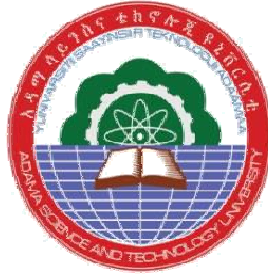


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**Assessing the Impact of Loading Lake Beseka Water Into the Awash River Along
With Potential Traits of Salinity/Sodicity Problems of Large Scale Irrigation
Farms in Middle and Lower Awash Basin**

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ABSTRACT

This study attempted to assess the current status of Awash River water quality with respect to spatial and temporal water quality variability along with the potential environmental effect of mixing the two water bodies. The objectives of this study were to determine the effect of blending of Lake Beseka in to Awash River with emphasis on Spatial and Temporal Variation to indicate the possible alternative recommendation options. Soil samples were collected during the month of October and November 2011. A total of 249 representative auger samples were taken from Melka Sedi and Melka Werer farms at a soil depth of 0-30 cm. Considering extreme heterogeneity of soils of Melka Sedi area with respect to salinity and sodicity and occurrence of wide range of the problem; attempt was made to collect soil sample systematically from every farm units of Melka Sedi area. While for Melka Werer area, with lesser extent of salinity and sodicity problems, soil samples was collected randomly at 2 km interval. Collected samples were delivered to the laboratory of Werer Research Centre, air-dried, ground to pass through 2 mm sieve and prepared for selected chemical analysis. Water sample were collected from the Awash River which is used as irrigation sources. The Awash River was sampled monthly at 10 sampling points for one year (June, 2014 - July, 2015) including Lake Beseka starting from upper to lower Awash along the main river course. Water samples were also collected from main irrigation and drainage canals of Amibara irrigation command area for one year.

Collected water samples were subjected to the analysis of pH, EC, dissolved cations (Ca, Mg, Na and K), alkalinity (HCO_3^- and CO_3^{2-}), Cl^- , SO_4^{2-} , NO_3^- Fluoride and Iron contents in the laboratory. EC and pH of the water samples were measured using conductivity meter and a digital pH meter, respectively (Greenberg et al., 1992). HCO_3^- and CO_3^{2-} ions were determined by titration with standard hydrochloric acid; Cl^- by silver nitrate titrimetion method, and SO_4^{2-} turbidimetrically by spectrophotometer. NO_3^- concentration in the samples was analyzed as per the methods outlined by Melese and Gemechu (2010), and fluoride and iron was determined following a standard analytical procedure. Ca and Mg ions were measured

using atomic absorption spectrophotometer, whilst Na and K was analyzed using flame photometer. Turbidity for Awash River water sample was measured using standard method. Derived parameters (SAR and RSC) were estimated from the measured constituents using appropriate equation. Finally, the water under investigation was classified to the different suitability classes as per the criteria established by the USSLS (1954) and Greenberg et al. (1992). Soils of the area exhibited high range of variation with respect to ECe values (Appendix Table 4A). ECe value varied from 0.33 dS/m to 82.1 dS/m and 0.4 dS/m to 37.5 dS/m, respectively for soil samples taken from Melka Sedi and Melka Werer farms. Regarding the magnitude of the problem, sever salinity problem was observed at Melka Sedi and former Banana farm areas. Even though the extent was less in terms of area affected, salinity problem in Melka Werer area was also observed. It was also observed that several hectares of cotton cultivated farms were at saline phase as witnessed from manifestation of frequent salinity patches elsewhere in the command area indicating the possibility of salinity expansion to take place in near future at more faster rate than ever seen before

The sodium adsorption ratio ranges from 0.7 to 27.2 in Melka sedi and 0.6 to 9.4 in Melka Werer farm areas (Appendix Table 4B). Soil sodicity problem were observed in Melka Sedi farm areas especially in some fields of former Banana farms, which had a very strongly sodic character. Soils of Melka Werer were not very much affected by sodicity problems so far. The analytical result obtained (Appendix Table 4) indicates that the electrical conductivity of the saturated extract at soil depth of 0-30 cm varies from 0.33 to 3.93 dS/m for non-saline, 23.00 to 45.90 dS/m for saline sodic soils and 4.02 to 82.10 dS/m for saline soils. Whereas the sodium adsorption ratio of the saturated extract varies from 0.6 to 4.05 for non-saline, 12.75 to 27.19 for saline sodic and 0.79 to 11.80 for saline soils. Hence considering the distribution of salt affected soils in Amibara Irrigation Schemes, about 34 % of the soils are salt affected soils.

From the results, considering the soil reaction (pH) of the study area almost all of the soil samples have a pH greater than 7 indicating general alkalinity reactions. Regarding soil salinity and sodicity assessment, detail soil salinity and sodicity map of the study area was conducted due to extreme heterogeneity of soils with respect to salinity and sodicity and occurrence of wide range of the problem. From the results around 34% has been mapped as saline soil and out of which around 20% as strongly to severe saline. Sodicity problem, only 1% has been mapped as slightly sodic to very strongly sodic soil. Combining both parameters (ECe and SARe values) were resulted 34% as saline soil and 0.05% as saline sodic soils. From the maps soil salinity/sodicity problems were also observed in Melka Werer areas but the extent was less compared to Melka Sedi area.

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1. INTRODUCTION

1.1 Background and Justification

Growing population density, excessive water abstraction, uncontrolled land use, accidental (or unauthorized) release of chemical substances, discharge of untreated wastes and water are putting more and more pressure on the Ethiopian rift lakes and rivers (Ayenew, 2004; Bedilu and Amare, 2006). These factors were contributed to the lake level fluctuation patterns in the Ethiopian rift. The levels of some of the lakes have shown a decreasing trend, while the others have shown an increasing trend. Some lakes remain stable because of little human influence and relatively better rainfall in the area (the case of lakes Langano and Abaya). A lake like Abiyata has shown a decreasing trend in level because of excessive abstraction of water for soda and irrigation use (Ayenew, 2004; Eleni, 2009). On the other hand Lake Beseka and to some extent Lake Awassa has shown an increasing trend in level rise resulting from land use changes and runoff develops from the surrounding catchments (Ayenew, 2004; Eleni, 2009; Olumana, 2009).

For long time, water abstraction from many rift lakes and rivers were preceded without the basic understanding of water resources management and this may lead to negative environmental changes in the very near future. The main large-scale withdrawals of water in the Ethiopian rift are for irrigation purpose. It is said that, one method of intensification of agricultural production is through irrigation. However, irrigation should be managed well to derive the merits out. In order to harvest the virtues of irrigation sustainably, the production system must be enhanced towards the potential use of resources and maintain it without degrading the resource. However these activities were affected the hydrologic characteristics of lakes and rivers as well as the ground-water systems and irrigation fields (Ayenew, 2001; Legesse et al., 2004). In the last few decades, over-irrigation has induced salinization of wide farmlands (Halcrow, 1982; Huluf, 1985; Tena, 2002). Application of agrochemicals and fertilizers has also slightly changed groundwater chemistry and soil salinity in the Adjacent Awash basin (Dechassa, 1999).

Among the various water bodies in Ethiopia, Awash River and Lake Beseka have attracted considerable attention, because of the discharge of Lake Beseka water in to Awash

River as a remedial measure for the continuous increase of the Lake Beseka water level (MoWR, 1999). However, such interference may lead to harmful impact on the Awash River water quality. Identification of the possible impacts of blending in relation to seasonal and spatial variation of water quality of both water bodies (Lake Beseka and Awash River) would be very important for the proper utilization of the water resources under consideration (Bedilu and Amare, 2006).

Lake Beseka has been expanding at an astonishing rate as compared with other rift valley lakes since the late 1960's. The surface area of the lake has increased from 3 km² in the 1960's to approximately 57 km² within five decades. According to Zemedagegneh and Egizabher (2004), the average annual increment of the lake was 0.2 m and the level of the lake has risen by 4 m from 1976-1997, and during past decades, the depth of the lake has increased at least by a depth of 5m, with a current average depth estimated at 8 ± 1 m (Olumana, 2009). The situation would not be as such worrying if the water could be used for drinking or irrigation purpose, but unfortunately the lake water is saline and alkaline.

The drastic expansion of the lake has led to many problems in the surrounding area, and is a severe threat to the wellbeing of the indigenous people and the economic welfare of the nation in general. The expanding lake is within 3 km range from the River Awash, which is the source of drinking water and irrigation for millions of people downstream. If the lake continues to expand at current rate and other influencing factors remain the same, the lake will cross the natural water divide and invade the town of Addis Ketema and probably join the River Awash. This would be disastrous, as the quality of the river water will be deteriorated such that agricultural development downstream (such as in Amibara) would be at risk (Eleni, 2009).

The mineral content of the lake water is high as compared to that of the Awash River. According to MoWR reports (1999), Water of the lake Beseka is very saline, and classified under brackish water, which therefore cannot fit for Human and Livestock consumption, Irrigation and other purposes without treatment. Lake Beseka, by virtue of its level rise, results serious environmental, economical and social problems. Thus in order to control the level rise problem the Ministry of Water Resources had implemented discharge of calculated amount of water from the lake through controlled gate valve into the Awash River in the year 2005. Hence since 2005 Awash Basin Authority has tried to release controlled amount of water into Awash River.

During those years the amount blended was 2% of river flow to reduce the lake level. According to the study proposal it was assumed to evacuate about 22Mm³ of water annually from the lake but in actual practices it was found only 7 Mm³ of water blended (Annual Reports of Awash Basin, 2011). Even though there were some inefficiencies that contribute for the reduced amount of discharge and because of other uncontrolled factors, like runoff from Abadir catchments that flow directly to the lake Beseka and the lake level rise has no shown a sign of decrease.

Statement of the Problem

For the last 50 years Lake Beseka is rising and expanding progressively. Despite the fact that the cause of lake level rise is not clearly recognized and it is near to the River Awash, unless some measures are taken to control its expansion rate it deteriorates the quality of Awash River. Blending the lake water with Awash River would potentially used for agriculture purpose. But such measures requires careful intervention so that there will be no environmental, social and economical deterioration in middle and lower valley of Awash Basin.

Temporal variation of the lake water quality needs to be addressed seriously. This has an impact on the hydrology of Awash River and irrigation induced salinity and sodicity problems in downstream areas of large scale irrigation farms. These issues demand proper investigation on the issue of blending of Lake Beseka water with Awash River water

Though a number of studies were conducted in water quality assessment of Awash River at different times, there has never been a comprehensive study relating the impact of loading Lake Beseka water into Awash River, especially downstream of the lake areas. Therefore, spatial and temporal variability of this behavior are important issues to be considered in water resources management. Reliable and up-dated information on the spatial and temporal variability of water quality is required to effectively manage the limited natural resources and maintain a viable agricultural industry that is highly dependent on conjunctive use of surface and ground waters with varying salinity levels.

This study attempted to asses of the current status of Awash River water quality with respect to spatial and temporal water quality variability along with the

potential environmental effect of mixing the two water bodies. Hence, the objectives of this study were to determine the effect of blending of Lake Beseka in to Awash River with emphasis on Spatial and Temporal Variation to indicate the possible alternative recommendation options.

1.2 Objectives

1.2.1 General Objective

To assess the impact of loading Lake Beseka water into the Awash River with respect to spatial and temporal water quality variability along the courses of the river

1.2.2 Specific Objectives

- To assess the seasonal and spatial variability of water quality changes of the two water bodies.
- To assess the suitability of Awash River for irrigation and drinking purpose downstream of the lake areas
- To identify the present status of soil salinity/sodicity problem in conjunction with assessing irrigation water management practices of downstream large scale irrigation farms
- To prepare salinity/sodicity map for downstream large Scale irrigation farms using GIS and Remote sensing

2. DESCRIPTION OF THE STUDY AREA

2.1 Awash River Basin

2.1.1 Physical settings

The Awash River Basin is the fourth largest catchment in Ethiopia in terms of area, following Wabi Shebele, Abay and Genale Dawa River Basins. Awash Basin is located between 70° 53' 42" to 120° 07' 20" North and 37° 56' 56" to 43° 17' 04" East. The basin is bordered by Danakil, Abay, Omo-Gibe, Rift Valley lakes and Wabi Shebele basins and Republic of Djibouti. The river originates near Ginchi in the central highlands of Ethiopia, and flows north east through the northern section of the Rift Valley to eventually discharging into Lake Abbe near Djibouti boarder, traveling a distance of about 1200km. The total catchment area of the basin is about 116,000 square kilometers

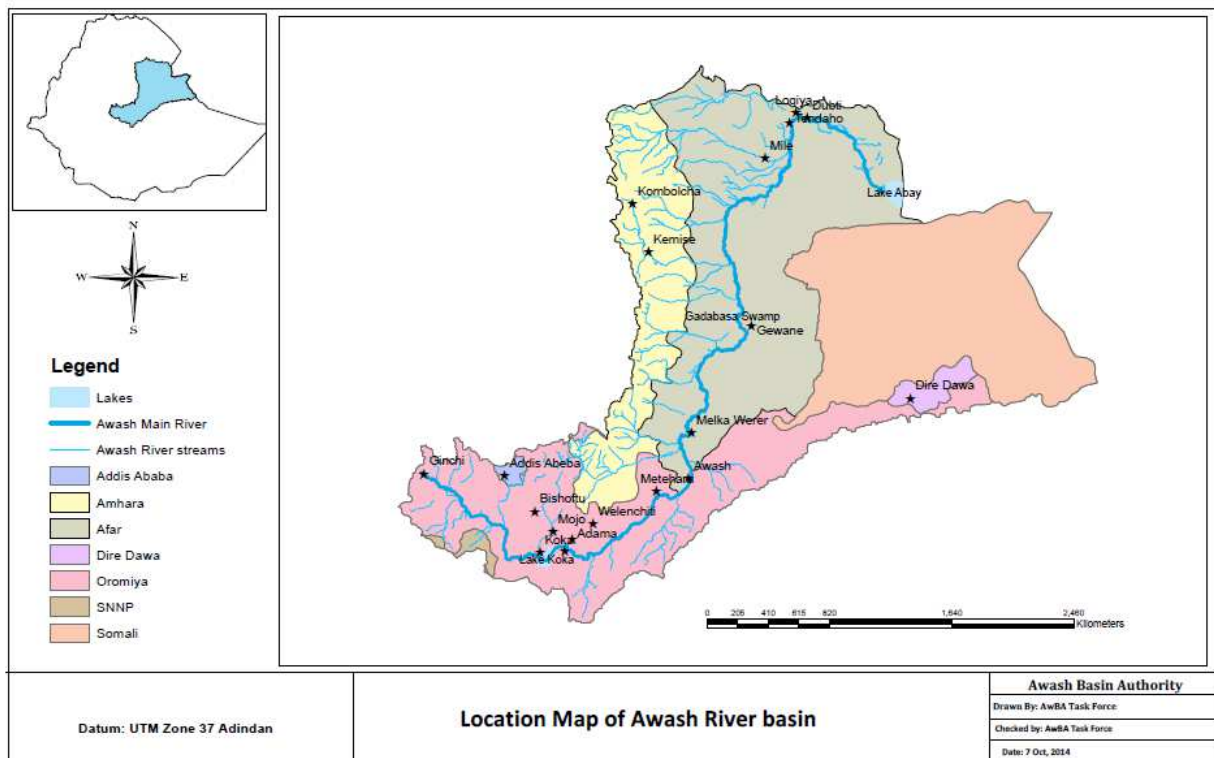


Figure 2.1: Location Map of Awash Basin (Adopted from AwBA, 2014)

To facilitate water resources planning, allocation and monitoring, the Awash Basin was sub divided into six basins, namely, Awash Upstream Koka, Awash Awash, Awash Halidebi, Awash Adaitu, Awash Terminal and Eastern sub basin. Awash US Koka sub basin comprises Awash Kuntre River, Mojo River and Akaki River. Awash at Awash sub basin includes Keleta-Werenso Rivers and Awash Arba 1 and 2 Rivers. Awash Halidebi sub basin contains Kesem-Kebena Rivers, Ankober River, Negeso-Gera River, Awadi River and Gedebasa Swamp. Awash Adaitu sub-basin includes Ataye River, Borkena River, ChelekaGewis River and Adaitu River. Awash Terminal sub-basin includes Mile River and Logia River. Since Eastern sub basin have a very typical characteristics and does not contribute directly to the surface river flow it was decided to considered separately. This sub division was based on topography, river gauging points, major tributary characteristics and location of water bodies.

