Economic and agricultural transformation through large-scale farming : impacts of large-scale farming on local economic development, household food security and the environment in Ethiopia

Bekele, M.S.

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Author: Bekele, M.S.
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CHAPTER 6: IMPACTS OF LARGE-SCALE FARMING ON LOCAL ENVIRONMENT

6.1 Introduction

The world's population is projected to increase from 7 billion today to 9 billion by 2050 (United Nations 2013) and the demand for food is expected to rise by 60% by 2050 from the 2005–2006 production level (FAO 2012e). While converting forests and grazing lands into farmlands to feed the increasing population has been a common practice (Gibbs *et al.* 2010), the rate of land conversion both for food and biofuel feedstock production has been unprecedented since 2007 following massive large-scale land acquisitions driven by the food, fuel and finance crises (Hall 2011). On the other hand, land alienation from local communities for conservation programmes has been widely practised in Africa (Brockington 2004). To deal with the oil price spike, the European Union mandated EU member states to meet at least 10% of their transport energy needs from renewable energy sources by 2020 (European Union 2009). To fulfil 10% of the transport energy from renewable sources, 20–30 million ha of land will be needed (HLPE 2011).

The increased global demand for land to produce biofuel feedstock was estimated to quadruple in the coming 15–20 years (Fairless 2007) and was projected to require 20% of the world's agricultural land by 2050 (White & Dasgupta 2010). This was also a major push factor for the increased demand for land for biofuel feedstock production. Opponents have also stated that biofuels are not necessarily a panacea for the twin crises of energy security and climate change that initially served as the justification for investing in biofuels. The magnitude of GHG emissions per unit of energy from biofuel feedstock production depends on how and where biofuel crops are produced (UNIDO 2010; Pacheco *et al.* 2012) and the conversion technology used (Alder *et al.* 2007; Pacheco *et al.* 2012). For instance, Fargione *et al.* (2008) estimated that expansion of biofuel crops into natural landscapes could release 17-420 times more CO_2 than annual GHG reductions by using liquid biofuels. Gibbs *et al.* (2008) noted that large-scale biofuel feedstock production is carbon-saving when produced on degraded/cultivated plots but is carbon-emitting when replacing tropical forests. Whether land is converted to produce biofuel feedstock, flowers or food crops, is one of the key determinants that affects environmental sustainability.

Recipient countries viewed the rush for farmland by wealthy nations and corporations as an opportunity to speed up their national development, and they provided investors with lucrative incentive packages (discussed in Chapter 1), which attracted investors to acquiring farmlands in the developing South. As a result, globally and also in Ethiopia, huge tracts of land have been leased out to foreign and domestic capital for long-term plantations.[63] Land Matrix (2015) estimated that over 16 m ha of land globally, of which about 55% from Africa, are acquired for agricultural production. In Ethiopia, close to 2.2 million ha of land was transferred to investors between 1992 and 2013, of which the lion's share was transacted in 2008 (Chapter 1). Government statistics revealed that close to 1.5 million ha of land were transacted to investors in Ethiopia for biodiesel feedstock production between 2005 and 2010, but only a few have started implementation (Shete & Rutten 2014).

The transfer of large swathes of land for food and biofuel production has changed pre-existing land uses both globally and in Ethiopia. Borras and Franco (2012, pp. 39–42) presented the dominant global land-use change typologies in four distinct patterns. The authors acknowledged that the typologies are simplified presentations of the complex realities of land-use changes across the globe and can be used as a conceptual map to explain the drivers of land-use change and its effects on the land users. I have adapted their conceptual framework to explain the dominant land-use changes in Ethiopia and added one more typology that shows a change from food and non-food land-uses to crop production for industrial raw materials. A brief description of the dominant land-use change typologies adapted from the authors is presented below (Figure 6.1).

