Assessment of Potential Environmental Impacts of Two Large Scale Irrigation Schemes in Ethiopia

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Abstract

This article presents the findings of a study undertaken to assess environmental impacts of two selected large scale irrigation schemes on natural resources in Ethiopia. The study puts special emphasis on linkages and implications of the utilized water source, ground water hydrology and soil characteristics, on the sustainability of the selected schemes. In addition, potential interference of irrigation projects with woodland ecosystems is highlighted. For this purpose primary soil and water data and data from research reports from Wonji/Shoa Sugar Plantation and Finchaa Valley Sugar Estate were collected and analysed using a "before-after" and "with or without" type of analysis. Rising of groundwater table, water logged within the root zone of the cultivated sugar cane and elevated EC values within 1m of soil depth indicate the risk of secondary salinization at Wonji/Shoa Sugar Plantation. Unfavourable EC, SAR and RNa values of the utilized irrigation source in combination with the CEC of soil and ongoing soil erosion processes suggests that irrigation might lead to long-term infiltration problems and destruction of the soil structure at Fincha Sugar Estate. The establishment of the scheme and migration tendencies increased the pressure on the eco-system of the valleys and led to clearing of wood and grass lands. To guarantee long-term sustainability, proper study and continuous research of already implemented and planned large scale irrigation projects is necessary, so that the positive roles of irrigation could be enhanced and timely mitigation measures taken for the negative impacts.

Keywords: large, irrigation, environment, impact, water, soil

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Introduction

The Ethiopian Government started an irrigation development program in 2001 under the title "Irrigation Infrastructures Development for Food Security and National Economic Growth" to meet the ambitious efforts of the Water Sector Development Program, which is scheduled from 2002 until 2016. Agriculture plays a dominant role in the overall Ethiopian economy and accounts for about 40-45 percent of GDP, generating 85 percent of export revenues and employing 85 percent of the labour forces. In an assessment for sugarcane development (MoWR, 2004) the increased supply of agricultural raw materials for agro-industry development, enhanced foreign currency earnings of the country, provision of employment opportunities were pin pointed as major drivers for investment in large scale systems.

Twenty-six medium and large scale irrigation projects are planned to be implemented. Irrigation infrastructures in the country will more than double by the end of the program period. According to Plan for Accelerated and Sustained Development to End Poverty (PASDEP), the irrigation sector development program was revised and the country has stepped up its efforts to establish additional large and medium-scale irrigated area of 493,000 hectares within the program period of PASDEP 2004/2005 to 2009/2010 (MOFED, 2006). Based on the Ministry of Water Resources (MoWR) classification, irrigation projects in Ethiopia are identified as large-scale irrigation with a command area larger than 3,000 hectares, medium-scale of 200 to 3,000 hectares and small-scale of less than 200 hectares (see also Werfring, 2004; Seleshi *et al.,* 2005). Estimates of the irrigated area presently vary, but range between 150,000 and 250,000 hectares, which is less than five percent of potentially irrigable land (Seleshi *et al.,* 2005). According to Seleshi *et al.* (2007), the total estimated area of irrigated agriculture in the country is 107,265.65 hectares out of which 20,038.39 hectares accounts for small-scale, 30,291.26 hectares for medium-scale and 56,936 hectares for large- scale.

In several studies a number of different environmental impacts have been identified which are directly caused by irrigation projects. Low water quality used for irrigation and rising water tables might lead to water logging, salinization and other risks involved, especially when effluent water is reused (Toze, 2006). The quality of irrigation return flows can have adverse impacts on downstream water bodies and lead to degradation of water quality by salts and agrochemicals. Ten per cent of the total irrigated area worldwide is estimated to be affected by irrigation induces water logging and salinization. Smedema and Shiati (2002) stated that the situation in large river basins in arid regions is much more severe, with salinity buildups in drainage water and the consequent salinization of the land and rivers. Drainage or proper management are systematically neglected until salinity problems are manifest, because of the additional capital cost it incurs (Comprehensive Assessment of Water Management in Agriculture, 2007).

Moltot (2005) noted that a number of researchers have reported the wide-spread occurrence of salt affected (saline, saline sodic and sodic) soils and soda-waters and soda-lakes in arid and semi-arid zones of Ethiopia (Makin *et al.,* 1976; AIP, 1982; Heluf and Mishra, 2005). Salt affected soils in Ethiopia cover a total land area of 11,033,000 ha (Szabolcs, 1979, 1989; FAO, 1988). Most of these soils are known to be concentrated in the plain lands of the arid and semi-arid regions of the country, mainly in the Ethiopian Rift Valley System, the Somali lowlands (specially the Lower Wabi Shebelle River Basin), the Denakil Plains and various other lowlands and valley bottoms throughout the country (Makin *et al.,* 1976; AIP, 1982; Heluf and Mishra, 2005). These are areas that have been proposed for irrigation development in several River Basin Master plan studies.

The landscape of the Awash Valley in general and the middle and the lower plain in particular are dominated by salt affected soils (Tadele, 1993). The large-scale irrigated farms in the area were established without much consideration for land development works; the lack of proper irrigation water delivery structures, no proper drainage facilities for disposal of excess water.

Poor water application techniques and inappropriate drainage systems that result in over irrigation and significant deep percolation often result in water logging ultimately leading to rapid rise in groundwater table that results in induced secondary salinization (Haider *et al.,* 1988). An irrigation evaluation study on 7,000 ha of cotton fields on Melka Sedi, Melka Werer and Amibara farms (AIP II), revealed that the crop was over or under irrigated at different growth stages.

The hazard of rising groundwater can be found in virtually all regions of Awash Valley, in particularly in the Middle Valley. Excess water from irrigation recharges the ground water causing it to rise. Crop yield losses associated with elevated water tables due to irrigation are commonly observed (Halcrow, 1989). The irrigation of multiple crops throughout the year effectively results in a permanent soil surface cover protection of the soil from splash erosion. However, high soil moisture content due to irrigation can increase surface run-off rates and thus makes soils more vulnerable to erosion.

Since the Ethiopian Government has started to focus its development strategies on the extension of irrigated agriculture especially of large scale projects during the last decade it has become more important to explore the nexus between irrigation investments, sustainable agricultural development and potential environmental impacts in the Ethiopian context. Improving the environmental performance of irrigation agriculture is of major importance for its long-term sustainability. We have shown elsewhere (Ruffeis *et al.*, 2010) that no effective EIA system is in place in Ethiopia, which could effectively prevent adverse environmental impacts of newly planned irrigation schemes in the first place. This and the fact that very little information and baseline date are available regarding irrigation and its environmental implications shows the need to generate more knowledge to fill this gap.

This article presents the findings of a study conducted for a project entitled "Impact of Irrigation on Poverty and Environment (IIPE)" sponsored by the Austrian Government. The findings presented in this article show the results of an assessment of potential environmental impacts of irrigated large scale sugarcane production in Ethiopia conducted in 2006. To investigate potential adverse impacts of irrigation on soil quality, downstream water bodies and groundwater hydrology primary and secondary water and soil data were collected and analysed. In addition, the alteration of the biophysical characteristics of potentially affected ecosystems and impact of land clearing for irrigation and related activities on land degradation through erosion are highlighted.

Material and Methods

Description of the Study Area

Figure 1. Location of the chosen irrigated large scale sugarcane plantations

Source: Authors' own creation based on Landsat 7 satellite image, 2006

Wonji/Shoa sugarcane plantation and Finchaa Valley Sugar Estate were selected as case study sites (Figure 1). Both schemes are commercial large-scale irrigation projects and of major importance for sugar production in the country and contribution to the GDP.

The Wonji-Shoa Irrigation Scheme (Figure 2) is located downstream of Koka Dam in the upper Awash River basin about 80 km south east of Addis Ababa at an altitude of approximately 1,500 m. The slope of the farm is very gentle and regular. It has a semi-arid climate and receives an average annual rainfall of 747 mm, mean annual potential evapotranspiration of 2519 mm and peak daily evapotranspiration of 4.5 mm. Mean annual maximum and minimum temperatures are 27.6°C and 15.2°C, respectively.

The total concession area of the estate is 6,162.8 hectares, of which 5,905.13 hectares are under cultivation, while 257 ha are occupied for canals, roads, living quarters, etc. Out-growers irrigate an additional area of 1,117 ha of land, which adds up to a total command area of app. 7000 ha (Table 1).

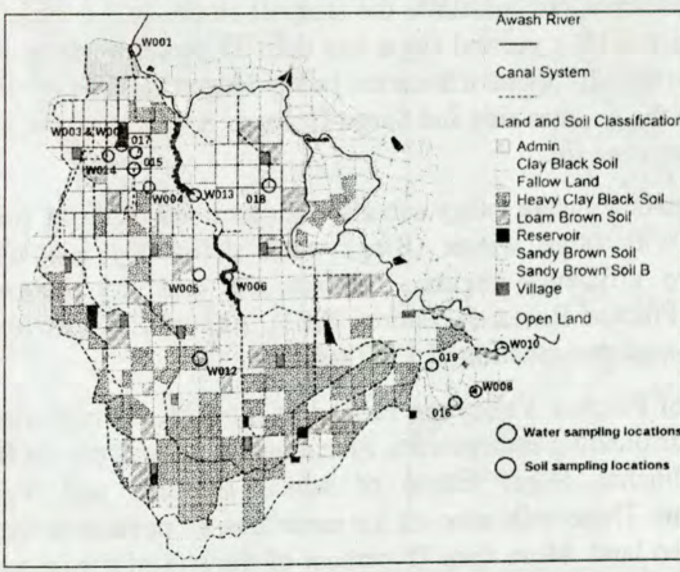
The major predominant soil types are described as Fluvisols, Andosols and Laptosols according to FAO soil classification. Soils of Wonji/Shoa are of alluvial-colluvial origin developed under hot, tropical conditions (Figure 2). In the region diverse soil types can be found which vary in their production potential. In general, soils of Wonji/Shoa can be described as a complex of grey cracking clays in the topographic depressions and semiarid brown soils (Ambachew *et al.*, 2000). According to their texture they are classified as light (coarse textured) soils and heavy soils (clayey black types), the latter are more common in Wonji/Shoa Sugarcane Plantation.

