farmer's wealth status, land tenure arrangements, and degree of access to information. Factors discouraging the adoption of SWC are the high labour demand of SWC measures and the lack of short-term benefit and of free grazing. The soil erosion problems in Fincha'a watershed have both on-site and off-site effects that require integrated SWC adoption at watershed scale.

Chapter 6: Integrated watershed management: a planning methodology for new dams in Ethiopia

This chapter presents the importance of integrated watershed management for planning new dams in Ethiopia. In many parts of the world, including Ethiopia, dam planning has been made top–down without involving the communities in the watershed area. The construction of dams, therefore, affects the livelihood of the communities and the benefits accrued from dams often go elsewhere. Watershed soil erosion and reservoir sedimentation is one of the major environmental problems reducing the functions of several dams in Ethiopia. Before a dam project is implemented, proper consideration has to be given to whether or not it is socially, environmentally, and economically justified. For effective implementation of soil conservation and sediment control measures, it is necessary to have sound knowledge of the spatial variability in soil erosion and sediment production within the watershed. Such information will also help to reduce the risk of not spreading the finances equally over the whole watershed. The construction of new dams should proceed only after satisfactory recognition and compensation of the affected population and completion of environmental protection measures. In the process of forging a partnership between the government, civil society, and community in order to use water resources, the prerequisite should be to bring all stakeholders to a common platform. In order to reduce funding problems, the concept of payment for ecological services generated by specific land uses within watersheds should be introduced as a key element of watershed intervention.

Population pressure, dam construction, and some government policies have caused the breakdown of traditional institutions and practices in Fincha'a watershed and elsewhere in Ethiopia. The resulting effects of these breakdowns are natural resources degradation, increasing problems of conflict, and food insecurity. To achieve integrated planning and decision-making processes, reliable information is required on land use change and factors driving it and on spatial erosion rates. This will enable the social, environmental and economic effects of implementing watershed-based development interventions to be analysed. Such information, however, should be complemented by other socio-economic information derived from analysing the agricultural problems of the community at watershed-scale. During this analysis, emphasis needs to be given to land tenure, wealth status, gender, age, education, and institutional supports. Since public goals are by nature trans-disciplinary, multi-disciplinary teams should be deployed, with each member contributing their professional perspective to the problem at hand. Thus a multi-stakeholder platform that addresses social, environmental, and economic problems of planning new dams is vital. In general, for better promotion and adoption of improved agriculture at watershed scale, the focal point of any agricultural development programme should be betterment of the people and sustenance of the resource base. What is important for farmers is production; what is most important for subsistence farmers is the production of the current season, because this guarantees the survival of their families.

Samenvatting

Hoofdstuk 1: Inleiding

De aanleg van stuwmeren heeft in Ethiopië geleid tot sociale-, economische- en milieuproblemen. De oorspronkelijke bewoners van de geïnundeerde gebieden werden gedwongen te verhuizen binnen het stroomgebied van het stuwmeer. Deze mensen werden niet betrokken in de planning en aanleg van de stuwmeren. De gedwongen migratie heeft in veel gevallen geleid tot landdegradatie door bodemerosie, doordat de druk van de bevolking op de bodem toenam. De erosie bovenstrooms van het stuwmeer veroorzaakt een verslechtering van de landbouw en toenemende sedimentatie in het reservoir waardoor de capaciteit afneemt. Programma's voor de aanleg van bodem- en waterconservering (BWC) hebben in Ethiopië nauwelijks geleid tot adoptie van de aanbevolen maatregelen, waardoor erosie nog steeds een toenemend probleem is.

In Ethiopië is weinig informatie beschikbaar over de dynamiek van veranderingen in het landgebruik, de factoren die bij deze veranderingen een rol spelen, en de effecten die de veranderingen hebben op stuwmeren. Beschikbaarheid van zulke informatie zou de planning en de levensduur van nieuwe stuwmeren kunnen verbeteren. Er kan beter rekening gehouden worden met de effecten op de lokale bevolking en tegelijkertijd met de aanleg van het reservoir kan een programma voor BWC in het stroomgebied gestart worden.