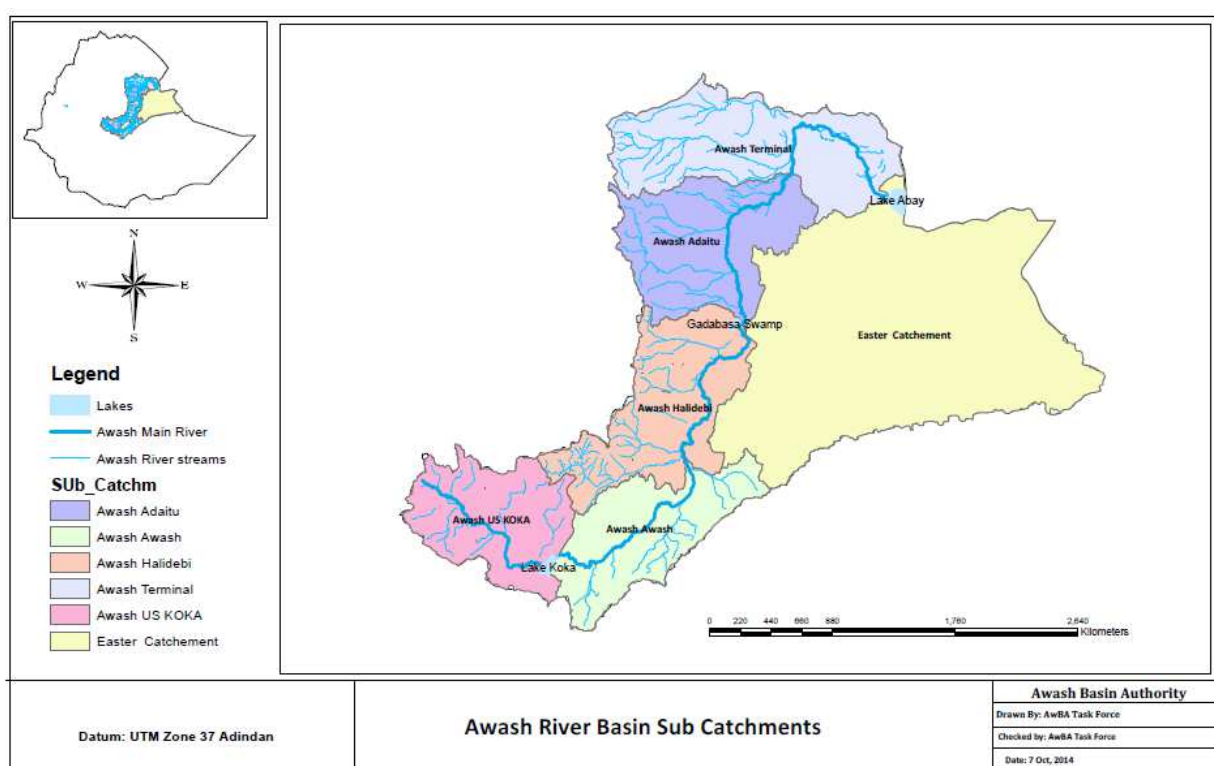


Figure 2.2: Awash River Basin Sub Catchments (Adopted from AwBA, 2014)

2.1.2 Socio-economic settings

The main population centers of the country i.e. Addis Ababa, Dire Dawa, Adama and Bishoftu lie in Awash Basin. The population of the Basin is currently estimated to be 14.8 million. This population is placing increasing pressure on the natural resources resulting in its degradation. Majority of this population is engaged in agriculture and animal husbandry. The number of industrial firms in Ethiopia has tripled in the past four decades. More than sixty five percent of these industrial firms are located in the Awash Basin mainly along the Addis Ababa - Adama, Addis Ababa - Holeta and Addis Ababa- Sebata industrial development corridor (Tecsult and PPESA, 2010). In addition, Dire Dawa and Kombolcha are among the main industrial zones of the country which are also found in the basin.

2.1.3 Water resources settings

Awash River basin ranks seventh from the twelve river basin of the country in terms of surface water resources. It is reported that the basin generates 4.65 BCM of annual runoff. Although the relative surface water resource is lesser than most of the basins in Ethiopia, Awash River basin is the most developed and utilized basin. So far, there has never been a comprehensive study that characterizes the ground water potential of the basin. It is believed that a tremendous amount of ground water exists in the basin. For instance, Alaydege plain is said to have a potential to irrigate more than 200, 000 ha using groundwater resources.

2.1.4 Agricultural settings

According to Water Audit Report, 77.4% of the irrigable land in the basin has been cultivated. This made Awash Basin to be the most developed basin in Ethiopia based on irrigation wise. Large scale mechanized state and private farms such as Wonji-Shoa, Metahara, Upper Awash Agro Industry, Amibara and Gewane are found in this basin. A wide varieties of crops are cultivated ranging from cereals, vegetables, flowers, cotton to perennial fruit orchards and sugarcane. Currently, there is a shift in crop preference following the Government's interest in sugar production. The dominantly cotton cultivating middle and lower valley areas have now transformed to sugarcane production.

2.2 Lake Beseka

2.2.1 Location and climate

Lake Beseka, one of Ethiopian rift valley lakes, is located at the center of the Ethiopian rift valley about 190 km east of the capital Addis Ababa. The lake watershed lies between 39°43' -39°59' east

longitude and 8°41' - 9°0' north latitude. The surface area of the lake has grown dramatically within the last three and half decades and now covers about 8 % of the total watershed area. The watershed is 505 km² in size, and the lake is located at the eastern part of the basin. Two towns, Methara and Addis Ketema are located close to the lake (Figure 2.1).

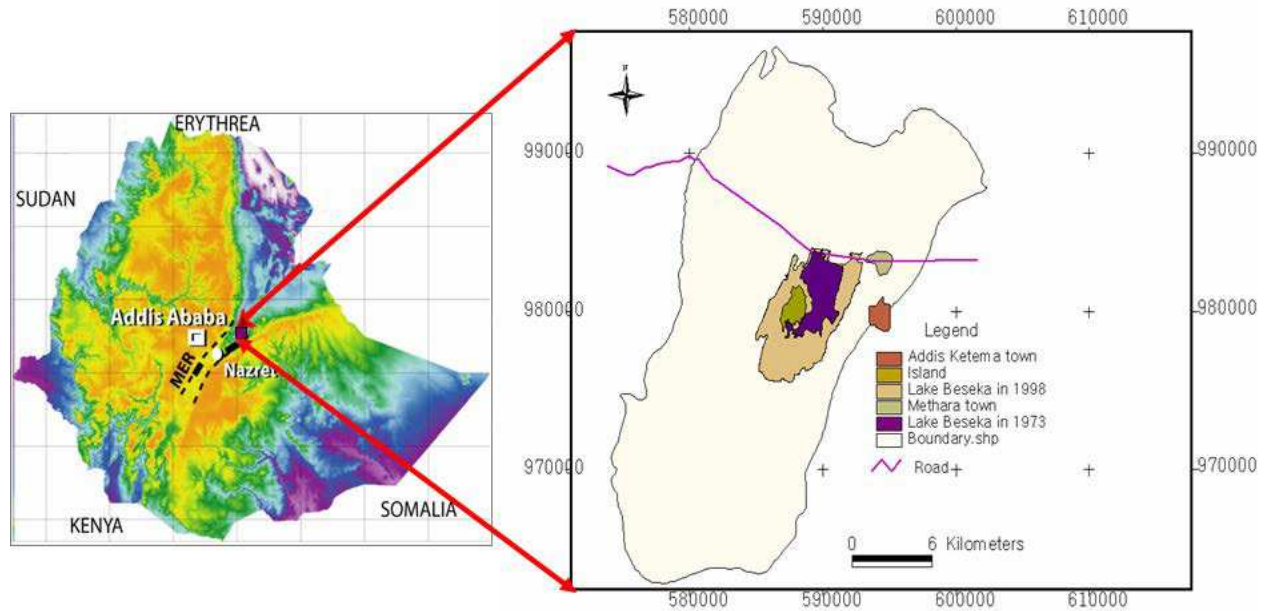


Figure 2.1: Location of the investigated watershed with two nearby towns, Methara and Addis Ketema, and the extension of the lake in 1973 (violet) and 1998 (orange), (Map of Ethiopia is adapted from Görner et al. (2006))

The study area is characterized by an average daily maximum and minimum temperature of 33°C and 17°C, respectively. The lowest temperatures are between November and January, while May and June are characterized by higher temperatures. Relative humidity is high during the main rainy season. Wind speed is at a maximum during the months June and July, and at a minimum value during October. Long- term average sunshine hours in the study area are 8.4 hours, and the lowest sunshine hours being during the main rainy season. Potential evapotranspiration exceeds monthly rainfall in nearly all months; thus the climate of the area can be defined as semi-arid according to the Thornthwaite climate classification scheme (FAO, 1984).

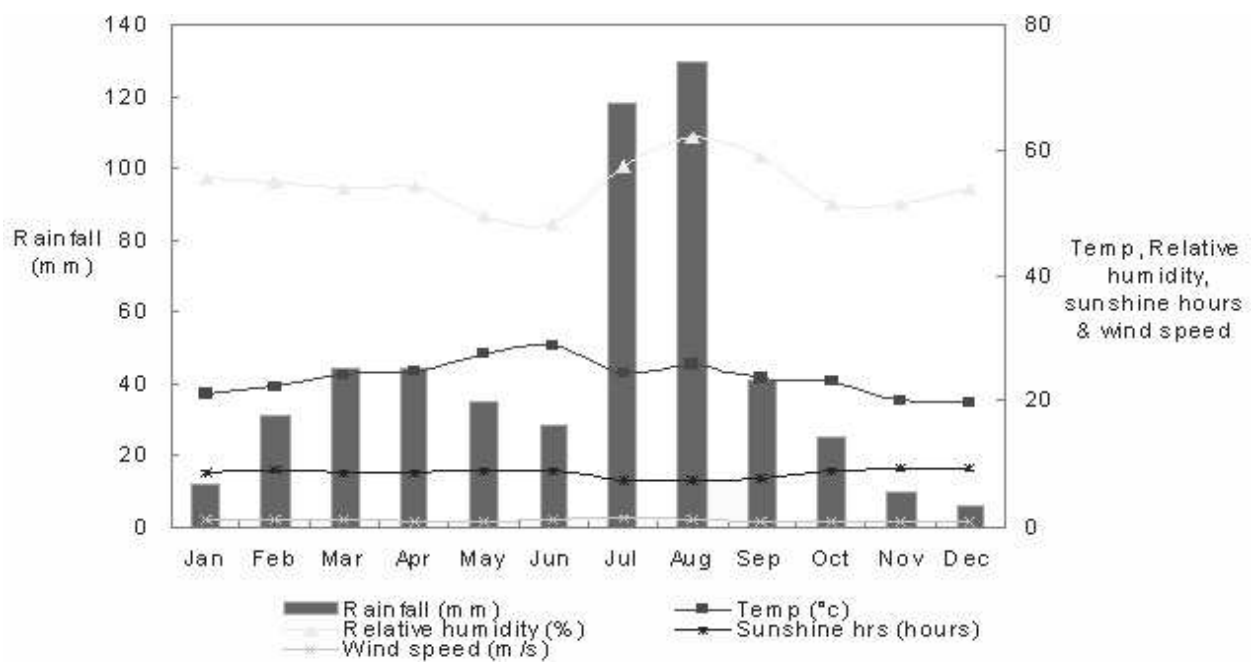


Figure 2.3: Long-term (1966-2007) mean monthly records of meteorological parameters at Methara (data from Research Center of Methara Sugar Estate and National Meteorological Service Agency).

2.2.2 Topography

The topography of the Lake area ranges from flat to undulating plains, and from hills to the high Mount Fentale. Most of the watershed is characterized by flat to undulating plains with altitudes ranging from 940 to 1100 m.a.s.l. Plains with small and high gradient are located in the northwestern and western part of the watershed. Volcanic cones are also concentrated in the western part. Hills with medium slopes are located in the south, while a high slope mountain is situated in the northern part of the watershed. The most fascinating and outstanding Quaternary Fentale volcano is located north of Lake Beseka, close to the southwestern corner of the Afar Depression. The Fentale volcano rises 1000 m above the surrounding plain and reaches to 2007 m at the center of the volcano. The last volcano erupted in the 1810s, and today the volcano is characterized by emanating volcanic gasses and is believed to be an active volcano.

2.2.3 Soils

A soil map of the Lake area exists at the scale of 1:50000 (WWDSE, 1999), and seven major soil units were identified. Leptosol (PLLp) is the dominant soil type covering about 33 % of the total watershed area. This soil unit is characterized by shallow soil with weakly developed structures,

coarse texture, and is covered mainly by open bushy woodland. Soil developed on mountains (TMLpro) covers about 17 % of the watershed area, commonly found around Mount Fentale and in the western part. This soil type is excessively drained, shallow and coarse textured and covered mainly by open and dense bushy woodland.

The cambisol (PLCm) is a well-drained, deep, and medium to coarse textured soil type, which is mainly located west of Lake Beseka and in the northeastern part of the watershed. It is mainly covered by open grassland and open bushy land. Podzoluvisol (PLPz) is a well-drained soil, medium to coarse textured and very deep, with moderately developed structures. It is mainly found in the southeastern part and covers about 6 % of the total area. The solonchak soil typically developed along the eastern edge of Lake Beseka. It is poorly drained, deep, weak to moderately developed and characterized by salt crests at the surface, which can be related to capillary rise of groundwater.

The CHPLp soil class is found on the hilly plains of the western watershed and covers about 5% of the total watershed area. This soil is excessively drained, very shallow and coarse textured with coarse fragments and stones. Luvisol (PLLv) is well drained, very deep, moderately developed, fine textured and characterized by none to very few coarse fragments. This soil type contains accumulated clay in the B-horizon and is the dominant soil type in the Abadir sugarcane farm. Fluvisols (PLFi) developed on alluvial deposits, which are found mainly in the northwestern corner of the watershed and cover about 4 % of the study area. They are well drained, very deep, weakly developed and characterized by a wide range of textures with few to frequent coarse fragments.

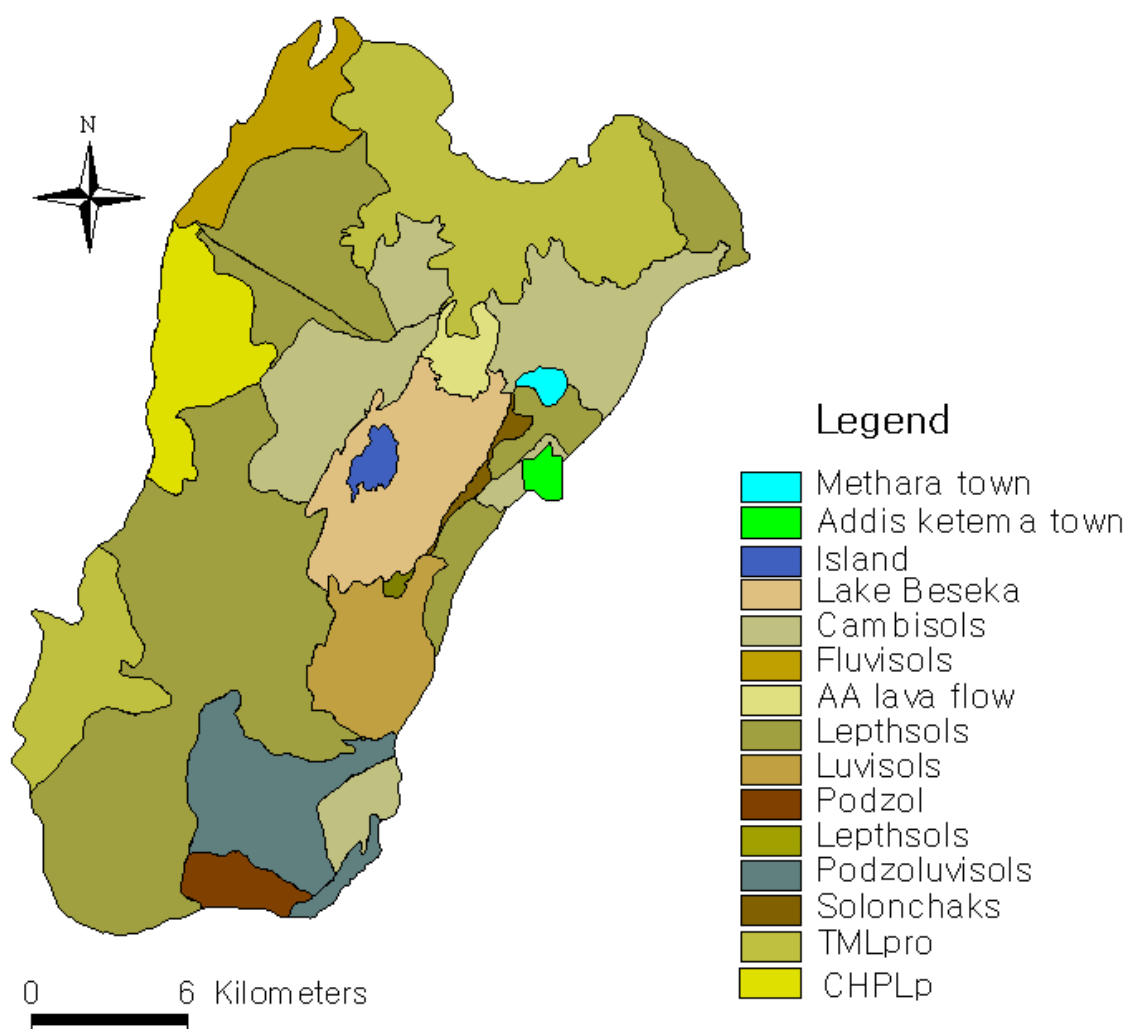


Figure 2.5: Soil types in the lake watershed (data from WWDSE, 1999).