Typology I: under typology I, three different sub-categories are identified. These are: (1) a change from subsistence food production to a more market-oriented domestic food production, (2) a shift to smallholder food production from large-scale food production, and (3) a shift from subsistence food production to food production for export. All these are taking place in Ethiopia. A shift in policy from smallholder-focused agriculture to commercialization of agriculture is observed in Ethiopia since the launch of the second national development plan – the Plan for

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[63] This includes land allocated for large-scale food, biofuel feedstock and industrial raw material (e.g. cotton, rubber tree, etc.) production.

Accelerated and Sustained Development to End Poverty (2005/06-2009/10) (see MoFED 2006). As a result, land devoted primarily to subsistence food production by households was allocated for the production of food for domestic markets. The shift from large-scale farming to smallholder subsistence food production, however, is also observed in Ethiopia in which the incumbent government re-distributed large-scale farms that were owned by the previous government regime among those landless youth with the objective of addressing food security at local levels. These two sub-categories are, however, beyond the topic of 'land grabbing', and are not the interest of this chapter.

In the second sub-category, farmlands previously devoted for food production by the local people either through statutory or customary ownership are transferred to large-scale food production for export. This is one of the dominant patterns of land-use change that is feared to bring negative outcomes to local people and is criticized by different rights groups, researchers and donor groups for the likely dispossession of local people from their land-based resources.