Het onderzoek beschreven in dit proefschrift werd uitgevoerd in Fincha'a, een representatief stroomgebied voor de westelijke hooglanden van Ethiopië. Karakteristiek voor deze hooglanden is het gemengd landbouwsysteem, waarbij gewasproductie wordt gecombineerd met veeteelt. In 1973 werd in Fincha'a een stuwmeer aangelegd voor stroomproductie. De aanleg van dit reservoir heeft consequenties gehad voor de lokale bevolking. De doelstellingen van het onderzoek waren: 1) het analyseren van de effecten van het Fincha'a reservoir op landgebruik, sociaal-economische omstandigheden en bodemerosie in het stroomgebied; 2) het bepalen van de factoren die adoptie van BWC maatregelen beïnvloeden; 3) het ontwikkelen van een methode voor het integraal plannen van nieuwe stuwmeren in Ethiopische stroomgebieden.

Hoofdstuk 2: Landgebruikveranderingen veroorzaakt door de aanleg van een stuwmeer in het Fincha'a stroomgebied, west Ethiopië.

Dit hoofdstuk beschrijft de veranderingen in landgebruik in het Fincha'a stroomgebied in de periode 1957 – 2001. Voor de aanleg van het stuwmeer in 1973 was er geen open water in het stroomgebied. In 1980, zeven jaar na de aanleg, was er een reservoir ontstaan met een oppervlak van 151 km^2. In 2001 was het reservoir gegroeid tot 239 km^2. Door de aanleg van het meer is 100 km^2 grasland, 120 km^2 moeras, 18 km^2 akkerland en 1,2 km^2 bos verloren gegaan. In dezelfde periode is het areaal akkerland uitgebreid in met name de steile en marginale delen van het stroomgebied. In 2001 bedekte akkerland 77% van het potentieel beschikbare areaal. In 1957 was dit nog maar 39%. In dezelfde periode nam het areaal grasland af van 54% (1957) tot 18% (2001). Verder expansie van akkerland voor de toenemende bevolking wordt steeds moeilijker. Alle voor akkerbouw geschikte grond is al in gebruik en de overgebleven marginale gebieden worden gebruikt voor begrazing door vee.

De toename van het areaal akkerland is extremer dan in vergelijkbare stroomgebieden waar geen reservoirs zijn aangelegd. De veranderingen in Fincha'a hebben geleid tot landdegradatie op met name de steile hellingen en sedimentatie in het stuwmeer. De veranderingen vormen daardoor een bedreiging voor de lokale bevolking en de levensduur van het reservoir.

Hoofdstuk 3: Sociaal-economische effecten van een stuwmeer op de landbouw in het Fincha'a stroomgebied, west Ethiopië.

In dit hoofdstuk zijn de sociaal-economische veranderingen als gevolg van de aanleg van het Fincha'a reservoir geanalyseerd. De mogelijke oorzaken en gevolgen van de veranderingen voor de lokale bevolking en het reservoir worden bediscussieerd. Circa 14% van de 120 ondervraagde families zijn gedwongen te verhuizen als gevolg van het reservoir. Deze families zijn overwegend naar de hoger gelegen delen van het stroomgebied getrokken, waar ze land hebben ontgonnen voor gewasproductie en begrazing door vee. Het totale areaal land beschikbaar voor de bevolking is afgenomen van 78% van het totale stroomgebied tot 60% van het totaal na de aanleg van het reservoir. Het areaal akkerland is dusdanig uitgebreid dat er weinig potentieel voor verdere uitbreiding is. Dit veroorzaakt een groot probleem voor de groeiende bevolking in Fincha'a. Uit de interviews bleek dat de families die gedwongen zijn verplaatst 23% minder land en 24% minder vee hebben dan andere families. De gewasopbrengsten van deze families was 35% lager dan de productie van de andere boeren. De belangrijkste oorzaken hiervoor zijn een minder gebruik van kunstmest, kleinere bedrijven en een gebrekkige landbouwvoorlichting. De inwoners van het Fincha'a stroomgebied profiteren op geen enkele wijze van het stuwmeer, maar klagen veel over verliezen van vee door verdrinking en water-gerelateerde ziekten.

Hoofdstuk 4: Modellering van erosie en sedimentatie in het Fincha'a stroomgebied, west Ethiopie.

Het Morgan, Morgan and Finney (MMF) model is gebruikt om de ruimtelijke patronen van watererosie in het Fincha'a stroomgebied en de sedimentatie in het stuwmeer te bepalen. Erosie bepalingen werden gedaan op 19 akkers en deze gegevens zijn gebruikt voor calibratie en validatie van het MMF model. Daarna is het model toegepast op twee sub-stroomgebieden (Hadocha en Qoricha) en de erosiepatronen bepaald voor het landgebruik in 1957, 1980 en 2001. De resultaten tonen een belangrijke toename van watererosie sinds 1957. Ook de sedimentlast uit de twee sub-stroomgebieden is sterk toegenomen over dezelfde periode.