2.2.4 Land use and land cover types

The land-use and land-cover (LUC) types of Lake Beseka watershed were mapped in 1999 by WWDSE based on aerial photos and field investigations, and 14 LUC units were identified. Open bushy woodland is the most dominant LUC type, accounting for 46 % of the total watershed area. This LUC unit is typically found covering the shallow soil of the plain, medium to high gradient hills, volcanic cones and Mount Fentale. This unit is mainly used for grazing, firewood collection, and charcoal production, and for very limited rainfed agriculture (Figure 2.6). Dense woodland, open grassland and open grassland with bare rock are common LUC types covering 24 % of the total lake watershed area. Dense woodland is commonly found in the northwestern part and covers 8.7 % of the total lake watershed area. Open grassland is mainly found on the eastern side of the lake, and

accounts for 8.5 % of the total watershed area. Both LUC units are used for grazing and browsing, and dense woodland is additionally used for firewood production. The northern margin of the lake is bare land consisting of fresh, aa lava which is believed to be the product of the 1820's volcanic eruption in the area (Halcrow, 1978).

The indigenous people in the study area are nomadic pastoralists and depend mainly on cattle and camel rearing. Cultivation is not a common practice in the area, though scattered and insignificant patches of land are used by semi-nomads for rainfed cultivation of sorghum and maize. In the lake watershed, cultivation is mainly confined to the state owned farms in Methara Sugar State (south of the lake) and Nura Era citrus farm (south end of the watershed). The Abadir farm is part of the Methara Sugar Plantation and lies directly south of Lake Beseka. Irrigation farming has been practiced in this area since 1968, however crops changed from cotton and citrus fruits to sugar cane production in 1978 (WWDSE, 1999).

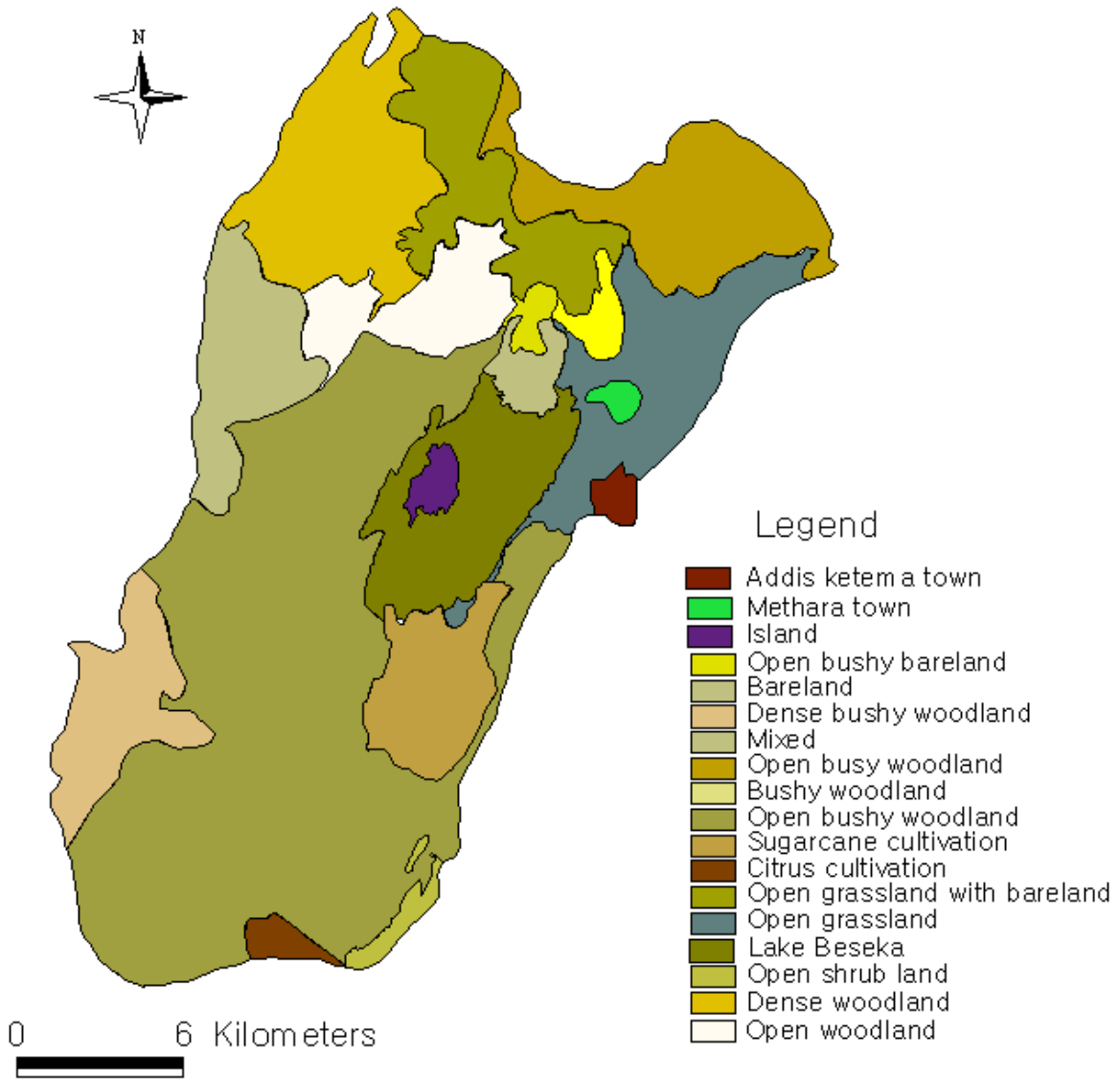


Figure 2.6: Land-use and land-cover (LUC) in the study area (data from WWSDE,1999).

3. Materials and Methods

3.1 Soil and Water Sampling

Soil samples were collected during the month of October and November 2011. A total of 249 representative auger samples were taken from Melka Sedi and Melka Werer farms at a soil depth of 0-30 cm. Considering extreme heterogeneity of soils of Melka Sedi area with respect to salinity and sodicity and occurrence of wide range of the problem; attempt was made to collect soil sample systematically from every farm units of Melka Sedi area. While for Melka Werer area, with lesser extent of salinity and sodicity problems, soil samples was collected randomly at 2 km interval. Collected samples were delivered to the laboratory of Werer Research Centre, air-dried, ground to pass through 2 mm sieve and prepared for selected chemical analysis. Each of the soil sampling points was spatially referenced using GPS (Figure 3.1).

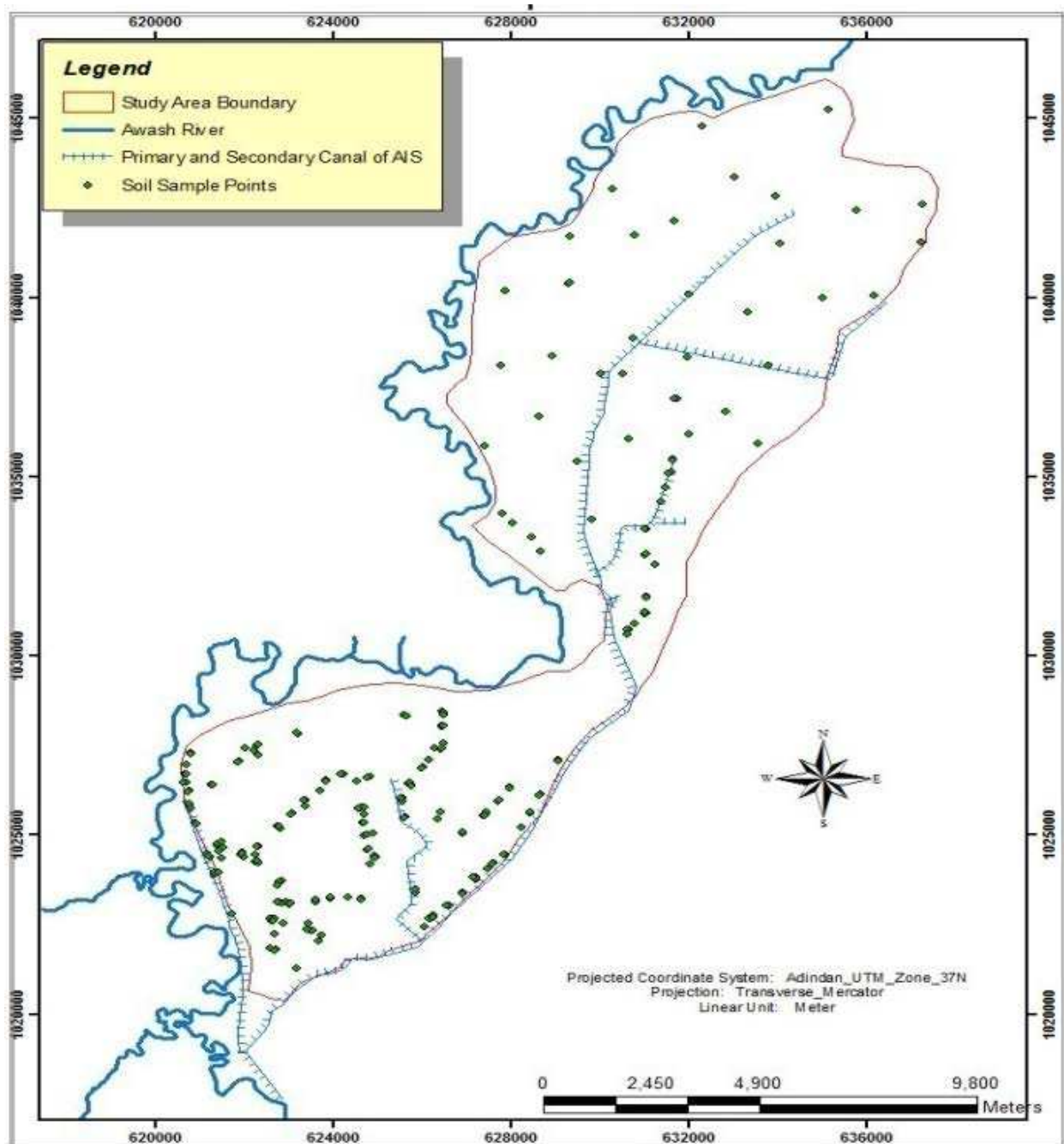


Figure3.1 Spatially Referenced Soil Samples

Water samples were collected from the Awash River which is used as irrigation sources. The Awash River was sampled monthly at 10 sampling points for one year (June, 2014 - July, 2015) including Lake Beseka starting from upper to lower Awash along the main river course. Water samples were also collected from main irrigation and drainage canals of Amibara irrigation command area for one year.

Acid-washed polyethylene bottles (2-liter) were used to collect water samples for all the water sources (Greenberg *et al.*, 1992). Following necessary procedures for safety handling, collected samples from Awash River were transported to the laboratory of Water Works Design and Supervision Enterprise for chemical and physical analysis. Each of the water sampling point was registered using GPS. Collected water samples from main irrigation and drainage canal were analyzed in the laboratory of Awash Basin Authority.

3.2 Laboratory Analysis Methods

Soil samples were collected during the month of October and November 2014. A total of 250 representative auger samples were taken from Melka Sedi and Melka Werer farms at a soil depth of 0-30 cm. Considering extreme heterogeneity of soils of Melka Sedi area with respect to salinity and sodicity and occurrence of wide range of the problem; attempt was made to collect soil sample systematically from every farm units of Melka Sedi area. While for Melka Werer area, with lesser extent of salinity and sodicity problems, soil samples was collected randomly at 2 km interval. Collected samples were delivered to the laboratory of Werer Research Centre, air-dried, ground to pass through 2 mm sieve and prepared for selected chemical analysis. Each of the soil sampling points was spatially referenced using GPS (Figure 3.1).

Collected water samples were subjected to the analysis of pH, EC, dissolved cations (Ca, Mg, Na and K), alkalinity (HCO₃⁻ and CO₃²⁻), Cl⁻, SO₄²⁻, NO₃⁻ Fluoride and Iron contents in the laboratory. EC and pH of the water samples were measured using conductivity meter and a digital pH meter, respectively (Greenberg *et al.*, 1992). HCO₃⁻ and CO₃²⁻ ions were determined by titration with standard hydrochloric acid; Cl⁻ by silver nitrate titrimetric method, and SO₄²⁻ turbidimetrically by spectrophotometer. NO₃⁻ concentration in the samples was analyzed as per the methods outlined by Melese and Gemechu (2010), and fluoride and iron was determined following a standard analytical procedure. Ca and Mg ions were measured

using atomic absorption spectrophotometer, whilst Na and K was analyzed using flame photometer. Turbidity for Awash River water sample was measured using standard method.

Derived parameters (SAR and RSC) were estimated from the measured constituents using appropriate equation. Finally, the water under investigation was classified to the different suitability classes as per the criteria established by the USSLS (1954) and Greenberg *et al.* (1992).

3.3 Soil Salinity Appraisal

Soil salinity appraisal and mapping was conducted in Arc GIS environment. To carry out the soil salinity appraisal, field collected data were used (Figure 3.1). Taking the ECe value of a randomly collected soils samples, a soil salinity raster map was created using Arc GIS 9.3 with Inverse Distance Weight (IDW) interpolation techniques. IDW interpolation method was selected for soil salinity map of the study area based on the minimum errors resulted from the methods used when compared to each other. According to FAO (1988) classification standards, the generated raster layers were further reclassified using reclassify tool in spatial analyst extension as salinity classes using different ECe ranges. Finally, layouts were prepared for the developed raster layers using layout view.

3.4 Soil Sodicity Appraisal

Exchangeable sodium percentage (ESP) is widely used to measure sodicity status of soils but experimental determination of exchangeable sodium percentage is tedious, time consuming and subject to errors (FAO, 1988). To overcome some of these difficulties several workers prefer to obtain an estimate of the exchangeable sodium percentage from an analysis of the saturated soil extract. Sodium adsorption ratio of the saturation extract (SAR_e) is another parameter that has long been recognized as an index or indicator of sodicity hazard (USSLS, 1954; Abrol *et al*, 1988). It is the proportion of water soluble sodium to calcium plus magnesium in the soil and is expressed in an equation form as:

$$SAR = \frac{(Na^+)}{(Ca^{2+} + Mg^{2+})^{0.5}}$$

Where concentration of the cations are expressed in meq/l

The calculated SAR_e for a randomly selected surface soil samples (Figure 2) were interpolated using IDW interpolation technique to create a potential soil sodicity raster map. Using reclassify tool the generated raster layers were classified to show the soil sodicity hazard of the study area. A layout for soil sodicity raster layer was also developed.

Moreover, to develop salt affected soil raster layer, the developed soil salinity and sodicity raster layers were combined to generate a single raster layer using combine tool in local toolset of spatial

analyst extension of the software. Further the combined raster layer was reclassified on the basis of USSLS [14] soil salinity/ sodicity standard analysis. Here also layouts were prepared for the developed raster layers using layout view in the Arc GIS environment.

3.5 Irrigation Water Quality Appraisal

The temporal and spatial variations of the Awash River water quality at critical sampling points were evaluated (Figure 3.2). The Awash water quality evaluation for irrigation requires assessing suitability of the Awash water at selected monitoring sites in view of short and long term effects on crops, soil and water resources. It also comes up with valuable information on key management issues related to irrigated agriculture in particular and the environment in general.

The amount and kind of salt present in water essentially determine the quality of water for irrigation. One of the mostly used irrigation water quality classification system is the FAO (1985) system. The salinity and sodicity of irrigation water are indicated by electrical conductivity (EC_w) and sodium-adsorption ratio (SAR) respectively with respect to their effects on crops and soils with potential management requirements.

3.6 Data Processing

In preparation for the overlaying and analyses, topographic map (1:50,000) of the study area was scanned and vectorized. The EC_e and SAR value of a randomly selected soil samples were used for soil salinity and sodicity map preparation. Polygons having similar attributes were merged in every process. Analysis were made easy by applying expressions and conditional statements using spatial manipulation language (SML). These techniques are very efficient method of identifying and merging thousands of features that met the set of criteria to generate the final category [11]. Polygons will be given a unique identity and assign a corresponding name registered as attributes to determine the features projected in the map. Various digital and statistical data were combined to generate final output.