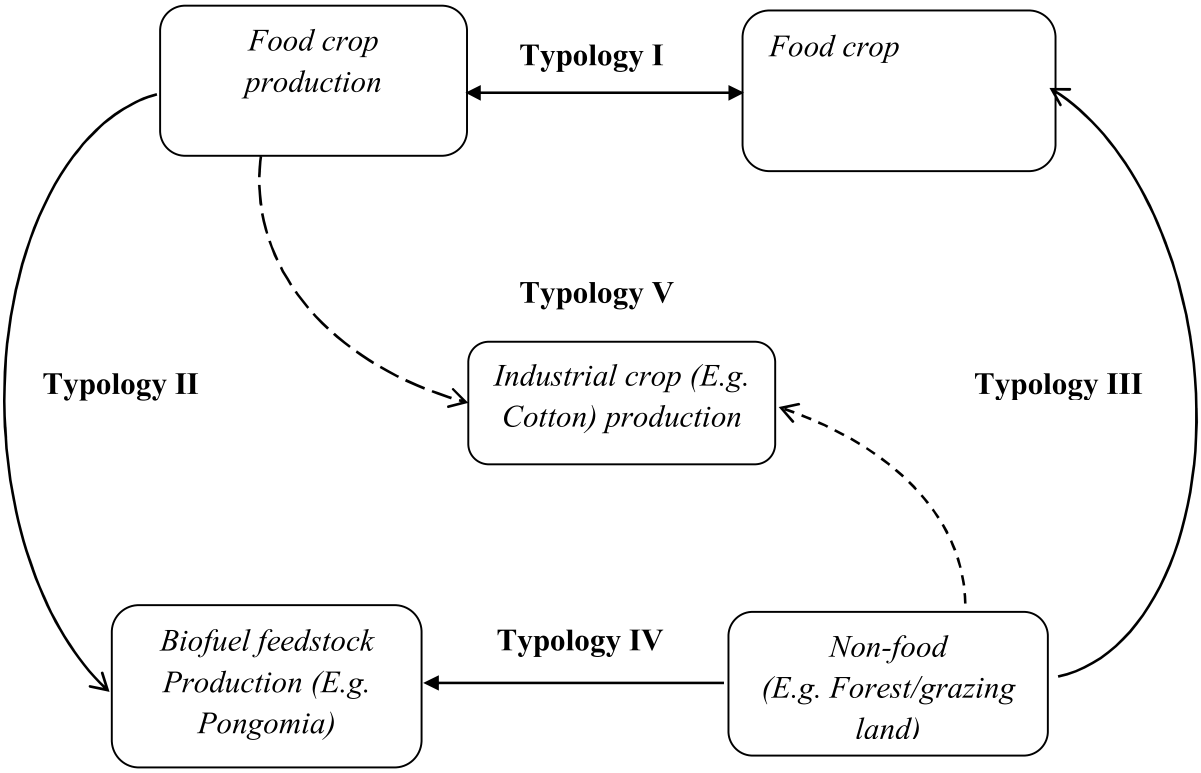

Figure 6.1: Conceptual framework for the dominant global land-use changes

Typology II, which is a shift in land uses from food production to biofuel feedstock production, is one of the typologies that has been the subject of global land grabbing in the recent past. While the land allocation was made with the dominant narrative of unused land that has neutral food security reducing impacts, critiques argued that lands suitable for food production were allocated for biofuels. Between 2003 and 2007, two thirds of the global increase in maize production went to biofuels (World Bank 2009, p.4). The pressure on arable land due to biofuel feedstock production has arguably set back food security for the coming 20 years (FAO 2011b). In Ethiopia, for example, the case of S&P Energy Solution and Karuturi Agro Products PLC falls partly under the pattern of land-use change from local food production to biofuel feedstock production (Table 6.1).

Typology III: depicts the shift from non-food land use to food production. While converting forest and grazing lands into farmlands to feed an increasing population has been a common practice (Gibbs *et al.* 2010), the 2007/2008 global food crisis has increased the rate of land conversion from other forms of land use to food production. In Ethiopia, this has been done under the narrative that the country is endowed with over 74 million ha of land suitable for annual and perennial crop production but only less than 25% of it (18 million ha) is under cultivation. As presented in Table 6.1, the majority of the lands transferred to domestic and foreign capital in Ethiopia falls under this land-use change typology.

Table 6.1: Patterns of dominant land-use changes due to large-scale farming in Ethiopia

Company	Origin of Investor	Region	Size (ha)	Year	**Dominant *ex ante* land use**$^{+}$	Current land use	**Pattern of land-use change**
Karuturi Global	Indian	Oromia	11,700	2008	Grazing land with scattered trees and partly used for *teff* and Niger seed	Maize cultivation	Typology I and III
Arjo-Dedessa Sugar Mills	Ethiopian Government	Oromia	28,000	2007	Shrub land and grassland	Sugar cane	Typology III and V
S&P Energy Solution	Indian	Benshanguel	50,000	2010	Forests, grassland and shrub land and shifting cultivation	Pongomia trees and food crops	Typology I, III and IV
Spentex	Indian	Benshanguel	25,000	2009	Forests, grassland and shrub land	Cotton	Typology V
Tana Beles Sugar Mills	Ethiopian Government	Benshanguel and Amhara	75,000	2010	Forests, bush land and shrub land	Sugar cane	Typology V
Omo Kuraz Sugar Mills	Ethiopian Government	SNNP	175,000	2011	Shrub land and grassland	Sugar cane	Typology V
Lucci	Ethiopian	SNNP	4003	2009	Grazing land and plots for maize and tobacco	Cotton farming	Typology V
Mela	Ethiopian	SNNP	5000	2010	Grassland and bush	Oil crops and cereals	Typology III
Adama	Ethiopian	SNNP	18,516	2010	Grassland	Cotton and cereals	Typology III and V
Whitefield	Indian	SNNP	10,000	2010	Grassland	Cotton	Typology V
Verdanta Harvest	Indian	Gambella	3012	2010	Indigenous forest	Tea plantation	Typology V
Sannati	Indian	Gambella	10,000	2010	Grassland and woodland	Rice and pulses	Typology III
BHO	Indian	Gambella	27,000	2010	Grassland and woodland	Edible oils	Typology III
Ruchi	Indian	Gambella	25,000	2010	Grassland and woodland	Soya beans	Typology III
Karuturi Global	Indian	Gambella	100,000	2010	Forest, Grassland and seasonal cultivation of maize and sorghum	Maize, sugar cane, oil-palm cultivation	Typology I, III and V
Basen Farm	Ethiopian	Gambella	10,000	2008	Scattered trees, bush land and cultivation of sorghum and maize	Cotton	Typology I and V
Saudi Star	Saudi	Gambella	10,000	2010	Grassland and woodland	Rice cultivation	Typology III
Kesem Sugar Plantation	Ethiopian Government	Afar	20,000	2010	Grassland and woodland	Sugar cane	Typology V
Tendaho Sugar Mills	Ethiopian Government	Afar	50,000	2010	Grassland and woodland	Sugar cane	Typology V

Source: Own survey (2011, 2012 and 2013) and Ethiopia Sugar Corporation (2013)

Note: It should be noted here that the cases are presented to capture the dominant forms of land-use changes and it is by no means a complete list. The shaded from the list are the large-scale farms that this study examined in detail.