Table 1. General description of the selected case study sites

	Finchaa Valley	**Wonji/Shoa**
Size	8500 ha	7000 ha
Location	9°30'-9°60'N; 37°10'- 37°30'E	8.40°N; 39.25°E
Altitude	1550 m	1540 m
Date of Establishment	1995	1956
Type	Public, large scale irrigation	Public, large scale irrigation
Management	Government Agency	Government Agency
Basin	Blue Nile Basin	Awash Basin
Water source	Lake Chomen, Finchaa River	Awash River, Reservoir (reused water from factory)
Diversion	Pump	Pump
Irrigation	Pump, Gravity, Sprinkler	Gravity, Furrow
N/ETo (mm/y)	1300/1500	747/2519
Agro-ecology	Weyna Dega (1500-2300 m)	Weyna Dega (1500-2300 m)
Main crop	Sugarcane (monoculture)	Sugarcane (monoculture)
Major soil type	Luvisol	Fluvisol

Water is abstracted from Awash River through a pumping station at Wonji and conveyed to almost the entire estate through an extensive earthen canal system and storage facilities. Pumps run continuously to store water in reservoirs, which are positioned at various locations throughout the estate. Water from the sugarcane factory is also stored in reservoirs and re-used for irrigation purposes. There are seven main, and twelve tertiary night storage reservoirs in the estate. The water delivery infrastructure is all open canals. Blocked-end furrow irrigation system is used to irrigate sugarcane fields in the estate as well as in the farms of the out-growers.

Figure 2. Scheme layout of Wonji/Shoa Sugar Plantation according to the schemes internal classification including sampling locations



Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

The Finchaa Valley Sugar Estate (Figure 3) is located in the Oromia Regional State, around 350 km north-west of Addis Ababa. Finchaa Sugar Estate has a total irrigated area of 8,500 hectares (Table 1). Out of this 8,286.77 ha is located on the west bank of Finchaa River and the remaining 233.26 on the east bank. The estate is currently engaged in extending the total irrigated area by 7,000 ha and plans exist to expand the irrigated area to 20,000 ha in the future (Girma *et al.*, 2007).

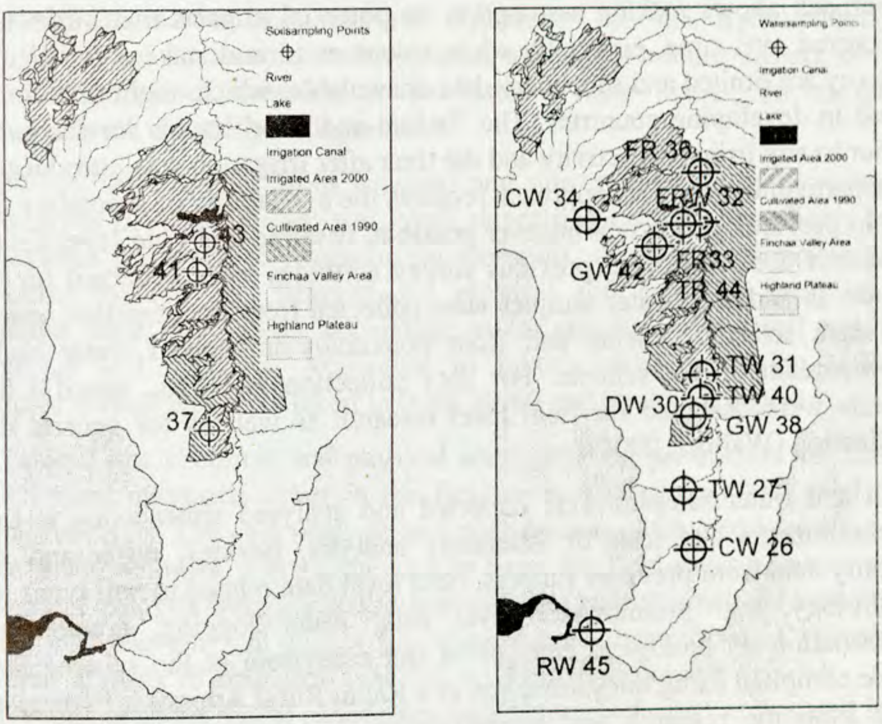
Finchaa valley is a low lying area surrounded by escarpments on the eastern, southern and western sides. The northern part of the valley is open and passes into Blue Nile Valley. The range of altitudes in this area varies from low land below 1000 m to high land over 2000 m. The average elevation of the valley floor is about 1550 meter, whereas the altitude of the surrounding high lands can reach more than 2250 meter. In the area of the Sugar Estate the valley is about 12 kilometres wide and extends northwards to about 35 kilometres. The South-North extension is about 50 kilometres. The Valley is divided by Finchaa River into west and east bank. The east and west escarpments constitute the steepest slopes in the area. The valley floor is marked by a general slope less than 25 percent. Many streams join Finchaa River, the main tributaries being Hagamsa, Korke, Fakare, and Boye from the western side and Sargo-Gobana, Aware, Sombo, and Andode from the eastern side.

The climate of Finchaa valley can also be described as moist sub-humid or semi-arid with large winter (Bleg) water deficiency and megathermic temperature efficiency regime. Distinct wet and dry seasons can be observed (Finchaa Research Station, 2002). Annual ET_o of over 1500 mm exceeds annual precipitation of 1300 mm.

The soils of Finchaa Valley are formed of alluvial and colluvial materials from the surrounding escarpments. Five major soil types can be found in the area of Finchaa Sugar Estate of which Luvisols and Vertisols are predominant. These soils account for more than 95 percent of the cultivated and irrigated land. More than 75 percent of the soil of the irrigated land is Luvisols and the rest is Vertisols (Girma *et al.*, 2007). The irrigation scheme is divided by Finchaa River into East and West Bank (Figure 3). Currently only the West Bank is under cultivation, but the extension of the irrigated area to the East bank is planned.

Irrigation water is diverted from the Finchaa River, which drains Lake Chomen, using a diversion weir and is conveyed to the pump station via a concrete main canal (45 km in length). Water for irrigation is abstracted from the canal using two different methods. Twenty five pumps at five pump stations divert the water serving 34 % of the command area and 66 % are irrigated using gravity off-takes for gravity sprinkler irrigation at three locations. No constructed drainage system exists. The runoff and excess water is drained from the fields by tributaries of Finchaa River which cross the irrigated areas from West to East.

Figure 3. Scheme layout of Finchaa Valley Sugar Estate including sampling locations



Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

Analytical Framework, Data Collection, and Sampling

Due to limitations and time constraints during the study only a limited set of water and soil samples was obtained, which only represents a snap-shot of the current situation and allows to make general assumption on pertinent environmental impacts of the selected study sites on soils and water bodies.

To overcome these limitations, research and data collection were conducted using a "with or without" and whenever possible a "before and after" type of analysis, comparing sampled field data and data compiled from research stations and from literature. "With or without" stands for irrigated and non-irrigated plots. For this purpose representative plots of similar soil types and characteristics were chosen for soil sampling which were either irrigated or non-irrigated and uncultivated at the time the survey was conducted. This approach allows making assumption on potential impacts that might have occurred over time, especially when resources to undertake a full-fledged survey are limited and secondary data unavailable, which might often be the case in developing countries. The "before and after" stands for the period prior to any irrigation activity and the time after irrigation was introduced to the particular area. This approach requires the availability of secondary data from previous surveys. Whenever possible, baseline and field level data of research documents and previous survey activities were collected for this study. In addition, water samples were collected from the irrigation sources of each selected scheme and from potentially influenced water bodies downstream of the scheme. For data collection activities, specific data sheets were designed for field level research as well as for general data collection (Wallner, 2006).

Soil and water samples were collected and analysed either using in-field measurements and tests or laboratory analysis. Besides, water and soil quality data from previous surveys, field level data related to soil types and hydrology, e.g. groundwater level data, water logging, erosion and information on biological changes of the ecosystem at the scheme level were compiled using questionnaires in a Rapid Rural Appraisal Framework and from the research and administrative departments of the irrigation projects of different departments of the MoWR, from river basin master plans and other literature sources.

Two samples, one control sample, of each water source were taken using 1 litre plastic bottles and immediately stored in a cooling box. As some parameters may change rapidly after sampling the pH of one of the two samples was brought down to 2 by adding nitric acid (HNO_3) to stop chemical reactions.

Water sampling locations were chosen based on the spatial variations in the water stream and irrigation system in order to obtain a representative sample. Depending on the local conditions and sampling possibilities water samples were taken from the irrigation sources, the distribution canals, reservoirs, main drain and from downstream water bodies. Groundwater samples within the irrigation scheme were taken from wells as far as they were available and accessible.

In order to assess the regional differences of the hydro-chemical composition of the sampled water sources and to get a better insight of the potential impact of irrigation on downstream water bodies, the samples were analysed using Piper diagrams.