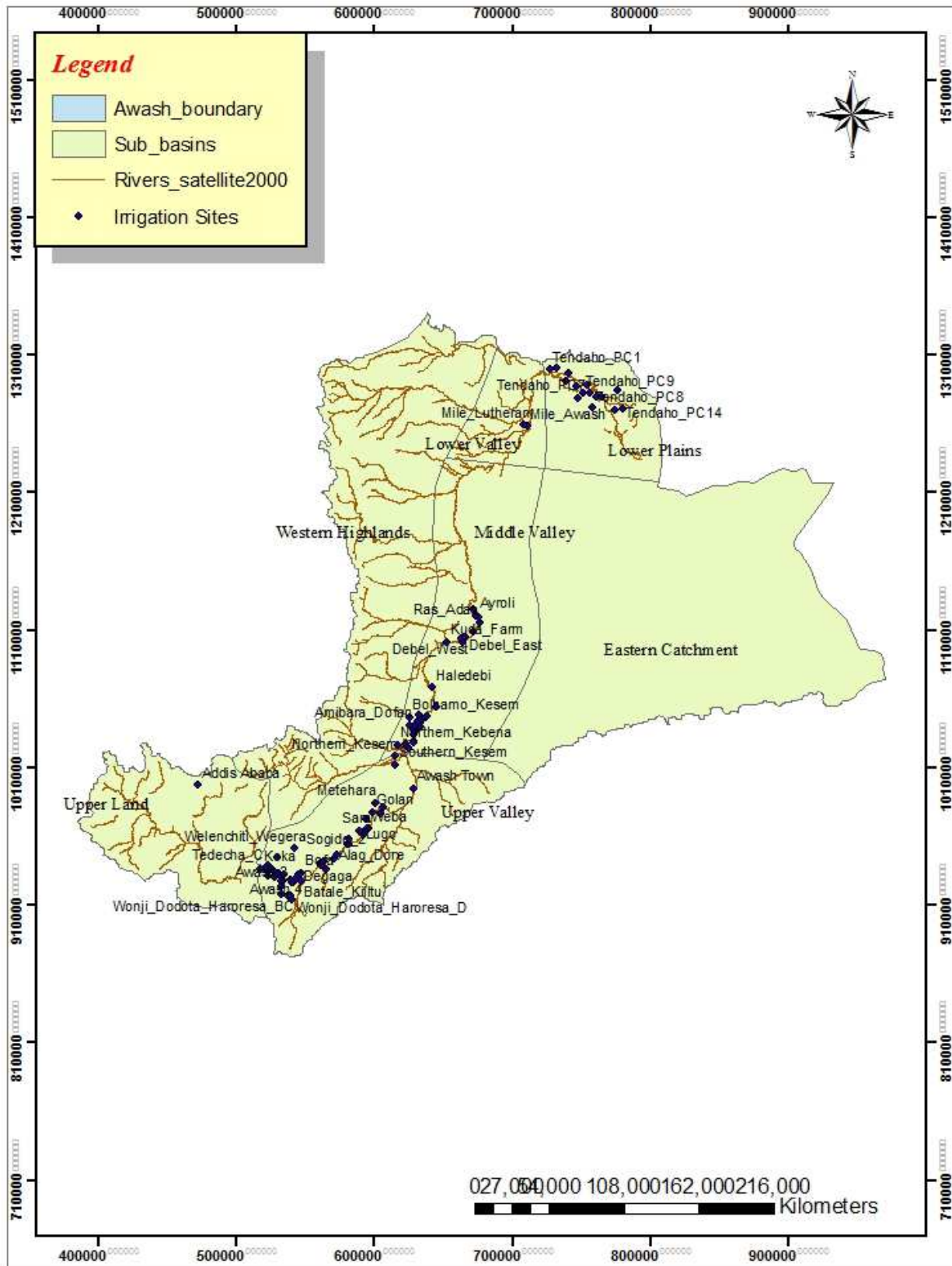


Figure 3.2 Spatially Referenced Awash River Irrigation Sites

4. RESULTS AND DISCUSSION

4.1 Spatial and Timely Expansion of The Lake from Satellite Images

4.1.1 Surface area (size) and shape of the lake

Figure 4.1 shows the individual lake (size & shape) in different periods and the figure indicates the Lake expansion extent in all periods considered. The surface area of the Lake is tabulated in Table 4.1. From Figure 4.1, it is obvious that the Lake expansion is very significant and very fast. The significant surface areal expansion of the lake was observed in the period of 1973 to 1986 (about 21 km²) due to the topographic favor. In the same period, the lake expansion is almost in all direction and mostly towards South (Abadir Farm). In the period 1986 to 2000, the lake surface area increased by about (11.6 km²), where the expansion direction is restricted almost towards the South (Abadir farm) and towards the West. In this period the Lake almost established its current shape. In the year 2000 – 2008, the expansion of the lake is further restricted towards Abadir Farm in the south and towards Matahara Town in the North East. In general, the recent expansion trend of the lake is in the south, east and northeast directions (Megersa, 2009).

Year	Area (Km ²)	Incremental area (Km ²)	Cum. Incremental Area (Km ² /yr)
1957	3.0	0.0	0.0
1973	8.4	5.4	0.3
1975	10.2	1.8	1.2
1986	29.5	19.3	3.0
2000	41.1	11.6	3.8
2008	42.6	1.5	4.0

Source: Megersa, 2009

The annual incremental area of the lake (column 4 of Table 4.1) was determined considering a linear increment for each period. The expansion of the Lake, as Table 4.1 shows, started after the establishment of MSE (Metahara Sugar Estate) (1970's) and the probable source of the Lake expansion can be the irrigation excess from the farms (drainage discharge into the Lake and/or the groundwater outflow towards the lake). However, it is difficult to conclude the source of the lake is

irrigation excess only since the area is prone to different tectonic activities as it is situated in central rift valley region (Megersa, 2009).

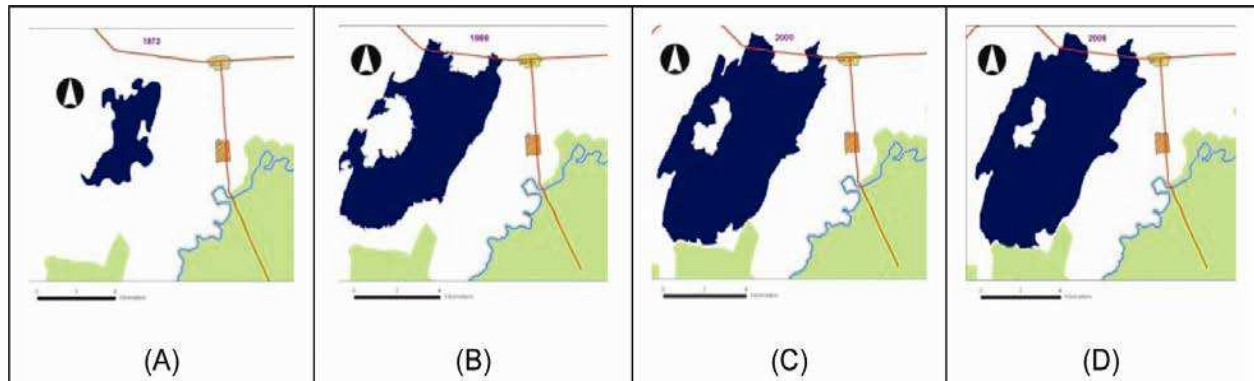


Figure 4.1 Baseka Lake expansion from 1973-2008: (A) 1973, (B) 1986, (C) 2000, (D) 2008 (Source Megersa, 2009)

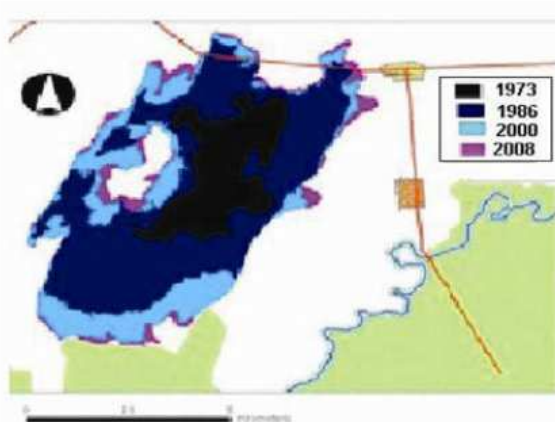


Figure 4.2 The expansion extent of Baseka area Lake in the periods between 1973 to 2008

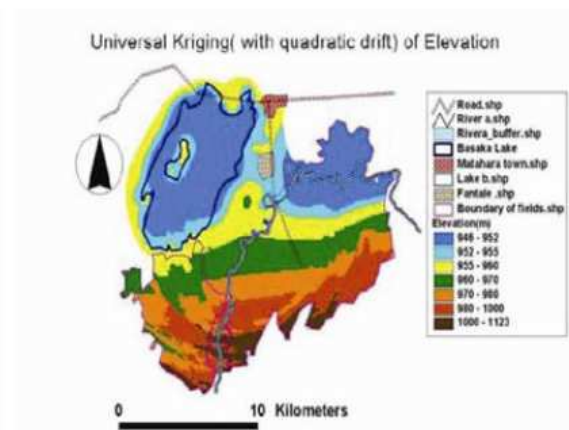


Figure 4.3 Elevation map of the study

4.1.2 Projection for the future lake expansion

The recent expansion of the lake towards the south (Abadir farm), east and northeast is in particular agreement with the topography of the area (Figure 4.3), and it seems the lake is finding a way to further expand in the east and northeast direction. This future expansion extent (depth & direction) was estimated based on the elevation of the lake in 1975 (944 m) and the current average elevation of the lake (950 m). During the past 35 years, the depth of the lake has increased – at least – by a depth of 5m, with a current average depth estimated at 8 ± 1 m

Considering the past expansion trend of the lake (Figure 4.2) and the topography of the area (Figure 4.3) and assuming that the past conditions will prevail in the future, it can be expected that the lake will inundate parts of Matahara town and start flowing towards the east, and probably passing through Fantale town towards the plantation in the north within the coming 25 years (Megersa, 2009). The trends in depth increment(@ 0.2 m/year) during the last two years is greater than previously as indicated by field managers of the sugar estate and observed during the field work. Assuming this accelerated trend, we argue that the displacement of nearby towns and the flow towards the north section may even occur during the coming 15 years. Based on this estimate, the Lake will join Awash River either through the north or the Awash section of the plantation, thereby impacting on the sustainability of the nearby sugar plantation, and possible negative impacts on all the downstream irrigation developments of the Awash River Basin more generally.

4.2 Change in Water Quality of the Awash River

4.2.1 Turbidity and total solids

Turbidity of Awash River water showed spatial variation (Figure 4.6 & 4.7). As shown in the figure, the mean turbidity value of Awash River was very high at Metehara above the lake, Melkasedi and Melka Werer sampling points. These were because of the inflow of different tributaries into the Awash River with their sediment loads that brought from the surrounding watershed area. Whereas for Lake Beseka the values for turbidity are low. All values recorded were greater than the WHO guide line value (5 NTU). Regarding total solids, higher mean value of total solids recorded at various locations in Awash River through out the study period. Mean total solid values of Awash River became pronounced at Metehara above the lake, Melkasedi and Melka Werer possibly due to the inflow of surface water with high sediment load, from the watershed due to runoff. Unlike the Awash River the major contributors for high total solids value of Lake Beseka is the total dissolved solids (TDS).

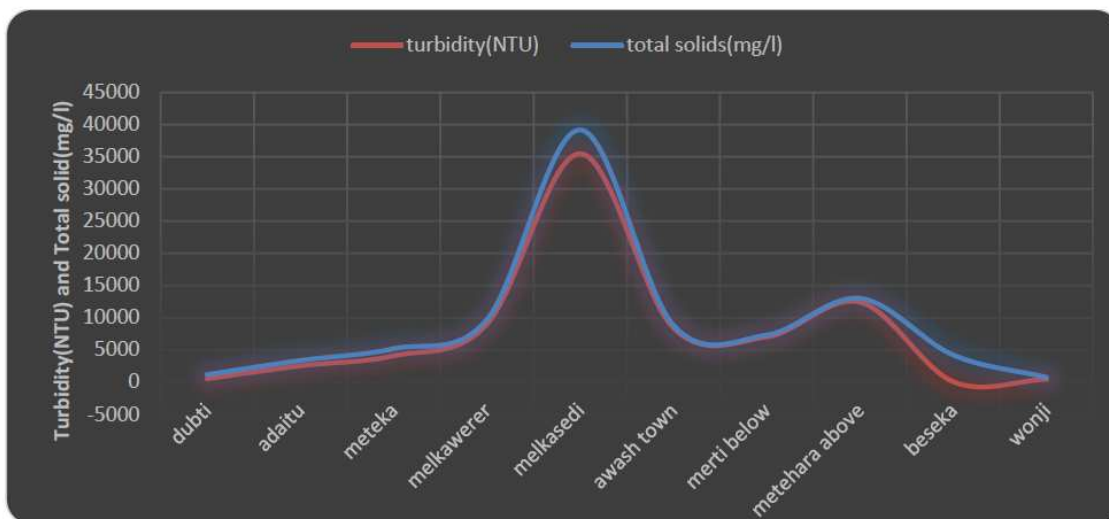


Figure 4.6 Total solid and turbidity of Awash River for the month of July, 2014

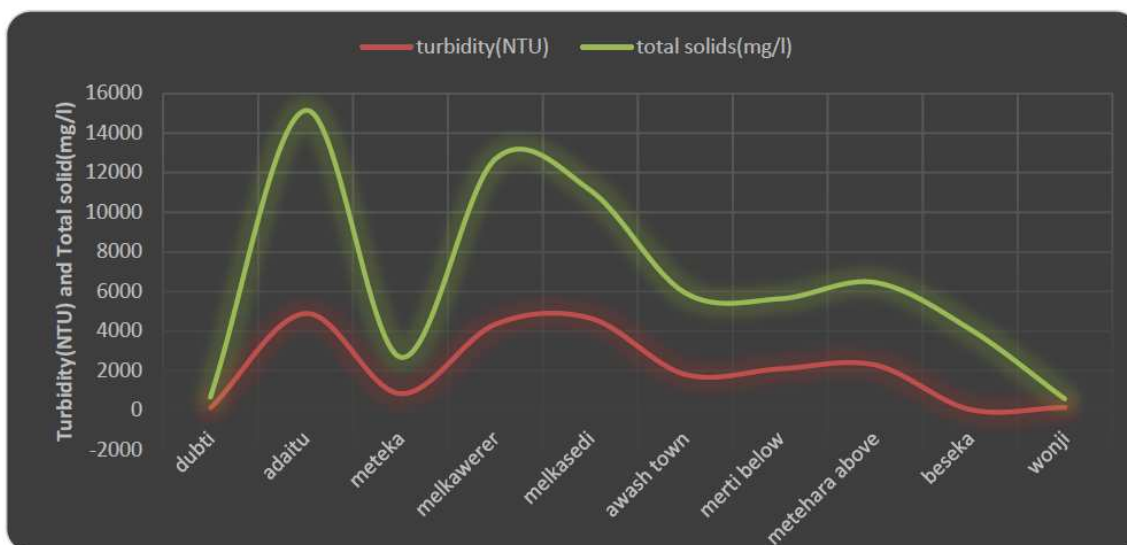


Figure 4.7 Mean total solids and Turbidity of Awash River and at various locations for the year 2014/15

4.2.2 Total Dissolved Solid (TDS) and Electrical Conductivity

Mean value of TDS and EC results (for the year 2014/15) were showed spatial variation along the river course (Figure 4.8). In most collected and analyzed water samples total dissolved solids (TDS) ranged from 233 to 423 mg/l except Lake Beseka which is 3980 mg/l. The excess value of TDS was mainly due to high concentration of soluble carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, iron, manganese and other minerals in the analyzed water sample. For example Melka Werer site is influenced by two Awash River tributaries (Kesem and Kebena).

Various hot springs with different effluents are also flowing into the river affects the TDS concentration. The acceptable range for TDS for irrigation water use is based on WHO standard is less than 1000 mg/l. In most cases TDS up to 500 mg/l is not objectionable. Hence, our TDS results in most of analyzed water samples were below 500 mg/l. From Fig.3, High Mean TDS values were recorded at Melka Werer, Meteka, Adaytu and Dubti points. Therefore from the results obtained the TDS values of Awash River are generally increase downstream.

The mean Electrical conductivity of the Awash River in all sampling areas were also measured and observed to generally increase downstream ranging from 0.347dS/m to 0.637dS/m, Except in Meteka, which is 1.05dS/m. The reason why the EC value was high in Meteka is may be because of Tikurwuha Swamp inflow to the river. The mean EC value of Lake Beseka is around 5.6dS/m, which is very high saline. Higher mean value of EC in the Awash River were recorded at Melka Werer, Meteka, Adaytu and Dubti points (Figure 4.8). According to USSLS (1954) classification, the Awash River, except at Meteka which is highly saline, was felt under medium salinity class. This is because of the thermal springs, like Sodere hot springs and Filwuha with EC values above 1dS/m , that are hydraulically connected to the Awash river that may partially contribute to the salt load downstream. In addition to the thermal springs, return flows from the various farms and the discharge of Lake Beseka into Awash River are also contributed to salt load downstream. But based on the amount of salt content on the river, Awash can be considered as suitable for irrigation purpose.