De belangrijkste oorzaken van erosie en sedimentatie zijn de landgebruikveranderingen door de aanleg van het stuwmeer en de bevolkingstoename in het stroomgebied. Watererosie is met name een probleem op de steile hellingen waar bodems vaak ondiep zijn en de gewasproductie bedreigd wordt. Deze hellingen waren in 1957 nog goed bedekt met vegetatie, maar zijn later in gebruik genomen voor akkerbouw waardoor de bodembedekking is afgenomen. Deze verminderde bescherming van de bodem heeft geleid tot minder infiltratie van regen en daardoor meer oppervlakkige afstroming en erosie. Belangrijke consequenties van deze bodemdegradatie in Fincha'a zijn mislukte oogsten door gebrek aan vocht, overstromingen van rivieren en het opdrogen van waterbronnen. Ondanks deze urgente problemen is er niet of nauwelijks geïnvesteerd in BWC maatregelen.

Hoofdstuk 5: Factoren die de adoptie van bodem en waterconservering beïnvloeden in het Fincha'a stroomgebied, west Ethiopië.

Adoptie van BWC maatregelen door boeren hangt af van hun kennis van erosieprocessen, het doelmatig gebruik van natuurlijke bestaansbronnen en institutionele ondersteuning. Het onderzoek beschreven in dit hoofdstuk is uitgevoerd om de belangrijkste factoren voor adoptie van BWC maatregelen te bepalen. Het onderzoek werd uitgevoerd door middel van interviews, groepdiscussies en veldobservaties. Op akkerland werd een gemiddeld bodemverlies van 7.2 kg ha^{-1} $jaar^{-1}$ geconstateerd, met een spreiding van 2.4 – 16 kg ha^{-1} $jaar^{-1}$. De boeren zijn zich bewust van dit probleem en relateerden het bodemverlies aan steile hellingen en afnemende bodemvruchtbaarheid. Echter de boeren investeerden nauwelijks in BWC maatregelen, maar passen wel bodemverbetering toe voor het verkrijgen van voldoende gewasproductie.

De belangrijkste factoren die adoptie van BWC maatregelen beïnvloeden zijn rijkdom, landgebruiksrechten en de mate van informatievoorziening. De belangrijkste aspecten die adoptie ontmoedigen zijn de arbeidintensiteit van maatregelen en het gebrek aan korte termijn opbrengsten. De ernst van watererosie en sedimentatie in Fincha'a maken een integrale planning van BWC maatregelen in het hele stroomgebied noodzakelijk.

Hoofdstuk 6: Integraal Stroomgebied Management: een methodologie voor het plannen van nieuwe stuwmeren in Ethiopië.

In dit hoofdstuk wordt het belang van Integraal Stroomgebied Management voor het plannen van nieuwe stuwmeren in Ethiopië beschreven. Wereldwijd wordt de planning en aanleg van stuwmeren centraal geregeld, zonder de lokale bevolking te consulteren. Het gevolg is meestal dat deze lokale bevolking negatief wordt beïnvloed door de aanleg van een stuwmeer, terwijl de opbrengsten vaak naar elders verdwijnen zonder de lokale bevolking te compenseren. Watererosie en sedimentatie zijn de belangrijkste milieuproblemen die het functioneren van reservoirs in Ethiopië negatief beïnvloeden.

Bij het plannen van nieuwe dammen moet een analyse gemaakt worden van de te verwachten sociale, economische en milieuveranderingen. In erosiegevoelige stroomgebieden moet tevens een BWC plan gemaakt worden waarvoor een goede analyse van ruimtelijke erosie en sedimentatiepatronen nodig is. Deze informatie kan helpen de beschikbare financiering evenwichtig te verspreiden. De aanleg van nieuwe reservoirs zou alleen mogen gebeuren als de lokale bevolking redelijk gecompenseerd wordt voor te verwachten sociaal-economische effecten, en de bescherming van het milieu voldoende gewaarborgd is. Hiervoor is het nodig alle belanghebbende bijeen te brengen in een overlegstructuur waarin alle problemen m.b.t. de aanleg van een reservoir kunnen worden besproken en oplossingen worden bedacht voor deze problemen. Tevens zou er financiering beschikbaar moeten worden gesteld voor vormen van landgebruik en bodembeheer die erosie en sedimentatie verminderen.

Hoofdstuk 7: Synthese.