Disturbed soil samples from irrigated and non-irrigated plots have been taken from the predominant soil types, depending on the accessibility and anticipated influence of irrigation on the spots, using the composite soil sampling method for chemical and physical soil analysis. Samples of different depth were taken, depending on the structure of the soil and the depth of soil horizons. According to FAO's recommendation (1986) samples at each plot were taken in 0-30, 30-60 and 60-90 cm depths.

In Table 2, the chemical and physical water and soil parameters are listed which were measured either in the field or in a laboratory and used for impact analysis. The case study related analysis was conducted according to three methodologies. Firstly, the results from the field measurements and laboratory analysis were compared with national and international threshold values of water and soil quality for irrigated agriculture to assess potential adverse impacts of irrigation schemes on natural resources. Secondly, the soil chemical and physical parameters which were measured at irrigated and non irrigated reference plots were compared in accordance with the before mentioned "with or without" approach. Thirdly, "before-after" type of analysis was used comparing available field level data of previous surveys with the results of the sampling activities conducted for this thesis.

Table 2. Measured chemical and physical soil and water parameters

Samples	In-field measurement	Laboratory Analysis - chemical & physical parameters	Derived parameters
Water	pH	pH, Electrical conductivity	
	Electrical conductivity	Cations: Na, Ca, Mg, K, NH4-N	SAR, adj. RNa
	Temperature	Anions: SO4, HCO3, Cl, NO3-N, PO4-P	
Soil	Profile pit investigation	Particle size distribution of silt, clay, sand	Soil texture
		pH, Electrical conductivity	
		Na, K, Ca, Mg	
		CEC	ESP, BSP

Source: Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

In order to assess the impact of irrigation on water quality of downstream water bodies the result of in-field and laboratory measurements were compared with threshold values and used to identify deviant values. The compiled field level data about hydrology of the schemes, water logging, soil erosion and information about biological changes of the ecosystem were analysed in order to identify other relevant impacts of the case studies.

The EC and the temperature of the irrigation water sources were measured with an EC-meter (WTW, LF340). The pH was either determined in the laboratory or with pH test stripes to have a first hint on the pH value in the field.

Table 3. Methodology for laboratory analysis (Sahlemedhin and Taye, 2000)

Chemical/Physical Parameter	Methodology
Particle Size	via the density of a soil-water suspension with a Bouyoucos hydrometer.
pH (soil)	Potentiometrically in the supernatant suspension of a 1:2,5 soil: water (H2O) mixture; with pH meter
Electrical Conductivity (EC)	Soluble salts were determined in an extract of 1:5 soil: water (H2O); with a conductivity meter
Cation Exchange Capacity (CEC)	by measuring the total amount of a given cation needed to replace all the exchangeable cations (Ca+, Mg+, Na+, K+ and Al3+ as well as H+)
Available Potassium (K+)	Extraction with Morgan's solution and K detection by flame photometer
Calcium (Ca+) and Magnesium (Mg+)	EDTA (Ethylenediamine tetra acetate solution) titration method
Sodium (Na+), Potassium (K+)	Flame-photometer
Base Saturation Percentage (BSP) $$BSP = \frac{\text{Sum of exchangeable bases (Ca, Mg, K, Na)} * 100}{\text{Cation Exchange Capacity}}$$	
Exchangeable Sodium Percentage (ESP) $$ESP = \frac{\text{Exchangeable Sodium (meq/100 g soil)} * 100}{\text{Cation Exchange Capacity (meq/100 g soil)}}$$	

Source: Procedures for Soil and Plant Analysis, National Soil Research Center by Sahlemedhin, S. and Taye, B. 2000.

In Table 3, the laboratory methods which were used to analyse the physical and chemical parameters of the water and soil samples are listed. The described analytical methods are standard methods used in the Ethiopian National Soil Laboratory (Sahlemedhin and Taye, 2000).

Soil salinity is measured via laboratory analysis measuring the electrical conductivity of a saturated soil paste extract (ECe) and is expressed in units of deciSiemens per metre (dS/m). For this study and in accordance with the available laboratory facilities, soluble salts were determined in an extract of 1:5 soil - water suspension with a conductivity meter. To be able to apply the classification system according to Richards *et al.* (1954), $EC_{1:5}$ had to be converted to ECe values. In accordance with a conversion factor of 4 to 5 (ECe = 4 to 5 $EC_{1:2}$) the conversion factor between $EC_{1:5}$ and ECe was used as 10 to 12.5. All given EC values of soil samples in this article, are therefore converted $EC_{1:5}$ values.

Standards and threshold values for water quality analysis were chosen according to FAO's guidelines on water quality for irrigated agriculture (FAO, 1989). The standards and threshold values for soil chemical and physical analysis were taken from the pertinent guidelines issued by the Ethiopian Ministry of Water Resources (2002). FAO guidelines, based on the results of Rhoades (1977) and Oster and Schroer (1979), were used to identify potential infiltration problem due to sodium in irrigation water (FAO 1989, 1992).

Results and Discussion

Irrigation water source of Wonji/Shoa Sugar Plantation

The EC value of the irrigation water source of Wonji/Shoa Sugar Plantation at the time of the study (May 2006) was 293 μS/cm (Table 4) which does not indicate any problems concerning salinity caused by the used water sources. The threshold value given by FAO is 700 μS/cm (FAO 1989). EC values as displayed in Table 4 of samples taken from water stored in night storages and reservoirs and reused for irrigation, including Awash River water blended with drainage and excess water from the sugar factory, range from 341 - 388 μS/cm which indicates that the usage of reservoir water for irrigation has no adverse effects on the irrigated soils with respect to salinity and can be used as irrigation source.

Table 4. Results of water sampling analysis at Wonji Sugar Plantation

Sample No	EC (field)	pH	Ca	Mg	K	Na	SAR	Type of Waterbody
	μS/cm		Meq/lt					
W 001	293	7,8	1,346	0,334	0,226	1,464	1,60	River
W 002	362	6,5	1,838	0,364	0,318	1,410	1,34	Reservoir (factory water)
W 003	341	6,6	1,576	0,374	0,278	1,500	1,52	Canal (river, effluent)
W 004	357	6,3	1,732	0,360	0,328	1,804	1,76	Drain
W 005	265	7,6	1,384	0,346	0,228	0,958	1,03	Canal
W 008	388	7,2	1,856	0,424	0,338	1,780	1,67	Reservoir
W 011	296	7,8	1,354	0,350	0,224	1,424	1,54	River
W 012	1391	7,8	4,626	1,258	0,124	8,640	5,04	Groundwater (Plot No 101)
W 013	963	7,8	5,290	2,096	0,448	4,264	2,22	Groundwater (Plot No 35)
W 014	1590	7,4	7,944	1,660	2,430	6,038	2,76	Groundwater (Plot No 21)

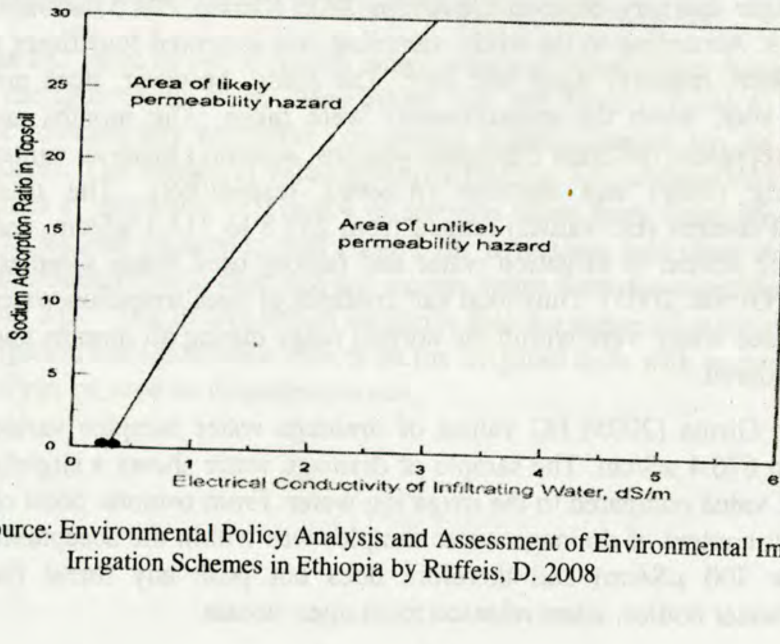
A study conducted by the Research and Training Services Division, Ethiopian Sugar Industry Support Centre in 2005 (Girma, 2005) showed similar results. According to the study, sampling was executed four times a year in October, January, April and July. The study, however, does not indicate the year, when the measurements were taken. The months are supposed to represent different Ethiopian seasons, autumn (*Tsedey*), winter (*Bega*), spring (*Belg*) and summer (*Kiremt*), respectively. The total measured salt content (EC values) ranged from 253.8 to 314.4 μS/cm, and 274.8 to 356.2 μS/cm in irrigation water and factory used water samples, respectively (Girma, 2005). Thus total salt contents of both irrigation water and factory used water were within the normal range during all months and seasons considered.

According to Girma (2005) EC values of drainage water samples varied from 391.6 to 676.4 μS/cm. The sample of drainage water shows a slightly increased EC value compared to the irrigation water. From osmotic point of view total salt content of drainage water samples was within the acceptable range (below 700 μS/cm) and therefore does not pose any threat for downstream water bodies, when released to an open stream.

Rhoades (1982) suggested threshold values of SAR of topsoil and EC of infiltrating irrigation water for maintenance of soil permeability. According to this diagram all water samples taken from the irrigation source and the reservoirs are slightly outside or within the range of likely permeability hazard (Figure 4); however, no infiltration problems due to the very low SAR values (Table 4) are to be expected, when water from various sources is used for irrigation purposes. This is true for the irrigation source as well as for re-used reservoir water and factory effluents.