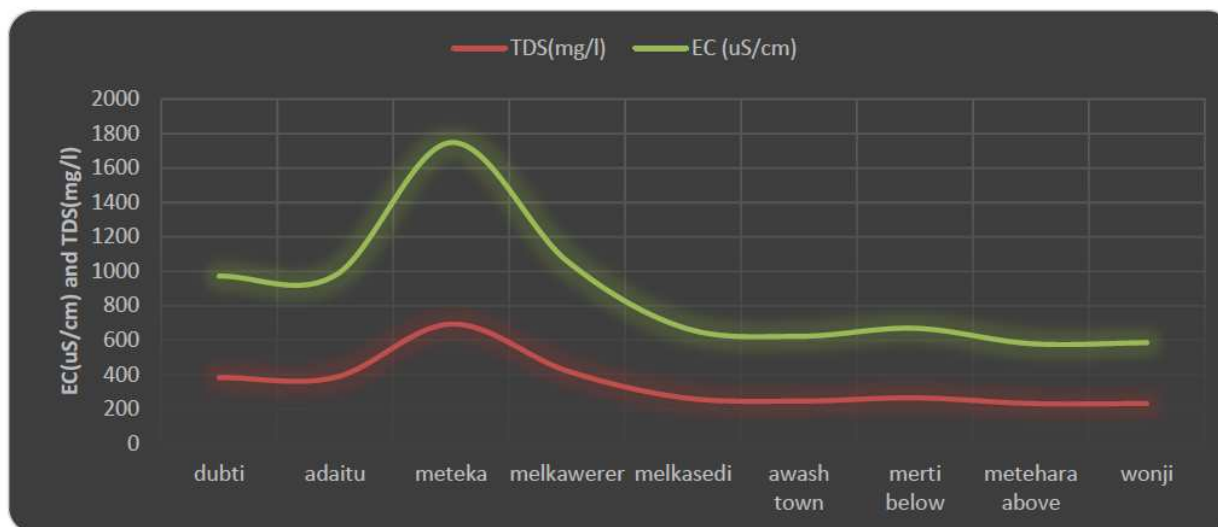


Figure 4.8 Spatial variation of Mean EC and TDS in Awash River

4.2.3 pH

The mean pH values for the Awash River at different location and time were between 7.76 & 8.2 (Figure 4.9). pH value of the Awash River after and before blending of lake Beseka at Metehara station showed an increase in pH after blending. These results may be related to the immediate impact of Lake Beseka loading. At points, Adaytu and Dubti mean pH values were higher than at any other points in the Awash River. Mean pH values for Lake Beseka water were greater or equal to 9.5 (Figure 4.9). This indicate that the Lake water is relatively alkaline than the Awash River. When the pH is outside the acceptable range (6.5-8.5), diversity within the water body may decrease due to physiological stresses and reduced reproduction (Bedilu and Feleke, 2006). The low pH values for the Awash River were attributed to the absence of alkali ions mainly CO₃⁻ (Huluf, 1985).

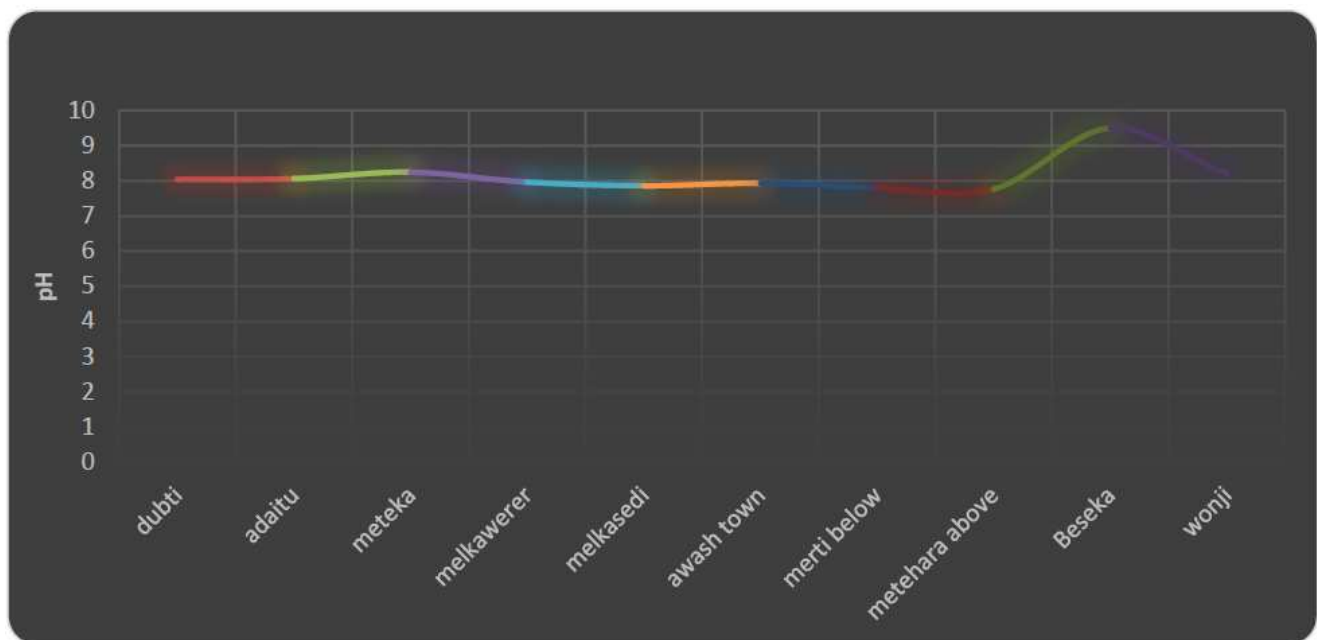


Figure 4.9 Spatial Variation of pH in Awash River and Lake Beseka

4.2.4 Major Anion

The mean values for most of anionic constituents in the Awash River were showed increasing Trend downstream of the course (Figure 4.10). But seasonal variation of the river shows decreasing trend in rainy season because of inflow of different tributaries like Arba and Kesem River that are responsible for dilution of Awash River. Whereas, the increasing trends at Metehara point was resulted from the immediate impact of Lake Beseka discharge in to the Awash River. Other sources like inflow of Tikurweha swamp with high value of anionic

constituents and farm drainages together with Lake Beseka discharge might contribute to the higher mean value downstream sampling Points. Regarding Lake Beseka water, its ionic constituents are higher than that of Awash River. From the figure shown below, the dominant anion was bicarbonate (HCO_3^-) and Carbonates were absent throughout the sampling period.

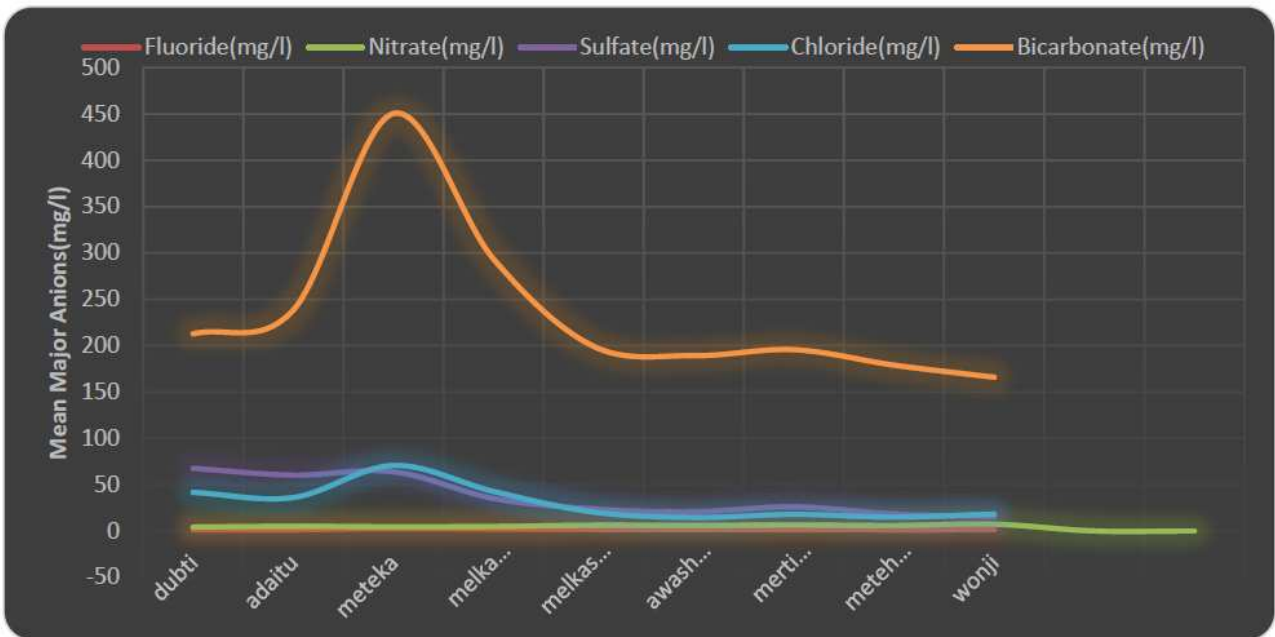


Figure 4.10 Spatial Variations of Mean Major Anions in Awash River

4.2.5 Major Cations

The mean values of cationic constituents at various locations in the Awash River were indicated in Figure 6. In the Awash River, the values for sodium and potassium that are more dominant in the Lake Beseka showed increased value at Metehara down stream than up stream, whereas, the reverse is true for calcium and magnesium (Figure 4.11). The reason for such variation is because of the immediate impact of Lake Beseka. High mean value was recorded for sodium at Meteka because of the inflow of Tikurweha swamp into the Awash River. Lake Beseka showed higher mean sodium value than the Awash River. Soluble sodium above **120 mg/l** in irrigation water can cause toxicity to many plants. Thus only Awash River water could be used for irrigation without any restriction. It is important to note that potassium, calcium and magnesium are important cations for plant nutrition compared to sodium cations. From the figure shown below the dominant cation in Awash River water samples was Na^+ .

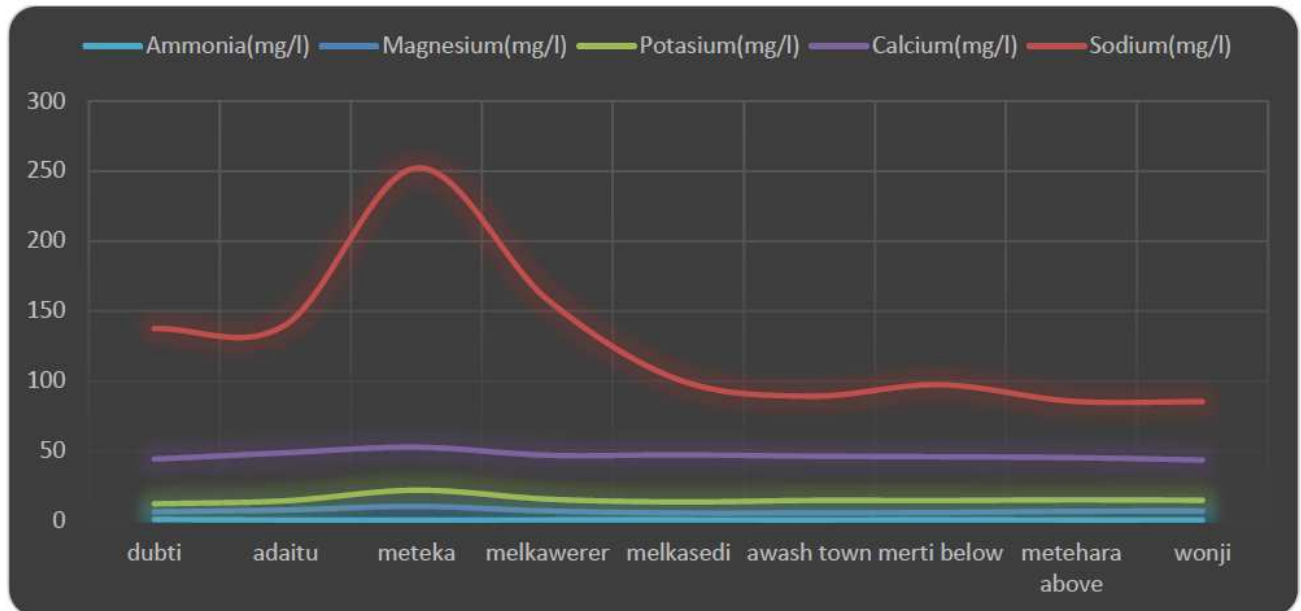


Figure 4.11 Spatial Variations of Mean Major Cations in Awash River

High concentrations of iron can be tolerated in some situations. However, the recommended maximum concentration of soluble iron (Fe^{2+}) in irrigation water is 5 mg/l (FAO, 1979). Most of the water samples collected from Awash River for quality analysis was below the restriction limit.

4.3 Environmental Status of Water for Irrigation Purpose

Water quality for irrigation purpose was determined by different parameters. In order to determine the suitability of water for irrigation Residual Sodium Carbonate (RSC) and Sodium Absorption Ratio (SAR) were taken as a parameter and details were discussed below.

4.3.1 Residual Sodium Carbonate

Residual Sodium Carbonate was one of the parameter that helps to determine the suitability of water for irrigation purpose. Water with high concentration of ions aggravate sodium hazard, which will happen when the carbonates and bicarbonates concentration increases. The relative proportion of $\text{HCO}_3^- + \text{CO}_3^{2-}$ to the contents of $\text{Ca}^{2+} + \text{Mg}^{2+}$ is known as residual sodium carbonate (RSC). RSC is a measure of HCO_3^- & CO_3^{2-} concentrations as related to Ca^{2+} & Mg^{2+} and is computed from the difference of the sum of the contents of these ions. In irrigation waters containing high carbonate and/or bicarbonate ions, it is recommended to adjust the SAR for the effect of precipitation of Ca/Mg as carbonates. RSC of less than 1.25 meq lt^{-1} guaranty a safe irrigation water while amount exceeding

2.5 results in an unsafe situations. Amounts ranging in between the two extremes are marginal (USSLS, 1954).

Results that were obtained throughout the sampling period at different points in the Awash River indicated that, there were increasing and decreasing trends along the water course (Figure 4.11). In addition to Lake Beseka other factors like inflow of Tikurweha swamp, drainage water, Sodere hot spring, Filwuha and evaporation might have contributed for higher values at downstream points especially in Melka Werer and Meteka. The lower values were attributed to the inflow of major tributaries that may had dilution effect. Except at Meteka and Melka Werer, the rest values were grouped under safe to marginally suitable for irrigation purpose. Mixing of the two water bodies at Metehara point indicated that there was a change of water chemistry as a result of the immediate impact of Lake Beseka.

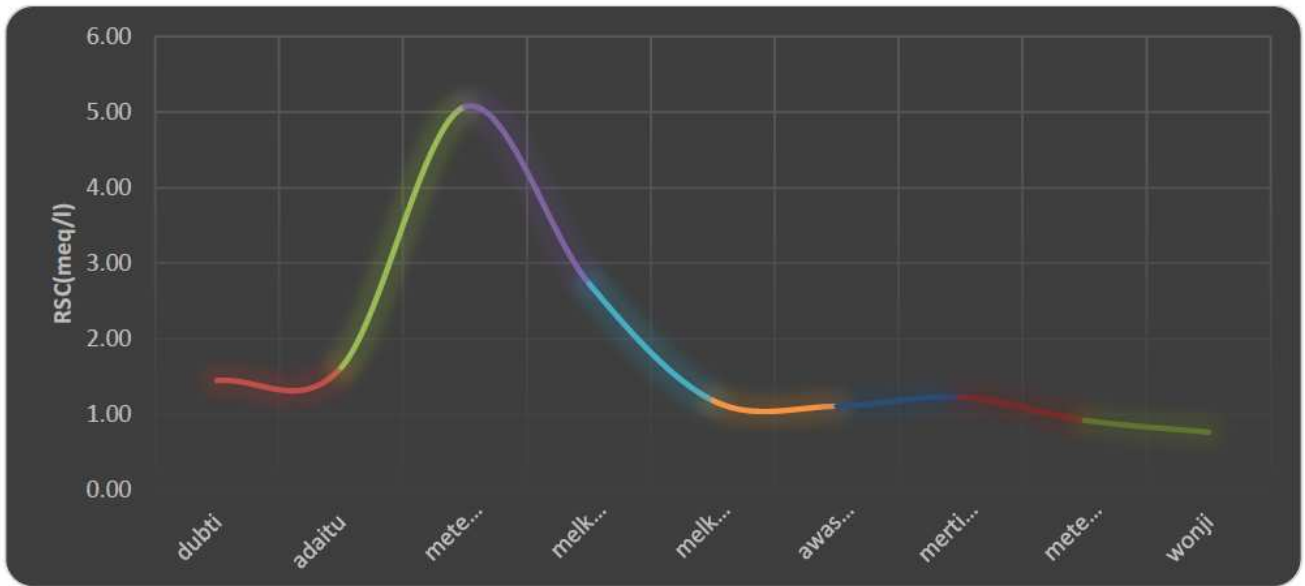


Figure 4.11 Spatial Data for Residual Sodium Carbonate (RSC) of Awash River

4.3.2 Sodium Absorption Ratio (SAR)

The adverse effect of sodium on some crops and soil physical condition becomes of a concern when sodium is present in the soil in significant quantities, especially in proportion to the other cations. Increased levels of sodium may result in soil clay dispersion. In doing so, soil structure may be lost and there may be reduction in infiltration and hydraulic conductivity of the soil. Surface crusting may develop forming a relatively impermeable layer.

Sodium Absorption Ratio is also used to evaluate the suitability of water for irrigation. According to the FAO guideline for irrigation water, the values obtained for Awash River at all sampling Points, except Meteka and Melka Werer, belongs to none restriction to use category (Figure 4.12) (FAO, 1998). Meteka and Melka Werer sampling points were grouped under slightly to moderate restriction to use group. Relatively very high SAR values were recorded with in Lake Beseka water, which is not suitable for irrigation and other purpose. Thus blending water with high SAR value may affect the irrigation potential of Awash River water and thus care should be taken when discharging Lake Beseka water in to the Awash River. According to FAO guideline SAR also helps to determine sodium ion toxicity in sensitive crops like tree crops and woody plants. If SAR value ranges 3-9, irrigation water grouped under slight to moderate degree of restriction to use category.