De aanleg van een stuwmeer in het Fincha'a stroomgebied heeft geleid tot een grote druk op het beschikbare land, sociale conflicten, bodemdegradatie en onzekere voedselproductie. Toekomstige ontwikkeling van stroomgebieden waar stuwmeren gepland worden vereist goede informatie over landgebruikveranderingen, de factoren die deze veranderingen beïnvloeden en ruimtelijk inzicht in problemen van bodemdegradatie. Verder is het nodig de sociaal-economische omstandigheden van de lokale bevolking goed te kennen en deze kennis te gebruiken voor het ontwikkelen van de nieuwe plannen.

Verschillende belanghebbenden hebben verschillende doelstellingen voor toekomstige ontwikkelingen. Hierdoor is het nodig een multidisciplinair team van deskundigen samen te stellen voor het oplossen van problemen rond de aanleg van nieuwe stuwmeren. Iedere deskundige kan zijn visie geven over de verschillende problemen die opgelost moeten worden. De mogelijke oplossingen dienen samen met de lokale bevolking worden ontwikkeld en geëvalueerd. In Ethiopië gaat het meestal om een agrarische bevolking die in de stroomgebieden woont en er zal dus veel aandacht aan het welzijn van deze groep besteed moeten worden in de planning van stuwmeren. Door de aanleg van stuwmeren gepaard te laten gaan met een goed landbouwontwikkelingsprogramma kan de lokale bevolking profiteren van de ontwikkeling van het stroomgebied en kan de voedselzekerheid voor de toekomst gewaarborgd worden.

Curriculum vitae

Bezuayehu Tefera Olana was born in Guduru, Wallagga, Ethiopia on the 25th of April 1966. After completing his Secondary School at Shambu in 1983, he joined Alemaya University of Agriculture where he obtained a BSc degree in Agricultural Engineering in June 1987. Since then he joined the Ministry of Agriculture and worked as a soil and water conservation expert in the then Gamo-Gofa region, southern Ethiopia. From 1995 to 1997, he attended the master courses in Soil and Water, Erosion and Soil and Water conservation specialisation, at the Wageningen University, The Netherlands. His MSc thesis was focused on the effect of different widths of grass strips on soil erosion control, in Limburg area, The Netherlands. The grass strips have showed satisfactory results in reducing soil erosion on different slope steepness. After obtaining his MSc degree he went back home and joined the same Ministry of Agriculture. He worked as senior soil and water conservation expert and as a department head for Land Use Planning and Environmental Protection Department in the Oromiya regional state between 1997 and 2001. He participated in the design and supervision of many watershed-based soil and water conservation programmes in different parts of Oromiya and elsewhere in Ethiopia. Besides he participated in the "Socio-economic and Policy Research in the Highlands of Oromiya, Ethiopia" and was a principal author for "Nature and causes of land degradation in the Oromiya region. Socio-economics and Policy Research Working Paper 36, ILRI (International Livestock Research Institute), Nairobi, Kenya, 82 pp". In September 2001, he was admitted to the PhD Sandwich Fellowship of Wageningen University within Erosion and Soil and Water Conservation Group. He studied: 1) the impacts of a dam on land use changes and social and farming systems in Fincha'a watershed, western Ethiopia, 2) erosion and sedimentation modelling and factors affecting soil and water conservation adoption, in Fincha'a watershed, western Ethiopia, and 3) integrated watershed management for planning new dams in Ethiopia. He can be reached at: bezuayehto@yahoo.com

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- Land Science: Concepts, tools and uncertainties in land use studies and landscape dynamics (2005)

Deficiency, Refresh, Brush-up and General Courses (3 credits)
- Processes and models in erosion and soil and water conservation (2001)

PhD Discussion Groups (3 credits)
- Ethiopian Agricultural Research Organization (EARO) (2002/2005)
- International Livestock Research Institute (ILRI) (2002/2005)
- The UN World Food Programme (WFP) (2002/2005)

PE&RC Annual Meetings, Seminars and Introduction Days (2.1 credit)
- Rainwater harvesting for food security in Ethiopia (2003)
- Cadastral survey for land registration in Oromiya, Ethiopia (2004)
- PE&RC 10 years anniversary (2005)
- PE&RC annual meeting "The truth of science"(2005)

International Symposia, Workshops and Conferences (2 credits)
- Remote sensing and geoinformation processing in the assessment and monitoring of land degradation and desertification, Trier, Germany (2005)

Laboratory Training and Working Visits (2 credits)
- Soil quality analysis, National Soils Laboratory of Ethiopia (2002-2003)