Considering the ratio of sodium to calcium (Na:Ca), which is below 3:1 for all water samples taken at Wonji/Shoa scheme problems regarding infiltration are unlikely. According to FAO (1999) the irrigation water in use might increase infiltration especially on light sandy soils because salinity is less than 0.5 dS/m, which is however very unlikely to occur, taking into account that most cultivated and irrigated soils can be classified as clay soils.

Figure 4. Effect of EC of irrigation water and SAR of top soil on infiltration rate according to Rhoades 1982) at Wonji/Shoa irrigation scheme

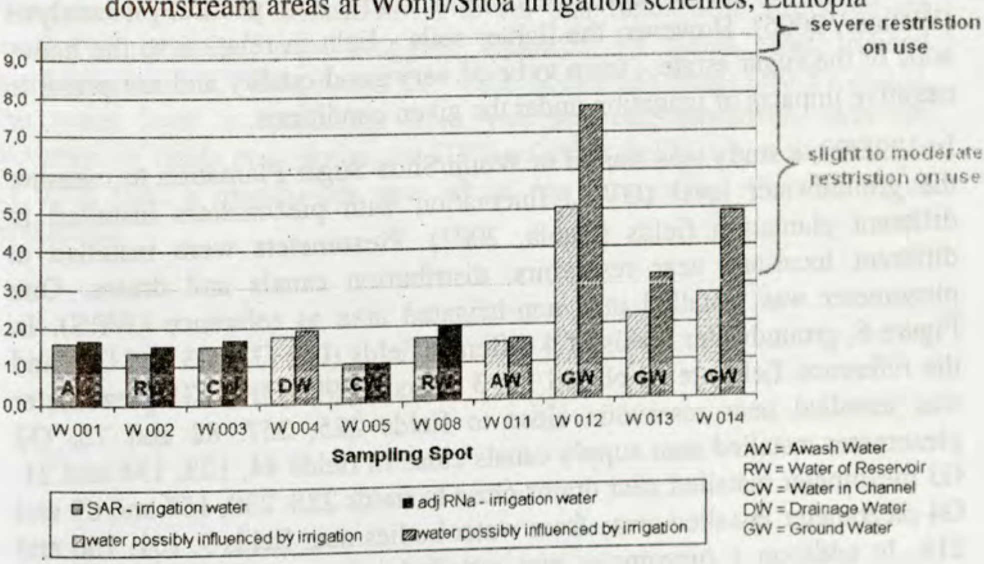


Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

Taking all evaluation methods related to sodicity and soil infiltration rate in to account, none of the sampled water sources is likely to have adverse effects on soil permeability if used for irrigation.

Samples taken from groundwater have to be classified as slightly to moderate saline with EC value ranging from 963-1590 μS/cm (Table 4). Most probably leached salts accumulate in the groundwater aquifer. The study by Girma (2005) shows that EC and SAR values of all groundwater samples indicate that the possibility of slight to moderate soil physical degradation exists, if such quality groundwater is allowed to appear to the soil surface. Observations of the ground water quality within one meter depth of all sugarcane fields were considered in this study. EC, SAR and adj. RNa values (Figure 5, Table 4) calculated for our study confirm this statement. It is conceivable that the occurrence of groundwater at shallow depth could result in both water logging and physical degradation, due to secondary salinization and unfavorable EC to SAR ratio, of topsoil in most sugarcane fields.

Figure 5. Sodium absorption ratio in different water bodies in upstream and downstream areas at Wonji/Shoa irrigation schemes, Ethiopia



Source: Field Parameter Evaluation to Support Environmental Impact Analysis of Irrigation in Ethiopia by Wallner, K. 2006.

Irrigation and Groundwater Hydrology at Wonji/Shoa Sugar Plantation

Investigations showed that on some fields the groundwater table is less than one meter underground level (ARS Annual Report, 1994). The same report indicated that in some fields downward percolation of irrigation water below the root zone, especially in soils classified as heavy black coloured soils, is so slow that it caused temporary storage within the root zone (in some places up to 10 days after irrigation). These drainage problems have even become one of the major factors in determining the composition of cane variety (Tariku, 2001). In fields located near reservoirs, irrigation canals and drains suppressed cane growth due to seepage and ground water table rise could be observed. Kediru (1997) stated that cane loss due to this problem is economically significant.

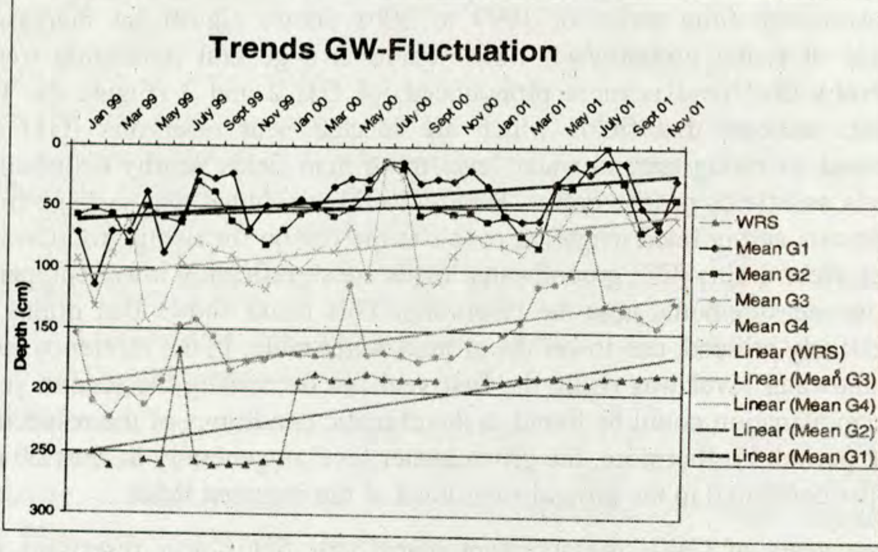
What has been reported before and confirmed in the field work for this study are problems with a high water table and waterlogged fields. Especially on fields with heavy clayey soils problems with water logging have been discovered during the field study and profile pit analysis (Wallner, 2006). However, the lighter soils - light in relation to the heavy soils of the sugar estate - seem to be of very good quality and not prone to negative impacts of irrigation under the given conditions.

In 1998/99, a study was started in Wonji/Shoa Sugar Plantation to measure the groundwater level (GWL) fluctuation with piezometers installed in different plantation fields (Habib, 2002). Piezometers were installed at different locations near reservoirs, distribution canals and drains. One piezometer was installed in a non-irrigated area as reference (WRS). In Figure 6, groundwater levels of 4 different fields (G1, G2, G3 and G4) and the reference field are displayed for 3 years (1999-2001). G1 piezometer was installed near reservoirs close to fields 225, 257, 82 and 75, G2 piezometer installed near supply canals close to fields 44, 128, 134 and 21, G3 piezometer installed near drains close to fields 228, 230, 157 and 69 and G4 piezometer installed away from water bodies near fields 9, 101, 166 and 214. In addition 1 piezometer was installed in an uncultivated reference location.

Measurements are given in depth in cm from soil surface. The measurement of groundwater table of the reference area (WRS) shows the maximum water table depth values in all years and months. Even this short measurement time series of 1999 to 2001 shows significant increasing trends of rising groundwater table. There is a general increasing trend, whereby this trend is more pronounced for G1, 2 and 3 (Figure 6). The results indicate that fields which are located near reservoirs (G1) are affected by rising ground water level more than fields nearby distribution canals and fields nearby drains. Habib (2002) concluded that seepage from reservoirs and unlined irrigation canals is the reason for rising groundwater level. Near drains (G3) groundwater levels are significantly lower compared to the measurements near the reservoirs. This result shows that drains, if effectively utilized, can lower the ground water table. In the reference area, groundwater level was rising the first year but decreasing the second year. One explanation could be found in the climatic conditions of the respective time period. Furthermore, the groundwater level is generally at least 50 cm deeper compared to the groundwater level of the irrigated fields.

Three years of GWL measurement reveal that fields near reservoirs are highly affected by water logging followed by fields near unlined distribution canals, fields away from water bodies and fields near by drains. The water level is increasing from year to year. Moreover, with the exception of fields near drains the GWL of other fields is less than 60 cm for more than 6 months per year which has a negative effect on sugar production.

Figure 6. Trends in the ground water level at Wonji/Shoa sugar plantation over three years (Habib, 2002; Wallner, 2006).



Source: Field Parameter Evaluation to Support Environmental Impact Analysis of Irrigation in Ethiopia by Wallner, K. 2006.

Upstream of Wonji/Shoa Sugar Plantation Koka Dam marks the biggest artificial water body in the Awash River Basin. The reservoir capacity during initial operation in 1959 was 1850 Mm3, in 1999 the capacity was reduced to 1186 Mm3 (McCartney, 2007). Within 40 years the capacity was reduced by 1/3, whereby siltation is the main cause. The reservoir has a significant influence on the groundwater flow of the Wonji Basin and potentially contributes to the rise of the groundwater table of the plantation. Teshome (1999) stated that the surface inflow from the highland regions and the mentioned groundwater inflow from Koka Dam make the area more complex as far as the hydrological system is concerned. Furthermore, the direction of the regional groundwater flow of the basin is from West to East. Groundwater recharge is estimated as 557.75x106 m³ per year based on meteorological and hydrological data. The estimated groundwater demand in the basin is approximately 4.7x106 m³ which is much less than the annual recharge.