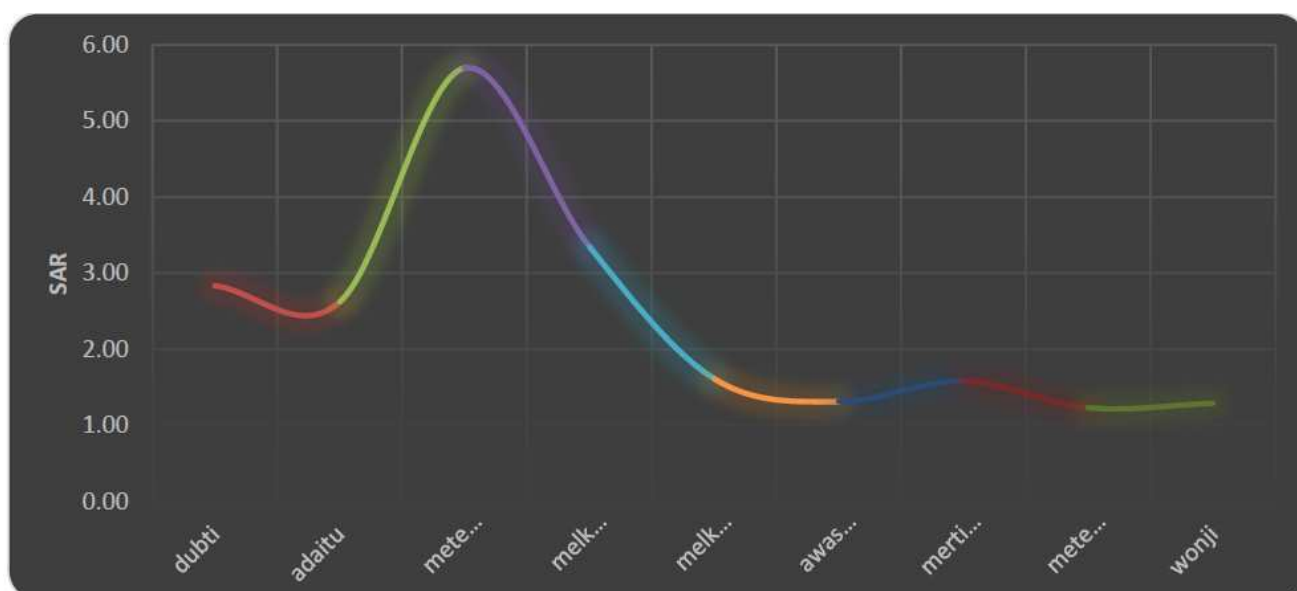


Figure 4.12 Spatial Data for Sodium Absorption Ratio of Awash River

4.4 Irrigation Practice and Challenges of Water Management in AIS

4.4.1 Introduction to AIS

The Amibara irrigation scheme (AIS), found in Amibara Wereda, Gebiresu zone of Afar National Regional State, cover a long broad alluvial plain along the right bank of the Awash river, locally known as Melka Sedi and Melka Werer with a net command area of about 10,300 ha. The main source of irrigation water is the Awash River by making use of

diversion weir at Melka Sedi. In addition to this, several pumps downstream of Melka Werer town also irrigate parts of the Amibara Settlement Farm, Algeta and Ambash . The area is at an elevation of about 740 meters above sea level and it is located at 9°16'N latitude and 40°9'E longitude in the Middle Awash Valley , close to the main high way linking Addis Ababa to Djibouti & is 275 kilometers far from Addis Ababa.

According to Werer Agricultural Research Center (35 years data), the average annual rainfall is around 560 mm, accumulated with the long and short rains. More than 85% of the rain occurs from June to September, with July and August being the wettest months. The mean maximum temperature is 35°C and mean minimum falls down to 19°C. The mean annual free water evaporation as recorded by the class A pan is around 3000 mm. According to the classification of Agro-Ecological zones by the Ministry of Agriculture and Rural Development (MoARD) the area is classified as semi-arid (Yibeltal, 2009).

The parent materials of the alluvial deposits in the rift valley of the study area are volcanic rocks. Weathered materials from the volcanic highlands have been transported and deposited in Middle Awash Valley by the Awash River and its tributaries. According to Halcrow (1983), the principal soil types in the study area are recent alluvial and vertisols with its textural class as clay, clay loam, silty clay loam, silty loam and silty clay. The alluvial soils are coarser in texture than vertisols and range between sandy loams and silty loams. The soils are brown in color and turned to dark brown when moist. The vertisols are silty clay to clay in texture with the clay content decreasing with depth. The color changes from very dark grey brown to black when wet.

The major crop grown is cotton, with minor crops including maize, sesame, banana and vegetables in some areas of research center. Crop production by the state farm and two large private enterprises (Amibara Farm Development and Africa Private farm) is entirely for commercial purposes, while small holders / agro-pastoralists cultivate cotton, sesame and vegetables for cash income and maize for subsistence. The large and medium enterprises practice mono-cropping, i.e cotton. Banana used to be grown in the former Melka Sedi banana unit, which was later replaced by cotton between 2001 and 2002 (Gedion, 2009).

The project area covers the Melka Sedi and Amibara plains in the middle valley. The net irrigable area of the project is 10,300 ha of which 4,600 ha are in Melka Sedi and 5,700 ha are in Amibara. Prior to the project implementation around 3,000 ha were served by pumps.

The diversion weir at the Headwork's is a rockfill structure founded on a blanket of graded filter material and having a synthetic impermeable membrane. The weir is 4 m high and designed for a flow of 700 cubic meters per second Halcrow (1983). The intake is sited on the right bank of the weir. It is the structure for drawing off irrigation water into twin barrels (each 1650 *1500 mm) with the entrance to the silt excluder or scour sluice barrel, (1500*1500 mm) passing through the weir, placed directly below the entrance to the twin barrels. The entrance to the twin barrels is provided with a trash track. The intake has been a regular source of worry during the rainy season. Bed load, silt and debris have blocked the intake resulting in water not being available to the entities for a few days at a time. Steps had been taken to alleviate such problems by constructing additional intake structure upstream of the old one in 2003.

The main canal is 25.5 km long, and is designed for a discharge of 13 m³/s with a velocity of 0.70 m/s and freeboard of 450 mm. Ten offtakes (PO 1-10) combined with controlled check drops (CD1-CD6), and three others (PO 11-13) sited at the tail end without a controlled check, serve the farms. In addition six drop structures in the Melka Sedi area are provided where the natural slope of the land exceeds the slope of the canal. The design slope of the main canal in its final reach is 2.80 m³/s.

The main canal offtakes are located immediately upstream of each check drop and comprise of an intake structure, discharge pipe and outlet structure, discharge pipe and outlet structure. Each intake structure has been filled with a rectangular orifice gate providing a means for measuring water issues to entities. The intake end of the pipe is fitted with a vertical lift gate and outfall structure incorporates a baffle beam to ensure energy dissipation. Offtakes from the primary canal provide irrigation water to the MAADE, Melka Werer Research Station and Amibara Settlement Farm in the Amibara area.

The project area is protected from flooding, both from the Awash River and from the adjacent hillside catchments, by a series of earth dykes. Irrigation water in the scheme is applied using furrow irrigation technique using siphons. The furrow length ranges from 200 to 250 m with furrow spacing of 0.9 m. In recent operations, furrow lengths are reduced by constructing small soil bunds within furrows to control irrigation water due to the problem of land leveling.

The Amibara irrigation schemes are provided with surface and sub-surface drainage facilities. The main drain 29 km long crosses the link road at 8 km and flows northwards along the eastern dyke, picking up surplus water from area in Amibara. The rejection flows from the four main canal spillways also lead into the main drain. A suitable gravity outlet for these drainage flows away from the project area back to the Awash River is available through a gravity flap gated outfall at Hassoba. The sub-surface drainage network consists of buried lateral and collector drains which are corrugated PVC pipes of varying size installed at an average depth of 1.7 and 2.5 meters respectively (Gedion, 2009). The collector drains receive percolated water from the slotted laterals and outfall into the deep surface drains. In some cases the lateral drains directly outfall into deep open drains. An area of 3820 ha in Melka Sedi is served by the existing surface drainage facility. The total length of the collector and lateral drains is 1010 km as specified in MacDonald (1996). Concrete manholes have been installed on the collector drains for inspection and maintenance

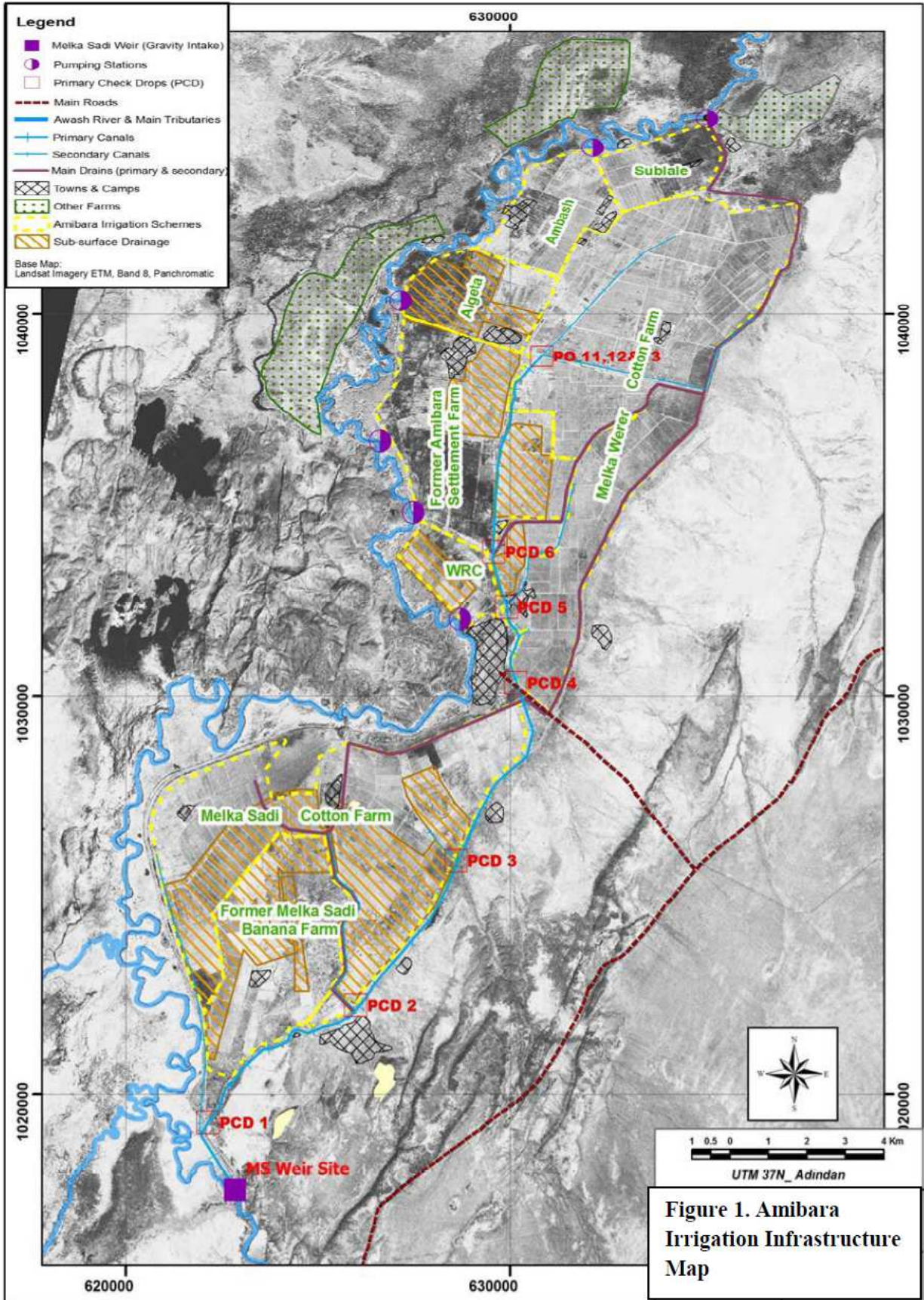


Figure 4.13 Amibara Irrigation Infrastructure (Source: Gedion, 2009)

4.4.2 Challenges of Irrigation Water Management in AIS

Irrigation water management has become a central issue in many countries, in particular after recent studies, which revealed the disappointing performance of many irrigation schemes. Inefficient water use and inadequate water management, both at farm and scheme level, mean much less area can be irrigated than planned, and agricultural production falls well below target (Mehta, 1994 and Solomon, 2006).

According to Salman *et al.* (1999), "Water management" is defined as the planned development, distribution, and use of irrigation water in accordance with predetermined objectives and with respect to both quantity and quality of the water resources. It is the specific control of all human intervention on surface and subterranean water. Every planning activity that has something to do with water can be looked upon as water management in the broadest sense of the term. According to U.S Bureau of Reclamation (2005), "Irrigation Water Management" means management of irrigation water on the farm. A good management, proper and timely application of water may result in better yield and reduction in drainage problems (Vidhya *et al.*, 2002).

The Awash Basin Authority is responsible for distributing water diverted from Awash River at Melka Sedi headwork to all entitled stakeholders as far as the Primary canal off take (PO) reaches. Distribution of irrigation water along secondary and tertiary canals and in fields is the stakeholders' responsibility. Water is transferred from field watercourses into field furrows using plastic hose siphons. Land levelling and ridging for efficient field water control and management is carried out using tractor pulled equipment.

Monthly water deliveries to each PO are calculated by the Authority and summarized on hand-written A3 sheets. Supply for different years are tabulated and shown below. Since the amount of water delivered to the farms varies with the irrigated areas, areas under cultivated different years are also considered to show the amount of water consumed per hectare. From the figures shown below, The Authority was delivered on average 100 to 160 million cubic metres of water per year to the 13 primary offtakes. This corresponds to between 10,000 and 16,000m³ per hectare, or between 1,000 and 1,600mm.

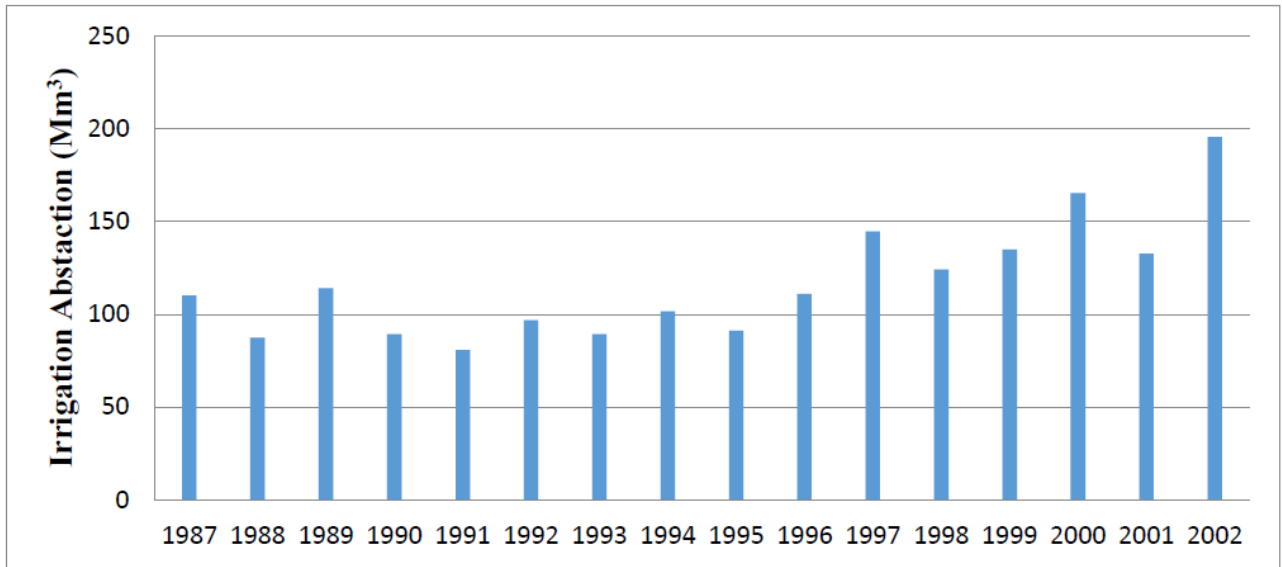


Figure 4.14 Annual Recorded Water Delivered to the Farms (Dates are in Ethiopian Calendar)

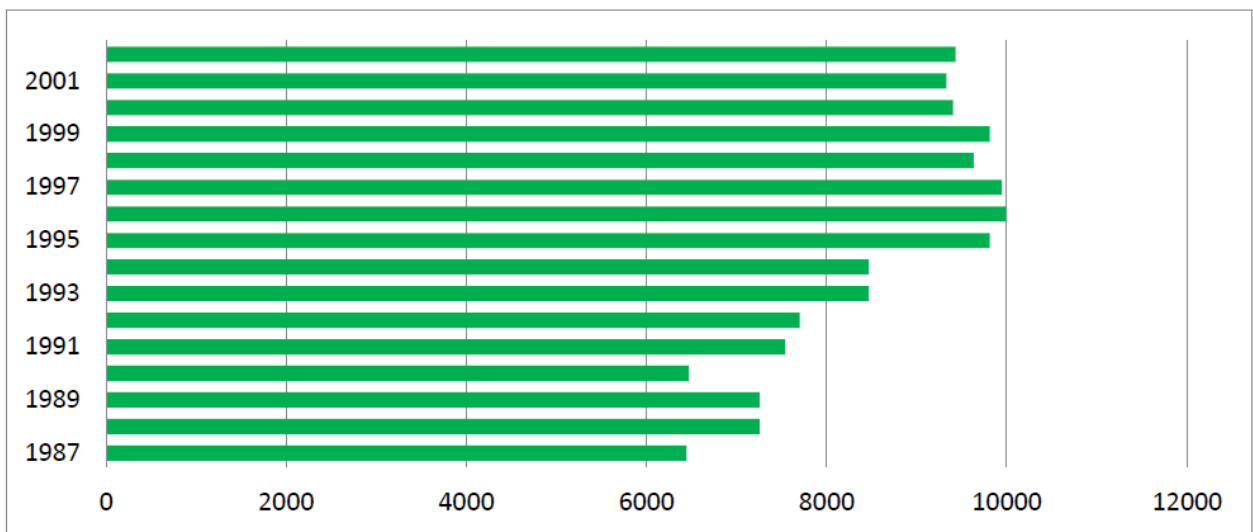


Figure 4.15 Annual Irrigated Farm Areas (Dates are in Ethiopian Calendar)

From data supplied by the Awash Basin Authority, the farms and clients provided with canal water are tabulated below. One of the problems in reconciling available data is that the 21 permits have been issued per entity rather than by primary offtakes. Permits for the large farms aggregate water supplied from several offtakes. Further complication arises as some offtakes are shared by several farmers.