Irrigation and Soils at Wonji/Shoa Sugar Plantation

The tested soils (Table 5) show an EC ranging from 2137.5 (017) to 5343.75 μS/cm (018) and can be rated as salt free to slightly salt-affected according to the Ethiopian Ministry of Water Resources (2002). The higher EC values were mainly measured at deeper soil depth. The topsoil layers generally show lower EC values. This can be taken as an indication for secondary salinisation induced by capillary rising from the shallow groundwater table as shown by Habib (2002). Considering the described rising of the groundwater table and the climatic conditions of this region, the elevated EC values of the groundwater samples could lead to secondary salinisation as observed in some parts of the Melka Sedi/Amibara project (EIAR, 2006). Despite the fact that the reason for the rising groundwater table has not yet been identified exactly as shown in the previous paragraph, an impact of irrigation activity can be assumed in some respects. Therefore proper irrigation water management and the lining of the reservoirs which are identified as potential sources of water percolating to the groundwater are highly recommendable to guarantee the sustainability of the irrigation project and minimize the negative impact the rising groundwater table could

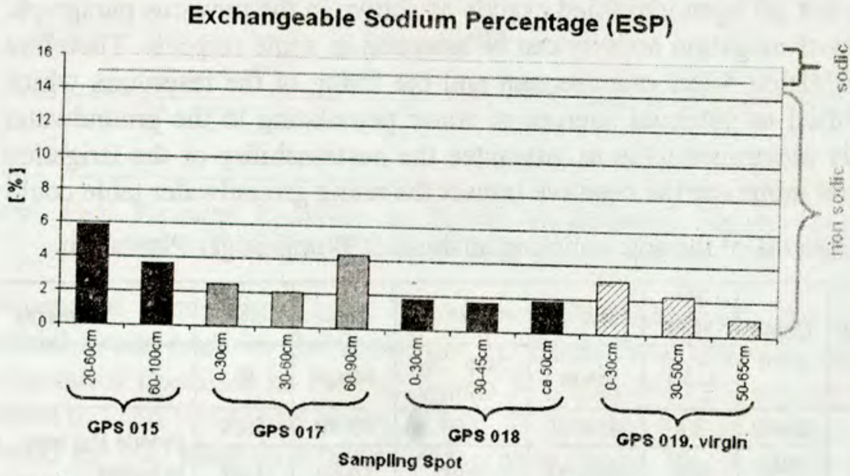
Table 5. Results of the soil sampling analysis at Wonji Sugar Plantation

Sampling No	Depth (cm)	P^H H_2O	ECe	Na	CEC	ESP	Remarks
		1:2.5	μs/m	meq/100g Soil	Meq/l	%	
015	20-60	8,4	4590,0	2,93	49,80	5,88	Profile Pit, non irrigated
	60-100	8,4	3521,25	1,85	50,60	3,67	
017	0-30	7,7	1698,75	0,98	39,60	2,47	Field Nr 22; irrigated with mixed water, wet soil; covered with sugar cane;
	30-60	7,8	1721,25	0,96	46,20	2,08	
	60-90	8,0	1912,5	2,23	51,40	4,34	
018	0-30	7,4	2925,0	0,99	55,20	1,79	irrigated
	30-45	7,4	5298,75	0,98	58,40	1,68	
	ca 50	7,7	5343,75	0,97	52,00	1,87	
019	0-30	8,1	2036,25	1,47	46,80	3,14	uncultivated soil close to field 261
	30-50	8,4	2137,5	1,17	51,40	2,28	
	50-65	6,7	2171,25	0,52	52,40	0,99	

either have on plant root development and therefore on plant growth and yield or on soil chemical and physical properties in terms of secondary salinisation and soil crusting which consequently influences the infiltration rate of the affected soils and the plant water uptake negatively.

The ESP (Figure 7) of the soils lies below 6% (0.99 to 5.88%) which is definitely below the threshold of 15% and therefore the soils can be rated as non-sodic. Decreases in yield would only be expected for extremely sensitive crops (ESP = 2 - 10) but should not pose any threat to cultivation of sugar cane.

Figure 7. Exchangeable sodium percentage of tested soil at Wonji Sugar Plantation



Source: Field Parameter Evaluation to Support Environmental Impact Analysis of Irrigation in Ethiopia by Wallner, K. 2006.

Irrigation water source of Finchaa Valley Sugar Estate

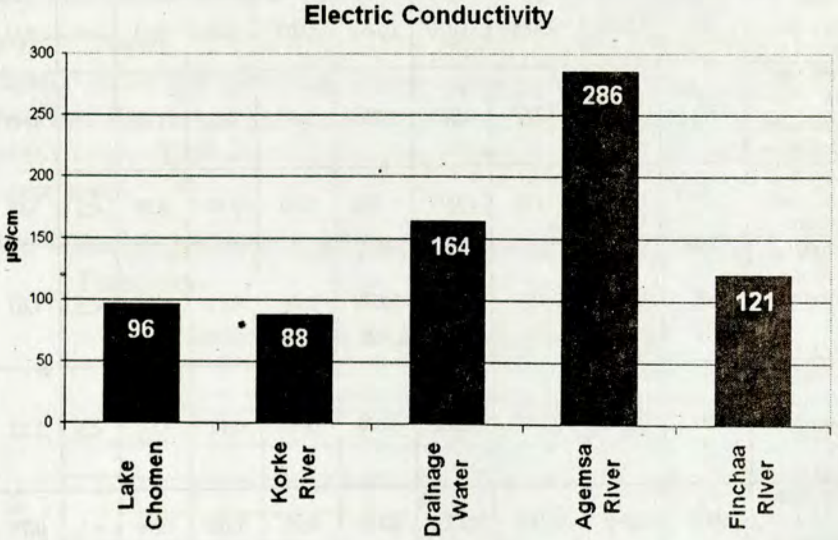
The values of the EC measurement in the field (Table 6) are all below the threshold value of non saline to slightly and moderate saline of 700 μS/cm, as given by FAO. This indicates no problems with salinity caused by the available water source. A detailed analysis of the EC values of different water bodies in the adjacent area of the estate provides an insight in the irrigation and drainage system of the estate.

Table 6. Results of water sampling analysis at Finchaa Sugar Estate

Sample No	Remarks	EC (field)	Ca	Mg	K	Na	RNa	SAR	Na:Ca		Ca:Mg	
		μS/cm	Meq/lt									
045 / RW	Finchaa dam, Lake Chomen	96	0,474	0,288	0,020	0,061	0,07	0,10	0,13	<3	1,65	>1
026 / CW	Main Canal, 3 km downstream of Diversion	99	0,359	0,247	0,021	0,061	0,07	0,11	0,17	<3	1,46	>1
030 / DW	Drainage ditch, young sugarcane	164	0,549	0,173	0,003	0,296	0,35	0,49	0,54	<3	3,18	>1
033 / FR upstr.	Finchaa river, upstream sugar factory	106	0,439	0,263	0,023	0,078	0,09	0,13	0,18	<3	1,67	>1
036 / FR downstr.	Finchaa river, downstream sugar factory	121	0,549	0,247	0,072	0,078	0,09	0,12	0,14	<3	2,22	>1
038 / GW	Groundwater, Piezometer	477	0,599	0,757	0,023	0,826	0,92	1,00	1,38	<3	0,79	<1
042 / GW	Groundwater, Piezometer	352	1,397	0,617	0,031	1,305	1,40	1,30	0,93	<3	2,26	>1

Figures 8 and 9 show the EC values of different water bodies within the irrigation scheme from upstream to downstream area of Finchaa Sugar Estate. The EC value of the reservoir is 96μS/cm and 88μS/cm for Korke River, one of the tributaries of Finchaa River in the far upstream area of the scheme. The EC values of the drainage water (164 μS/cm) and of tributaries of Finchaa River, e.g. Agemsa River (286 μS/cm) which are located further downstream of the estate are higher compared to the values in the upstream area.

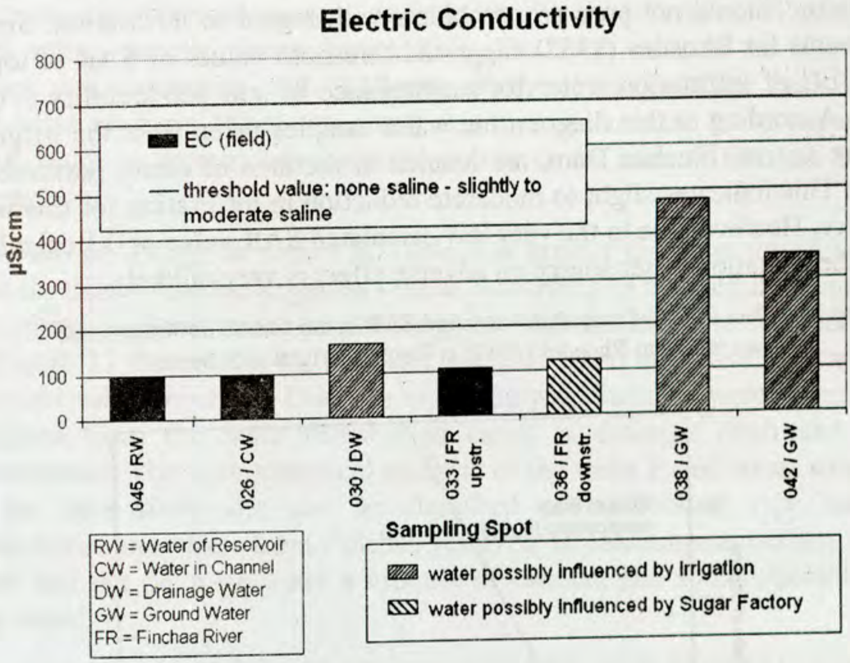
Figure 8. Electric conductivity (EC, in μS/cm) in irrigation water source, drainage water, Finchaa River and tributaries at Finchaa Irrigation Scheme



Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

This fact together with the increased EC value of Finchaa River (121 μS/cm) measured at a location downstream of the schemes' command area shows that the tributaries of Finchaa River crossing the irrigated area serve as the natural drainage system of the sugar farm. The increasing EC value of Finchaa River indicates that salts are being leached from the soils due to irrigation, but are highly diluted further downstream. An adverse impact on downstream water bodies and downstream users solely derived from EC measurements cannot be assumed. This however does not include potential negative impacts by the use of agro-chemicals, which could not be determined during this study, but needs further investigation.

Figure 9. Electric conductivity (EC, in µS/cm) in different water bodies in upstream and downstream areas at Finchaa Irrigation Scheme

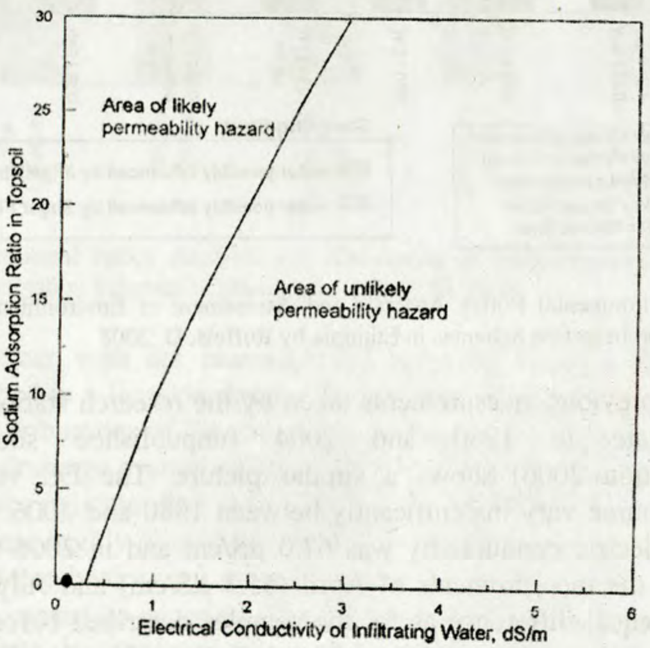


Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

Data from previous measurements taken by the research station at Finchaa Sugar Estate in 1980 and 2004 (unpublished source/personal communication 2006) shows a similar picture. The EC values of the irrigation source vary insignificantly between 1980 and 2006. In 1980 the measured electric conductivity was 67.0 μS/cm and in 2006 99.0 μS/cm. Comparing the measurements of April (65.3 μS/cm) and July 2004 (88.1 μS/cm) an equal difference as for the samples described before is visible. Almost no difference was observed in the values from April 2004 (88.1 μS/cm) and May 2006 (99.0 μS/cm). The compared EC measurements of different years and seasons indicate rather a seasonal variation than a change during the last 26 years. One possible reason could be heavy rains during rainy season (*Belg*) and the dilution caused thereby of the water source. Rain water usually is characterised by low EC values.

With respect to potential infiltration problems the ratio of sodium to calcium (Na:Ca) of all samples, as shown in Table 6, is below 3:1 and therefore should not pose any problems with regard to infiltration. Similar accounts for Rhoades (1982) suggested threshold values of SAR of topsoil and EC of infiltration water for maintenance of soil permeability (Figure 10). According to this diagram the water samples taken from the irrigation water source, Finchaa Dam, are located in the area of likely permeability risk. This indicates slight to moderate reduction in infiltration for this water source. However due to the very low calculated SAR value of 0.1 calculated for the irrigation water source an adverse effect is very unlikely.

Figure 10. Effect of EC of irrigation water and SAR in top soil on infiltration rate according to Rhoades (1982) at Finchaa Irrigation Scheme



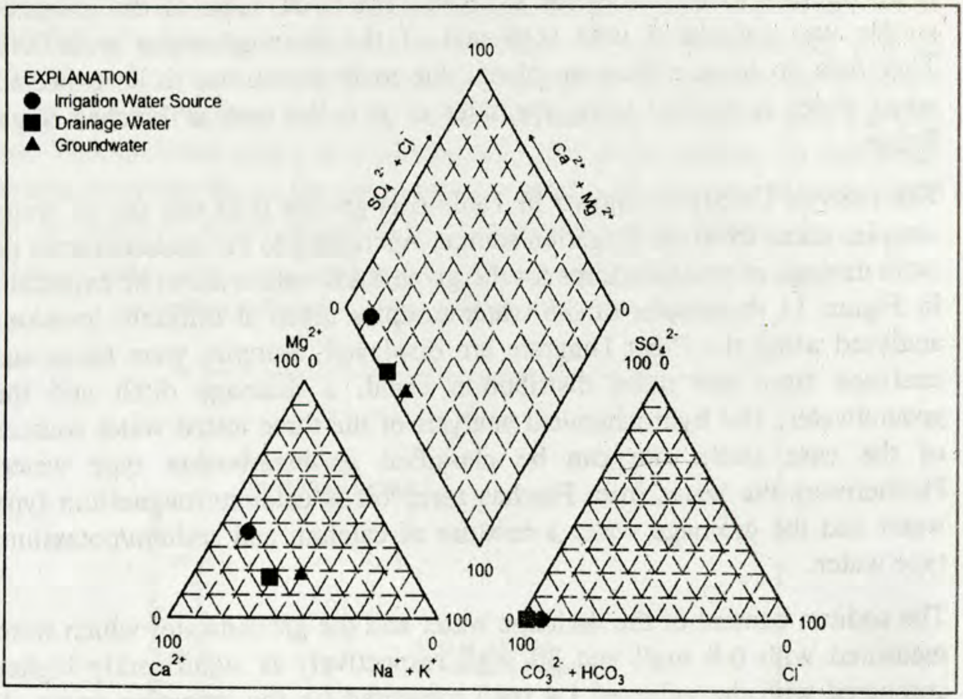
Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

Taking these two evaluation methods related to sodicity and soil infiltration rate into account, none of the sampled water sources is likely to have an adverse effect on soil permeability if used for irrigation. The threshold values for sodium are given as SAR values. The rating for slight to moderate restriction on use ranging from 3 to 9 neither is obtained using the SAR values nor the values for adj RNa. The SAR value of the irrigation source was calculated with 0.10 and of the drainage water with 0.49. Therefore no toxic effects on plants due to irrigation are to be expected, when water is applied using sprinkler as it is the case at Finchaa Sugar Estate.

The ratio of Ca/Mg as shown in Table 6 is greater than one for all water samples taken from the irrigation source. According to the measurements no extra damage of soil structures for the given SAR-values are to be expected. In Figure 11 the results of the water samples taken at different locations analysed using the Piper Diagram are displayed. Samples were taken and analysed from the main distribution canal, a drainage ditch and the groundwater. The hydrochemical analysis of the three tested water sources of the case study site can be classified as bicarbonate type water. Furthermore the water from Finchaa reservoir is calcium-magnesium type water and the drainage water a mixture of calcium and sodium/potassium type water.

The sodium content of the drainage water and the groundwater which were measured with 6.8 mg/l and 30 mg/l respectively is significantly higher compared with the value of 1.4 mg/l measured for the irrigation water. A possible explanation could be leaching of sodium from the soil through applied irrigation water.

Figure 11. Chemical analysis of the water samples at Finchaa Valley Sugar Estate using Piper Diagrams



Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

The ratio of adj RNa to EC of the irrigation water source indicates a potentially severe reduction of the infiltration rate over time. This imposed sodicity has the potential to destroy the soil structure and lead to soil crusting of the affected soil especially when EC value is low as it is the case for the utilized water source (96 μS/cm). The dispersive effects adversely influence the physical properties, e.g. infiltration rate and aggregate stability of the soil (FAO, 1989). The extent of the impact highly depends on the texture, clay-sized particles and CEC of the soil (van de Graaff and Patterson, 2001). Since the filling of smaller pore space, sealing the soil surface and therefore reduces infiltration rates, by dispersion of finer soil particles is more likely to happen in soils with high clay content and CEC value. Impact on soils which can be classified as sandy loam to sandy clay loam with sand content over 60 % found within the irrigated area of Finchaa Valley might prove to be less severe. As salinity of both applied water and the soil solution is relatively low no further swelling and dispersion of clay minerals caused by the water source are to be expected.

Ayers and Westcot (1985) stated that low salinity water is corrosive and tends to leach surface soils free of soluble minerals and salts, especially calcium, reducing their strong stabilizing influence on soil aggregates and soil structure. They further state that without salts and without calcium, the soil disperses and the dispersed finer soil particles fill many of the smaller pore spaces; sealing the surface and greatly reducing the rate at which water infiltrates the soil surface. Soil crusting and crop emergence problems often result, in addition to a reduction in the amount of water that will enter the soil in a given amount of time and which may ultimately cause water stress between irrigations.