One secondary canal where the large number of clients complicates distribution is that supplied by PO11. Water supplied to this canal is shared by the Melker Werer State Farm and more than 15 small private farmers. While the area of land held by small landowners is not large, the resulting confusion causes difficulties in distribution and water charging and compounds discontent.

The table below also lists farms supplied by pumping in or near the Amibara scheme. Included are smallholder farms, the majority of which are supplied by pumping. A small part (less than 250ha) of this area also receives water from the gravity canal system.

Table 4.2: Gravity System: Farms served by each Primary Offtakes (2010-11)

Offtake Number	Farms Served	Ownership	Area (ha)
1	<i>MAAE ; Sidha Faghi</i>	State	<i>1209.5</i>
2	<i>MAAE ; Melka Sedi</i>	State	<i>1008.0</i>
3	<i>MAAE ; Melka Sedi</i>	State	<i>1012.9</i>
4	Bedualala	Private	137.0
	Ezacan private Farm	Private	500.0
	<i>Sub-total 4</i>		<i>637.0</i>
5	<i>MAAE ; (Melker werer)</i>	State	<i>203.2</i>
6	MAAE; (Melker werer)	State	445.3
	Amibara Farm Development	Private	80.0
	<i>Sub-total 6</i>		<i>525.3</i>
7	MAAE ; Melker Werer	State	494.0
	Amibara Farm Development	Private	80.0
	<i>Sub-total 7</i>		<i>574.0</i>
8	Werer Research Centre	State	169.0
	Mahado Farm Development	Private	26.0
	Mahado Cooperative Farm	Private	30.0
	<i>Sub-total 8</i>		<i>225.0</i>
9	Amibara Farm Development	Private	1200.0
	Obito Cooperative Farm	Private	26.0
	<i>Sub-total 9</i>		<i>1226.0</i>
10	<i>Amibara Farm Development</i>	<i>Private</i>	<i>900.0</i>
11	MAAE; Melker Werer	State	999.0
	Muluken Alemu Farm	Private	3.0
	Hassen Nuru Farm	Private	6.0
	Aberra Soroto Farm	Private	27.0
	Abdo Seid Farm	Private	18.0
	Tadesse Yadene Farm	Private	60.0

Offtake Number	Farms Served	Ownership	Area (ha)
	Abdukerim Farm	Private	40.0
	Tinsae Farm Development	Private	9.0
	Atoba Mohammed Farm	Private	4.0
	Seid Alayteli	Private	5.0
	Debessay Tsegaye Farm	Private	5.0
	Bezzu Anshebo Farm Development	Private	13.0
	Nuriya Mohammed Farm	Private	10.0
	<i>Sub-total 11</i>		<i>1159.0</i>
12	<i>MAAE ; Melker Werer</i>	<i>State</i>	<i>1100.0</i>
13	Girma Feysa Farm	Private	3.0
	Hussen Ebrahim Farm	Private	8.0
	Edole Nasir Farm	Private	8.0
	Amibara Farm Development	Private	199.0
	<i>Sub-total 13</i>		<i>218.0</i>
	SUB-TOTAL (GRAVITY)		9997.9

Source: ABA, Water Resource Administration Department (2011)

Table 4.3: Pumped Water System: Farms served by pumping (2011)

Farm		Area (ha)
Werer Research Centre	State	130.0
Badahamo 2, Site 1	Private	469.0
Badahamo 2, Site 2	Private	
Algeta site	Private	419.0
Gidaro Amibara (Ambash)	Private	500.0
Sublele Site	Private	500.0
Asoba Site	Private	500.0
Angelele Site	Private	1000.0
SUB-TOTAL (PUMPED)		3518.0

Source: ABA, Water Resource Administration Department (2011)

The total area under gravity and / or pumped irrigation is about 13515.9ha.

Irrigation frequency is uniform and six irrigations are usually planned for the cotton crop: one pre planting irrigation and five post-planting irrigations (Halcrow, 1983). In practice most farmers apply three to five irrigations. Only the Research Station, with its relatively small command area and ability to combine both gravity and pumped irrigation water, achieves seven irrigations in a season. A common problem in

Amibara irrigation schemes is the poor condition and inefficient way of water conveyance in the farm canal network. To improve the exploitation of the canal system it is important that users (farmers) do understand the functioning of the canal system, the different problems that may occur in irrigation canals, their causes and how to avoid or overcome these problems. It should be kept in mind that irrigation schedules must be simple, in particular in irrigation schemes where many farmers are involved. It will often be necessary to discuss with the farmers the various alternatives and come to an agreement which best satisfies all parties involved (FAO, 1989).

Shortages of canal water occur during the dry and wet seasons. This is likely due to low flows in the Awash River during the dry season and chronic sedimentation of the primary and secondary canals in the wet season. This is because the original diversion works comprised a rock-fill weir and a submerged offtake with a scour sluice below, which was intended to ensure that the intake of the diversion conduit to the head of the main canal remained free of sediment. Over time the aggradation of the river bed has completely buried the weir, intake, and scour sluice with sediment. A new free intake was constructed about 25m upstream of the existing headworks, but this only operates when the water level is high. Although sited on the outside of a bend there is no scour sluice or sediment exclusion facility and as a result sediment laden water is being drawn straight into the main canal.

The annual accumulation of silt along the whole of the main canal raises the bed level between 0.6 and 0.8m, which reduces the carrying capacity and blocks the offtakes. The annual volume of sediment excavated from the main canal over the last three years is given in the following text table:

Year	Sediment Excavated (m ³)
2010	113,113
2009	119,732
2008	102,467

Source: ABA, Water Resource Administration Department, 2011

Over the years the spoil heaps of excavated materials along the canal have become so big that during local storms soil is washed straight back into the canal. Considering the Drainage problem in Amibara, the main drain outfall is controlled by flap gates, which are normally closed from the end of June to the end of August to prevent water backing up the drain when the water level in the Awash is high. However, this restricts the outflow of drainage water resulting in flooding and the silting up of the drain, which has buried the sub-surface drainage pipe outfalls. The inadequate drainage has caused salinity problems and water-logging especially near the irrigation canals and in low lying areas. There is also a delay in supplying water for planting due to an extended closure in March for canal desilting and maintenance. Examination of the Authorities' water supply records for the last five years confirms this. It also seems that filling of the primary canal starts before desilting is completed so that canal capacity is reduced right from the start of the season. For such reasons the stakeholders become dissatisfied and ask more water than they want.

In addition to non-timely supply of adequate irrigation, precise land levelling to improve on-farm water use efficiency is required. This would also reduce salinity. There is a shortage of adequately trained irrigation staff working with the state and private farms to improve water distribution below the PO and on-farm levelling activities. This poor land levelling practice affects the farm irrigation system, hence results for the recharge of ground water, which in turn aggravates the salinity problem.

4.4.3 Operation and Maintenance of Irrigation System

Irrigation operation in its simplest definition is the opening and closing of gates for water distribution. This operation delivers irrigation water to the farmer's terms of timing (frequency), flow rate and duration of irrigation application. Hence the measurement of irrigation water is an essential element for its fair distribution and economical use. Measurement serves to ensure the maintenance of proper delivery schedules, to determine the amounts of water delivered and to single out anomalies in distribution. According to Ertsen (2005), by means of weirs, dams, canals and other constructions, the spatial and temporal distribution of water is regulated. An important aspect of water control relates to the temporal and spatial distribution of water, or in other words the modification of an (agriculturally) unfavorable timing of watering in the annual cultivation cycle. Unfavorable timing includes both the transfer of water to overcome shortages (irrigation) and to remove excess water (drainage).

Water control refers to the ability of the system to distribute, apply, or remove water at the right time, in the right quantity, and at the right place. The main objectives of water control in an irrigation project are reliability (temporal), adequacy (volume balance, including seepage, operational and application losses), and equity (spatial parameters) (Lowdermilk, 1981).

In AIS, the responsibility for the management of the on-farm water distribution and the water application belongs to an individual farmer. ABA is responsible for the operation and maintenance of the irrigation system. Flows released into the 13 secondary canals are measured by the Authority. Standard forms, filled in by **gate operators**, record flows through each primary offtake. These are submitted to the **Irrigation and Water Control Unit**, and form the basis of water charges. The Authority charges Birr 3.0 / 1000m³ of water delivered at the PO. Generally in AIS, two management levels can be distinguished:

- Conveyance or main level by the Awash Basin Authority;
- Field level or on-farm distribution and application system managed by the farmers (state farms and investors).

The problem is obtaining payment from the clients especially from small farmers is more difficult. It is much more difficult to stop water deliveries to one farmer when water is delivered to a group. While it is technically possible to close the gate of the farmer, this is not attractive for the basin Authority. The other source of conflict in Amibara is when the Irrigation demand exceeds supply. During dry season shortage of canal water will happen due to low flow of the Awash River. Operating the irrigation schemes requires joint action between the Authority and its clients or farmers using the water for production. Therefore an agreement by-law is needed between the two bodies with clear and justified responsibility. The Authority should work with its clients to improve transparency of distribution, with meetings and dissemination of flow data on a weekly or monthly basis. Clients are entitled to have reasonable confirmation of the volumes of water received they will be paying for, and to the extent their request are received. Routine maintenance of the headworks, primary canal and main drain is carried out by the Awash Basin Authority according to a programme and associated budget approved by the (larger) stakeholder clients. The budget was spent on machinery operating costs and fuel and the rest on labour and allowances.

Current practice is to draw up a Maintenance Plan before the irrigation season and levy maintenance charges on clients to meet the expected costs before carrying out the maintenance.

Problems and constraints relating to maintenance include:

- Costs and hence charges are relatively high because of the large annual volume of silt to be removed. Some farmers have difficulty paying the charges as single lump sum.
- The Authority strives to minimise maintenance charges by only carrying out vital maintenance. In the long term this results in a deterioration of infrastructure.
- Removal of sediment from the primary starts late if clients pay late or the Authority delays preparing and concluding agreement to Maintenance Plan.

Hence increased competition between users in AIS requires some form of organization, like water user association of the scheme for sustainable management and sound operation and maintenance activities. The Basin Authority as a regulatory body should work on accurate planning, allocation and conveyance of irrigation water to the clients, in this case to the water users association. Therefore the Authority should immediately start organizing the stakeholders and form the association.

4.5 Soil Salinity and Sodicity Characteristics

Analytical results of electrical conductivity, pH, SAR, concentration of major cations of the soil solution used as an important parameter to explain salinity and sodicity characteristics of soils of the studied area, are presented in Appendix Table 4A. Four classes of soils were defined based on their chemical properties, accounting for changes in pH, E_c and Sodium Adsorption Ratio (SAR): non-affected, saline, sodic, and saline-sodic soils, each of the last three with different degrees of salinity/sodicity. The threshold value for E_c was set at 4 dS/m according to the saline or non-saline boundary in USDA soil salinity standard analysis; and for SAR, which is an indicator of sodic or non-sodic characteristics, was set at 13.

4.5.1 Soil reaction (pH)

Soil pH varied between 6.9 to 8.9 for Melka Sedi and 7.06 to 9.1 for Melka Werer farm areas (Appendix Table 4A). The pH values appeared to be low in saline soils, where calcium and magnesium were dominant and on the other hand the pH is high in sodic and saline sodic soils where sodium seems dominant. The pH of the study site is in general greater than 7, indicating alkalinity reaction. Since the pH value or the soil reaction is influenced by the presence and concentration of cations, its ranges varies in salt affected soils. Early reports by Girma and Geremew (1996) and recent study conducted by Gedion (2009) also reveals that the pH of the study area has a value greater than

7. The probable reason for this high pH value could be attributed due to high concentration of bicarbonates.

4.5.2 Soil salinity appraisal

Soils of the area exhibited high range of variation with respect to ECe values (Appendix Table 4A). ECe value varied from 0.33 dS/m to 82.1 dS/m and 0.4 dS/m to 37.5 dS/m, respectively for soil samples taken from Melka Sedi and Melka Werer farms. Regarding the magnitude of the problem, sever salinity problem was observed at Melka Sedi and former Banana farm areas. Even though the extent was less in terms of area affected, salinity problem in Melka Werer area was also observed. It was also observed that several hectares of cotton cultivated farms were at saline phase as witnessed from manifestation of frequent salinity patches elsewhere in the command area indicating the possibility of salinity expansion to take place in near future at more faster rate than ever seen before. According to the classification system of the USSLS (1954) and FAO (1988), out of 249 soil samples, 48 % of the soil samples were mapped as non-saline soils with ECe values less than 2 dS/m. 18 % of the soil ranges for slightly saline soils with ECe values between 2 dS/m to 4 dS/m and the rest 34 % of the soil ranges between moderately saline to severe sainity with ECe values greater than 4 dS/m (Table 4.4).

Table 4.4 Area coverage per salinity levels for 0-30cm depth

Farm Unit	Percentage area per salinity level					
	Total Area (ha)	Non Saline	Slightly Saline	Moderately Saline	Strongly Saline	Severe Salinity
ECe (dS/m)		0-2	2-4	4-8	8-16	>16
Amibara Farms	15256.22	7294.65	2712.65	2089.68	2013.42	1145.82
% Area	100	47.8	17.8	13.7	13.2	7.5

Hence Cotton yields may start to decrease when ECe value is greater than 7 dS/m (FAO, 1988). Even now relative decrease in cotton yield occurred in Melka sedi and former banana farms and it will be aggravated unless salinity levels are controlled using proper reclamation measures.