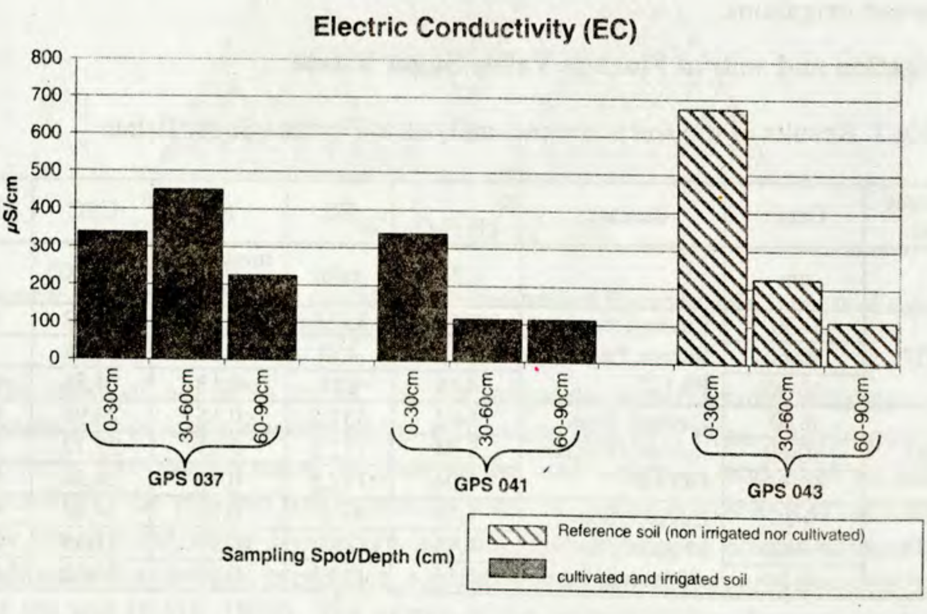
Irrigation and soils at Finchaa Valley Sugar Estate

Table 7. Results of the soil sampling analysis at Finchaa Sugar Estate

Sample No.	Depth	Remarks	pH H_2O	EC	Na	CEC	ESP
	cm		1:2.5	μs/m	meq/100g Soil	meq/100	%
037	0-30	Luvisol, from furrow, field Nr. PS 122	5,62	337,5	0,13	14,02	0,93
	30-60		5,2	450	0,16	14,48	1,10
	60-90		4,89	225	0,13	14,56	0,89
041	0-30	Luvisol, from furrow, field Nr. GO 107	5,62	337,5	0,15	23,95	0,63
	30-60		5,04	112,5	0,13	25,12	0,52
	60-90		5,04	·112,5	0,17	26,54	0,64
043	0-30	Luvisol, non irrigated, not cultivated, forest	4,86	675	0,13	24,87	0;52
	30-60		4,48	225	0,11	21,46	0,51
	69-90		4,56	112,5	0,13	15,52	0,84

In the case of Finchaa Sugar Estate results of previous research activities conducted in Finchaa Valley were taken as reference data. Before the establishment of Finchaa Sugar Farm in 1998 a comprehensive soil survey campaign was conducted on East and West Bank of Finchaa River. Before that only the East Bank had been used for crop cultivation by a state farm established in 1975 operating until 1995. The West Bank had neither been used for crop production nor irrigation at that point of time. Therefore the data of the previous soil survey and the survey conducted for this study show the different status of soil quality of cultivated, fallow and irrigated land over a period of more than 30 years. The sampling activities for this study were compared with the data from the soil survey of the West Bank undertaken in 1998.

Figure 12. Electric conductivity (in μS/cm) of irrigated and reference plot at Finchaa Irrigation Scheme

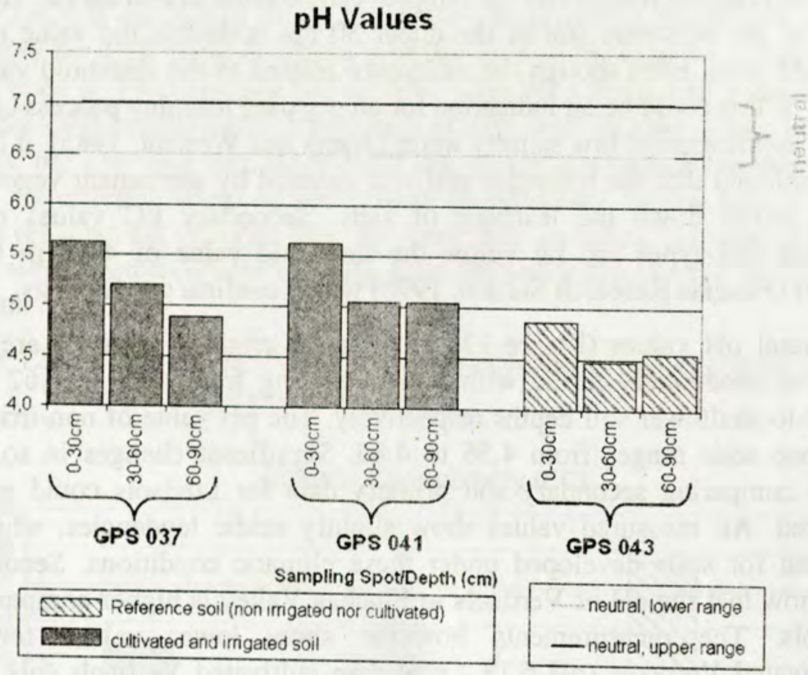


Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

The EC values of all analysed soils of Finchaa (Figure 12 & Table 7) range from 112.5 to 675 μS/cm, which is far below the threshold value of 4 dS/m (4000 μS/cm). Therefore they are not affected by salinisation. According to the Ethiopian MoWR (2002) the samples can be rated as non saline. The EC value of the reference soil of the upper 30 cm is double the value of the irrigated plots. Even though the difference related to the threshold value is only 8 % this could be an indication for an ongoing leaching process caused by the application of low salinity water (Ayers and Westcot, 1985). It has to be mentioned that the reference soil was covered by permanent vegetation which slows down the leaching of salts. Secondary EC values of all analysed soil types are far below the threshold value of 4 dS/m (4000 μS/cm) (Finchaa Research Station, 1998) which confirm our findings.

In general pH values (Figure 13) of sampled irrigated Luvisols are very acidic to moderately acidic with values ranging from 4.89 to 5.62 from deeper to shallower soil depths respectively. The pH value of non-irrigated reference soils ranges from 4.56 to 4.86. Significant changes in soil pH values comparing secondary and primary data for Luvisols could not be observed. All measured values show slightly acidic tendencies, which is common for soils developed under these climatic conditions. Secondary data show that the pH of Vertisols in Finchaa Valley is higher compared to Luvisols. The measurements however show lower values for the uncultivated Vertisols (pH 6.13 - 6.5) than cultivated Vertisols (pH 6.9 - 7.37). This difference between secondary and primary data might be an indicator for ongoing decline of soil pH caused by irrigation and leaching processes. Washed-out-soils tend to undergo acidification. Water dominated soils (soils of humid regions) have low values of pH, because their content of organic and carbonic acids is often subject to replenishing and recharge by rainfall. Under these conditions, the acids attack minerals, producing more acidity (Mirsal, 2004). In moderately acidic soils P, Ca, Mg and Mb may be deficient. Fertilizers (ammonium sulphate and triple super phosphate) which may increase the acidity should be avoided (MoWR, 2002).

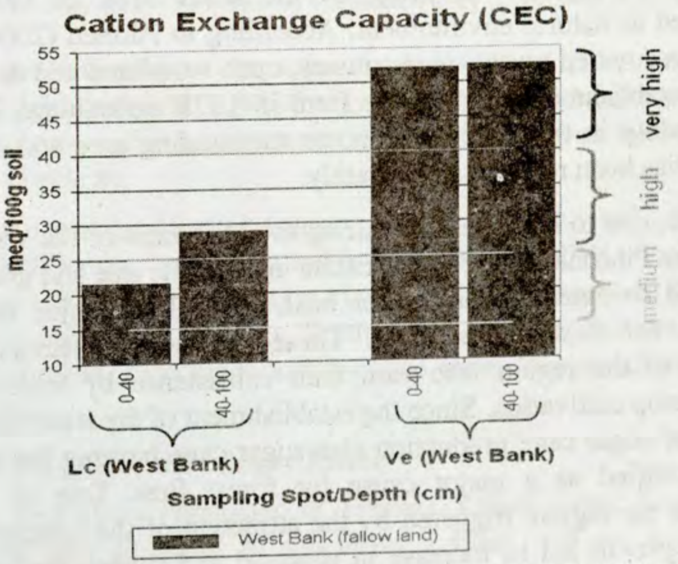
Figure 13. pH values of irrigated plots (037, 042) and reference plot (043) at Finchaa Irrigation Scheme



Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

The CEC values as displayed in Table 7 of the tested Luvisols (14.02 to 14.56 meq/100g) indicate low to medium response to fertilizer application which is typical for soils with low clay content. Low CEC values can be caused by losses resulting from leaching-out, especially sodium (Na) is highly exposed to this process (MoWR 2002).The CEC of Vertisols (23.95 and 26.54 meq/100g) however shows a different picture. The CEC shows an increasing trend with increasing soil depths. As the clay content of this soil type is significantly higher, the response to fertilizer application is more effective. This makes it even more important to plan agrochemical management for each soil type differently. The reference soil however shows a contrariwise tendency with a CEC value of 24.87 meq/100g in the upper 30 cm of soil depth and 15.52 meq/100g below 60 cm. The primary data of the year 2006 confirm the findings of the feasibility study conducted in the pre-design phase of the irrigation scheme. Proper management of agrochemicals is indispensable to avoid contamination of Finchaa Valley aquifers.

Figure 14. Cation Exchange Capacity of soil samples of Finchaa Valley Sugar Estate (Finchaa Research Station, 1998)



Source: Environmental Policy Analysis and Assessment of Environmental Impacts of some Irrigation Schemes in Ethiopia by Ruffeis, D. 2008

Irrigation and ecosystem at Finchaa Valley Sugar Estate

In terms of land use Finchaa Valley was mainly dominated by agro-pastoral activities. In 1975 the state farm which mainly produced food and commercial crops until 1991 was established. About 3500 ha of land were cleared for these agricultural activities. Before that the valley was under natural vegetation cover and very few agricultural plots could be observed. Starting from 1991 up to now more than 8064 ha of land has been cleared and irrigated for sugar production (Ahmed, 2006). From 1975 to 1991 these parts of Finchaa Valley area have changed from primary to tertiary economic production; from traditional agricultural to industrial and commercial production respectively. The dominant land use classes are irrigation agriculture and agro-pastoral within the valley area and rain fed agriculture mainly in the high land area. These figures demonstrate clearly that tremendous land use and land cover changes in Finchaa valley area have taken place over the last 30 years. Agricultural land increased and the natural vegetation coverage decreased significantly (Zeleke, 2005). More than 95 % of the land coverage of the study area in 1972 can be characterised as natural environment. According to Ahmed (2006) most of the area was covered by savannah grasses, open woodland and dense forest. With the establishment of the state farm in 1975 agricultural lands have been expanding in the valley and in the surrounding area and the natural land cover has been reduced significantly.

Furthermore, due to land clearing during establishment of the state farm in 1975 and the Finchaa Valley Sugar Estate in 1991 the tree and grass species are exposed to extensive and sever bush fires. Two major reasons are responsible for these forest fires. These are natural factors and the inhabitants of the region who earn their subsistence by collecting wild honey and crop cultivation. Since the establishment of the state farm and the beginning of sugar cane production also sugar cane burning for harvesting can be identified as a major cause for forest fires. Due to migration processes to the region, triggered by the attraction of the scheme, boosted population growth led to increase in charcoal and timber production and demand for firewood. Besides the agricultural activities of the Sugar Estate due to land clearing for irrigation purposes these fires put high pressure on the natural environment of the valley area and cause severe damages of the original land cover (Ahmed, 2006). This development over the past 30 years brought changes in the land use, land cover and especially in the natural ecosystem of Finchaa Valley.

An afforestation program was installed by the management of the sugar factory under the forestry department which managed to reclaim not more than 7.5 percent of the land under irrigation. If the future goal of the department is attained only 27.3 percent of the equivalent area currently under irrigation would be reclaimed.

Table 8. Present and projected land use (in hectares) for forest and irrigated agriculture in the Finchaa Valley Sugar Estate

Land use	Current area (ha) in 2006	Planned area for extension (ha)
Forest	600	2200
Irrigated agriculture	8064	13000

Source: Geographic Information Systems and Remote Sensing Integrated Environmental Impact Assessment of Irrigation in Fincha Valley by Ahmed, A. 2006.

Since the establishment of the sugar estate the area under irrigation has increased significantly. In 1997/98 about 932.27 ha of land was harvested and after eight years this area increased by more than seven folds to 8064 ha in 2005/06 (Table 8).

The assessment of land cover change undertaken by Ahmed (2006) using normalized difference vegetation index (NDVI) of satellite images of 1972 and 2000 reveals that the vegetation biomass of 2000 compared to the 1972 has been diminished significantly. Furthermore he states that the expansion of cultivated areas, bare lands and built up areas become obvious in the NDVI analysis.

Erosion at Finchaa Valley Sugar Estate

According to a study conducted at Finchaa Valley Sugar Estate, Girma (1995) stated that all forms of soil erosion, sheet, rill and gully erosion occur in the project area and the surrounding land. All these forms of erosion can be found on both the cleared land (former state farm) and the virgin bush land. The soil types in the area are characterised by medium to coarse texture with sand content of the topsoil layers of the sampled soils ranging from 50 to 70 %. This can be seen as an indication that the erosivity potential in this region is very high. Random measurements show that sheet erosion occurs estimated in the range of 5 to 10 mm/y or equivalent to approximately 100 ton/ha-y (Girma, 2005). In the report it is mentioned that gullies have grown by up to 150 m in length over the past 15 years. Gully depth up to 4 m and width up to 20 m were measured.

One factor which is considerably contributing to soil erosion is the current practice of burning biomass and fallow left land during dry season. This leaves the soil almost totally exposed to direct rain impact. Another factor is the uncontrolled degradation of the biomass caused by cutting trees used as firewood, shown in the previous section of the paper. The large scale deforestation exposed the soil for agents of erosion and contributes for high runoff. This cumulative impact induced by migration tendencies which are caused by the attraction of the large scale irrigation system aggravates deforestation, destruction of functioning eco-systems and therefore erosion in the Valley area. The demographic data of Finchaa Valley clearly shows this development. Pre 1975 before the state farm was established, Finchaa Valley was not permanently inhibited. The commencement of the state farm attracted people and let people migrate to the area settle down permanently. In 1991, when the potential of the valley for sugar production was identified, the state farm handed over the area to Finchaa Sugar Project, which triggered another migration movement into the area. Population numbers radically increased. From 1991 to 2005 the population of Finchaa Valley has increased by more than ten folds, from 2243 to 26130, respectively.

To reduce erosion hazards caused by rainfall run-off and splash erosion Girma (1995) recommended that before and during land clearing, cane fields should be at or near canopy by June before the rainy season starts. Girma (1995) further mentioned that the surrounding steep escarpments of Finchaa Valley with average slopes ranging from 5 to 65 percent create favourable condition for erosion. High rain fall intensity of 90-120 mm/hr aggravates the erosion hazard as rain fall intensity greater than 50mm/hr is believed to be erosive. On one hand the eroded soil material from the steep escarpments increases soil fertility of the irrigated areas of the valley bottom, on the other hand however these soil deposits can lead to soil degradation in the long run. Ahmed (2006) stated that according to digital elevation model analysis that elevation of the Finchaa Valley bottom declines from south to north and from the eastern and western edges to Finchaa River. The run off estimations indicate that the eroded fertile soil is deposited to the tributaries of Finchaa River which finally drains to Abay (Blue Nile) River. The topographic set-up of Finchaa Valley as well as human activities makes soil erosion to be a critical problem in the study area. Assuming that these present trends continue, the problem of soil and land degradation induced by soil erosion may threaten the sustainability of the irrigation project.

Conclusions

According to the Ethiopian Irrigation Development Program 26 medium and large-scale irrigation projects are planned to be implemented in the near future. Due to topographic reasons most of these already established or proposed large-scale irrigation schemes can be found in the lowlands of Ethiopia's major river basins such as Awash, Blue Nile and Wabe Shebelle River Basin. Over 11 million ha of land in the arid, semi-arid and desert parts of Ethiopia are known to be salt affected. Large areas of the Awash River Basin especially the middle and lower parts of the basin are saline or sodic or in saline or sodic phase and thus potentially exposed to salinisation and sodicity (EIAR, 2006). In order to avoid possible negative impacts of the expansion of irrigated agriculture in causing deterioration of land and soil quality, proper understanding of the quality of soil and irrigation water and implementation of appropriate measures have paramount importance for sustainable development.

As regards Wonji/Shoa Sugar Plantation, the most crucial environmental impact identified is related to improper irrigation management or impact of seepage from Koka Dam. Either way, inefficient drainage and seepage of water from reservoirs and unlined distribution canals contribute to rising of groundwater table. Investigations showed that on some fields of the Wonji/Shoa Plantation the groundwater table is less than one meter below soil surface. This tendency has mainly two adverse effects. The rise of the groundwater table up to the root zone interferes with the proper development of the planted crop, leads to damage of the soil structure and insufficient soil ventilation. Secondly it induces secondary salinisation due to capillary rising, a process which is indicated by the increasing EC values of the sampled soils. Lining of the distribution canals and the reservoirs could avoid excessive loss of irrigation water and make the application of water more efficient and therefore increase the overall water productivity of the schemes. More insight in the hydrological set-up of the whole region is required to plan for meaningful interventions on field scale level as well as regional level.

Irrigation with low salinity water has the potential of degrading irrigated soils and leaches salts from the soil continuum to downstream water bodies at Finchaa Sugar Estate and eventually can have adverse long-term effects on the sustainability of the sugar production. EC, SAR and RNa values of the utilized irrigation source in combination of the soils CEC suggests that application of this water might lead to infiltration problems and destroy the soil structure and lead to soil crusting over time. The evidence of soil erosion within and outside the projects command area has the potential to aggravate this tendency, affecting the soil composition and structure of cultivated and irrigated soils. The extent of the impact highly depends on the texture, clay-sized particles and CEC of the soil (van de Graaff and Patterson, 2001). In order to rule out soil degradation process caused by irrigation activities in combination with ongoing erosion processes further detailed analysis of aforementioned parameters and linkages is required.

Evaluation of past developments in the history of Finchaa Sugar Estate clearly shows the impact the establishment had on the existing ecosystem in Finchaa Valley. In developing countries like Ethiopia the GDP of a country highly depends on agricultural production and export earnings. Priorities have to be outweighed between conservation of valuable ecosystems and important contribution to a country's economy. In order to justify clearance of large natural forest areas agricultural production needs to be sustainable to avoid large scale land degradation and further adverse environmental impacts. Considering the planned extension of the scheme, Finchaa Sugar Factory under the forestry department will have to step-up the afforestation program to compensate negative implications on still intact and already destroyed forests and ecosystems in the valley.

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ETHIOPIAN JOURNAL OF DEVELOPMENT RESEARCH
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