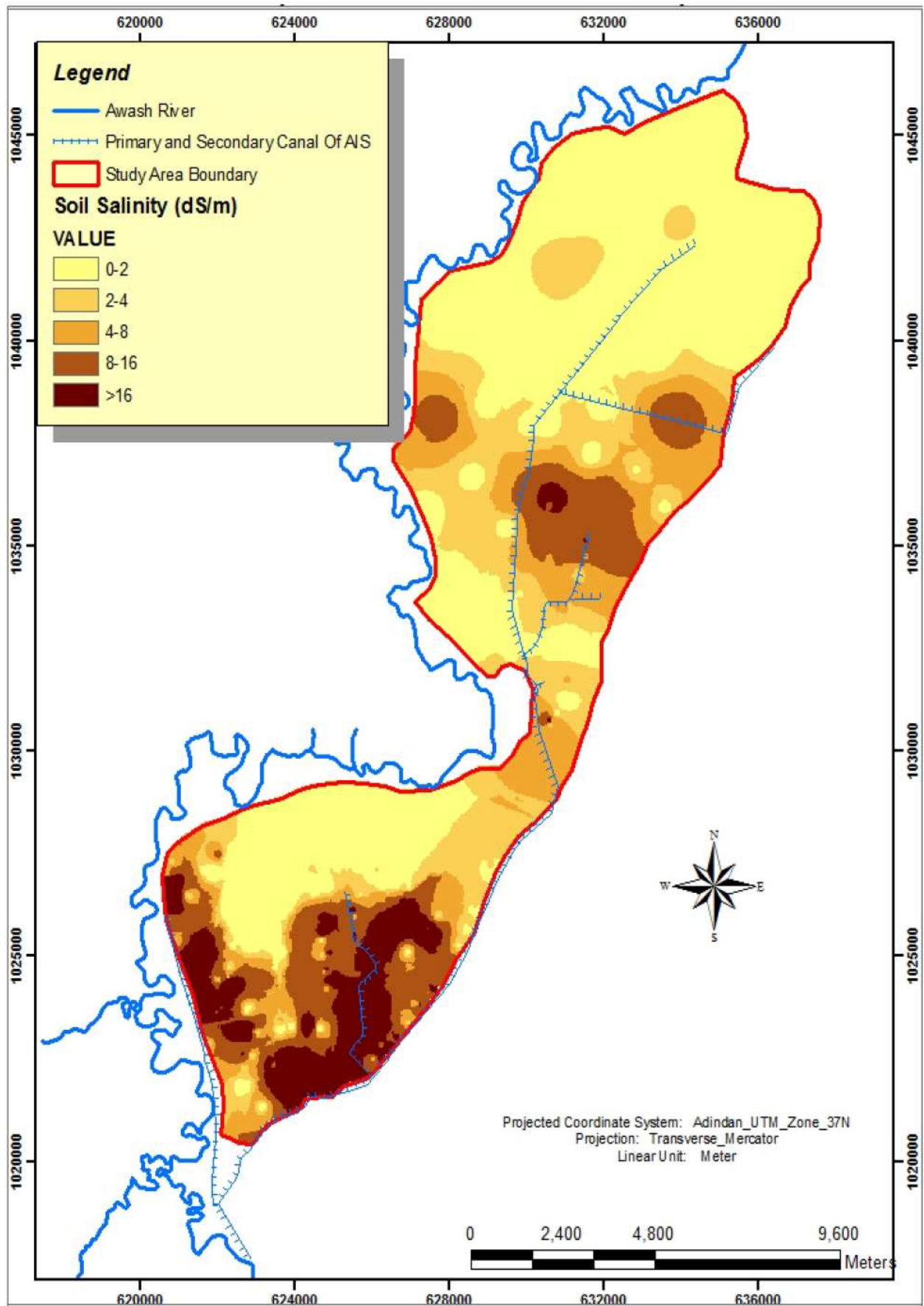


Figure 4.16 Soil salinity map of AIS

4.5.3 Soil sodicity appraisal

The sodium adsorption ratio ranges from 0.7 to 27.2 in Melka sedi and 0.6 to 9.4 in Melka Werer farm areas (Appendix Table 4B). Soil sodicity problem were observed in Melka Sedi farm areas especially in some fields of former Banana farms, which had a very strongly sodic character. Soils of Melka Werer were not very much affected by sodicity problems so far.

The probable reason for high SAR value on the former Banana farms may be explained by the fact that this part of the farm had been waterlogged for many years compared to other farms. During this time, due to annual variation in dynamic nature of the water table, much of the calcium and magnesium might have precipitated having behind the sodium to accumulate.

According to FAO (1988) classification, taking the SAR_e values of the saturated extract at a soil depth of 0-30 cm, out of 249 soil samples 78 % the soil is mapped as non sodic with SAR_e values less than 3. About 21 % of the soil is very slightly sodic with SAR_e value ranges between 3 and 7. The rest 1 % is fall under classes of slightly sodic to very strongly sodic (Table 4.5).

Table 4.5 Area Coverage per Sodicity Levels for 0-30cm depth

Farm Unit	Percentage area per salinity level					
	Total Area (ha)	Non Sodic	Very slightly sodic	Slightly Sodic	Moderately Sodic	Strongly Sodic
SAR _e		0-3	3-7	7-13	13-21	21-37
Amibara Farms	15256.22	11863.49	3168.93	214.74	6.71	2.35
% Area	100	77.76	20.77	1.41	0.04	0.02

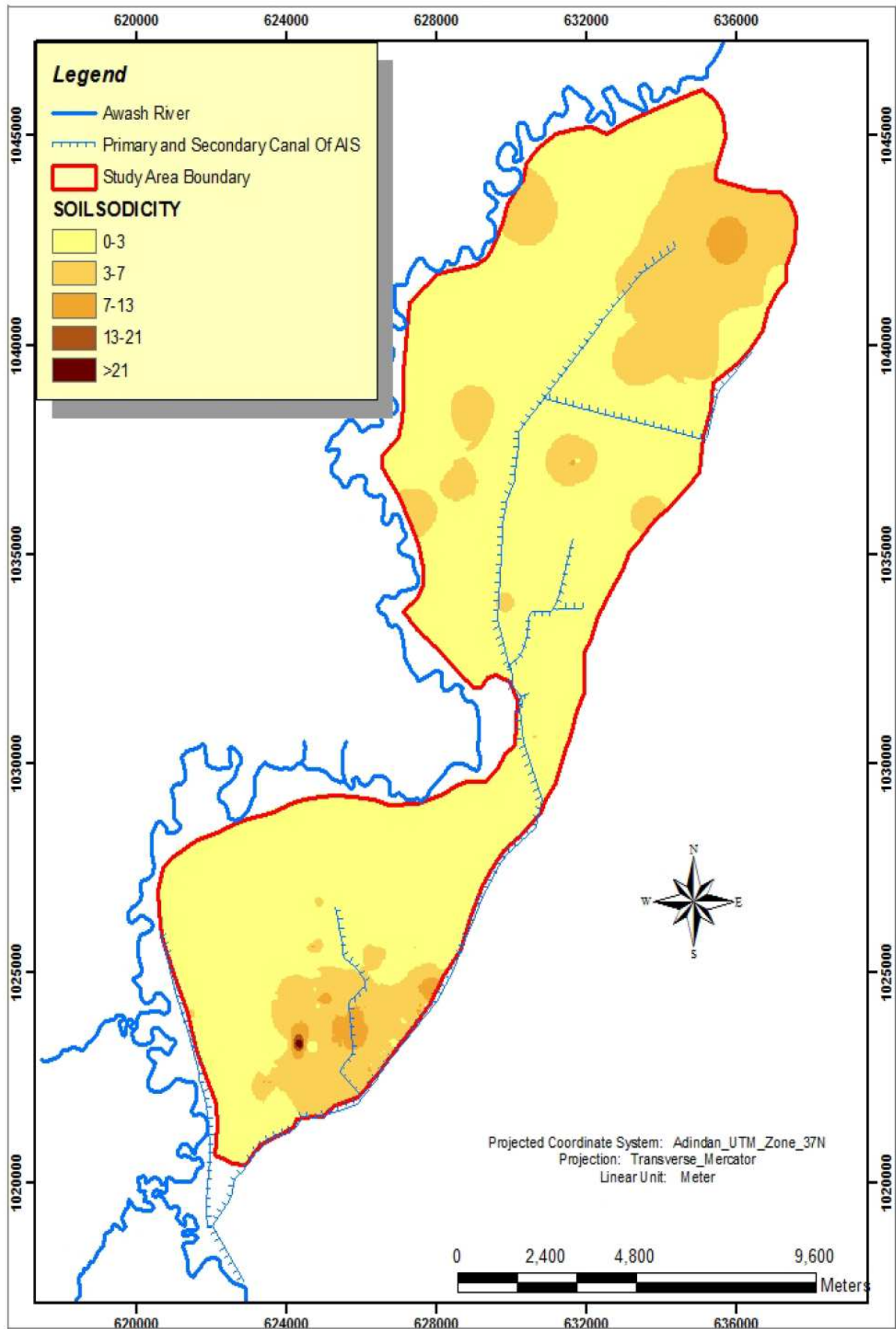


Figure 4.17 Soil sodicity map of AIS

4.5.4 Salt affected soils in Amibara irrigation schemes

The analytical result obtained (Appendix Table 4) indicates that the electrical conductivity of the saturated extract at soil depth of 0-30 cm varies from 0.33 to 3.93 dS/m for non-saline, 23.00 to 45.90 dS/m for saline sodic soils and 4.02 to 82.10 dS/m for saline soils. Whereas the sodium adsorption ratio of the saturated extract varies from 0.6 to 4.05 for non-saline, 12.75 to 27.19 for saline sodic and 0.79 to 11.80 for saline soils. Hence considering the distribution of salt affected soils in Amibara Irrigation Schemes, about 34 % of the soils are salt affected soils (Table 4.6).

According to U.S. Salinity Laboratory Staff (1954) classification, significant part of Melka Sedi farm and former Banana farms are mapped as saline and saline sodic soils. Around 34 % of AIS soils are saline soils with EC_e greater than 4 dS/m and SAR_e less than 13. About 0.05 % of the area is mapped as saline sodic soils with EC_e and SAR_e values greater than 4 dS/m and 13. This saline sodic soils were found in former Banana Farm (Field Number 2A4). Sodic soils, with EC_e less than 4 dS/m and SAR_e greater than 13, in the farm area were not identified (Table 4.6).

Table 4.6 Area Coverages of Salt Affected Soils in AIS

No.	Salt affected soils Class	EC _e (dS/m)	SAR _e	Area (ha)	% Area
1	Non Saline –Non Sodic Soils	< 4	< 13	10007.30	65.60
2	Saline Soils	> 4	< 13	5239.79	34.34
3	Saline Sodic Soils	> 4	> 13	9.13	0.06
Area				15256.22	100%

Because of the insufficient annual rainfall, evapotranspiration exceeding rainfall (evapotranspiration rate of 3000 mm/year, as compared with 500 mm annual precipitations) to leach down salts from the plant rooting zone and lack of natural drainage, soils of Amibara irrigated command areas were developed into salt affected soils. Here also, due to poor irrigation practice and lack of appropriate drainage, the groundwater levels have come closer to the surface; the farm areas are prone to secondary salinization. Development of productive and sustainable irrigated agriculture in such areas must then be preceded by necessary precautionary measures and followed by proper management practices.

From the map it can be shown that about 66 % of the farm area is non saline and non sodic with E_{Ce} and S_{ARe} less than 4dS/m and 13. But soil salinity and sodicity problem is never a static soil behavior; there will always be change in the distribution of salt affected soils spatially. Unless salts are leached down and drainage is provided soon, more area will be affected by salinity and sodicity.

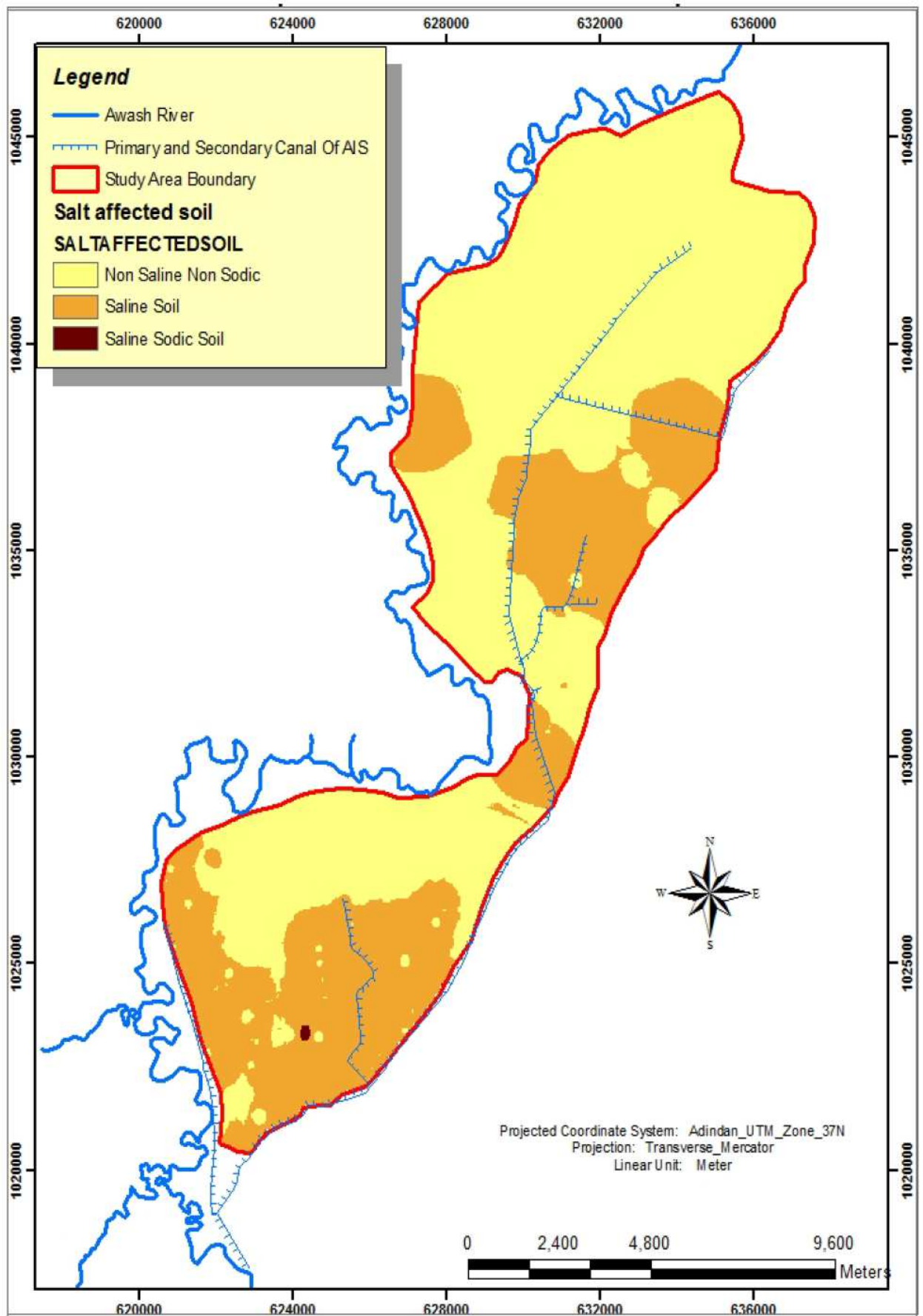


Figure 4.18 Salt affected soils map of AIS

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Assessments of water quality changes in the Awash River together with the impact of loading of Lake Beseka water in to the Awash River has paramount importance to indicate the current status of Awash River and Lake Beseka water chemistry. Results that were discussed together with the discharge of Awash River flow at the sampling points and time revealed that temporal and spatial variations have been observed in both water bodies. Spatial variability was observed in Awash River along the river due to the inflow of tributaries and other natural water source.

Spatial and temporal variability of Awash River at selected sampling points were assessed along the main river courses from the upper valley to the lower valley. From the results, regarding the physicochemical parameters, spatial variability was observed in the Awash River along the courses due to inflows from other tributaries and natural thermal springs that are hydrologically connected to the Awash River. Lake Beseka discharge into Awash River also affects the water chemistry downstream of the of the lake area. In addition to Lake Beseka return flows from the farm areas were also contributed to the increased concentration of different species downstream of Awash River. Regardless of the above mentioned factors with moderate salinity and low sodicity class, the Awash River water can be considered as suitable for irrigation purpose. Samples taken from the Amibara irrigation canal have similar pH and EC values as that of the Awash River sample taken at Melka Sedi. Whereas results obtained from the main drain have relatively higher values than the irrigation waters.

Some 249 soil samples were collected from Amibara irrigation farm areas during the months of October and November 2011. A standard methods were followed to measure pH, EC and soluble cations and anions. Arc GIS 9.3 was used to map the over all salinity and sodicity problem of the area.

From the results, considering the soil reaction (pH) of the study area almost all of the soil samples have a pH greater than 7 indicating general alkalinity reactions. Regarding soil salinity and sodicity assessment, detail soil salinity and sodicity map of the study area was conducted due to extreme heterogeneity of soils with respect to salinity and sodicity and

occurrence of wide range of the problem. From the results around 34% has been mapped as saline soil and out of which around 20% as strongly to severe saline. Sodicity problem, only 1% has been

mapped as slightly sodic to very strongly sodic soil. Combining both parameters (EC_e and SAR_e values) were resulted 34% as saline soil and 0.05% as saline sodic soils. From the maps soil salinity/sodicity problems were also observed in Melka Werer areas but the extent was less compared to Melka Sedi area.

Based on the findings reported in the previous section the following major conclusions are drawn.

1. With regard to water quality assessment, spatial variability was observed in the Awash River along the courses due to inflows from other tributaries and natural thermal springs. But from the analysis it can be concluded that, Awash River water can be considered as suitable for irrigation purpose, with moderate salinity (C2) and low sodicity class (S1).

2. Soil salinity and sodicity assessment of the study area revealed that, substantial parts of Amibara farm areas were consistently and continuously affected by salinity problem. Significant proportion of the irrigated land has been abandoned or soon will be abandoned mainly because of secondary salinization resulted from shallow saline groundwater table.

5.2 Recommendation

Given the conclusion stated and the field observation, the following recommendations are forwarded

- The expansion of the lake has already started affecting Matahar Sugar Estate (MSE) and it should be considered seriously before it brings total devastation. Optimum irrigation and appropriate drainage should be adopted, in order to limit the inflow into the lake.

- It is difficult to conclude that the irrigation/rainfall excess from the nearby farms is the only cause for the expansion of the lake. As the area is situated in the rift valley system, where there are active tectonic activities, other factors are expected to aggravate its expansion even in the future. Hence, further and detail investigation that considers all the parameters affecting lake expansion is needed to justify the cause for the expansion.
- The expansion extent of the lake is very terrible and creates a great developmental challenge in the Awash basin. All the beneficiaries of the basin, concerned institutions and the decision makers of the country should consider the condition seriously and adopt mitigation measures before it brings irreversible damage to the region.

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