Typology IV: represents the shift in land-use from non-food production to the production of biofuels. As a double solution to the fossil fuel price and climate change crises in 2007–2008, the use of biofuels was advocated and subsequently resulted in the conversion of lands from other forms of use to the production of biofuels. In Ethiopia, both bio-ethanol and biodiesel production are advocated. The country is estimated to have 23.3 million ha of land suitable for biodiesel (Forum for Environment 2011) and 333,500 ha of land for irrigated and rain-fed sugar cane and associated bio-ethanol production (Ethiopia Investment Agency 2008). Government records show that a total of 1.5 million ha of land was leased to 34 investors for biodiesel feedstock production (Annex 6.1) and 294,000 ha of land is allocated for eleven new sugar plantations (Annex 6.2) planned for three regional states[64] in the country. Data from the Ethiopian Sugar Corporation showed that 330,000 ha of land is already allocated to the state-owned Sugar Corporation and private investors for the production of sugar cane and bio-ethanol (Ethiopian Sugar Corporation 2013). Ethanol production for blending with gasoline is one of the products targeted in these projects. The transfer of land for biodiesel and bio-ethanol production has brought substantial changes in land-use in Ethiopia from non-food and sometimes from temporary food production to biofuel production.

Environmental degradation is generally conceptualized as the deterioration of natural resources such as natural vegetation, soil, water, wildlife, aquatic resource, etc. due to the deleterious effect of human activity (Johnson *et al.* 1997). Intervention through large-scale farming is one area of human interference that affects the natural environment. Researchers reported the impact of land-use change due to large-scale farming on different environmental parameters in different countries. For example, land conversion for food and flower production was reported to accelerate deforestation and loss of biodiversity (Foley *et al.* 2005; Pimentel *et al.* 2006), increased encroachment of national parks by local people who have been displaced by large-scale farms (Deininger *et al.* 2011), and contributed to water scarcity (Rutten & Mwangi 2008; Woodhouse 2012). Land-use change is also reported as a major contributor to climate change and is estimated to account for 13–17% of global anthropogenic Green House Gas (GHG) emissions (FAO 2008). Corollary to this, the fifth assessment of the Intergovernmental Panel on Climate

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[64] In Southern Nations, Nationalities and Peoples Regional State, a total of seven new sugarcane production farms are being established on 175,000 ha of land; in Amhara Regional State, three new sugarcane production farms will be established on 75,000 ha of land; and in Tigray Regional State, one new sugar factory is being established on 44,000 ha of land (Ethiopian Sugar Corporation 2013).

Change (IPCC) report emphasized that humans are responsible for global climate change (IPCC 2013). A report by the National Meteorological Service Agency (NMSA) in Ethiopia also indicated that land-use change is a major source of GHG emission, and agricultural activities accounted for 80% of the total CO_2 equivalent emissions (NMSA 2001).

Although there is a growing body of literature about the environmental effects of large-scale land acquisition (cf. Shete 2010; Agrarian Justice 2013; Balehegn 2015), the subject is less researched compared to scholarly works that study the impact of large-scale land acquisitions on the human dimensions (Lazarus 2014). More importantly, the term environment embraces several components and requires more in-depth analyses of specific environmental parameters. Some researchers exerted scholarly efforts to analyse the impact of large-scale land acquisitions on specific environmental parameters. For example, Rodrigues *et al.* (2009) linked deforestation in Amazonia with regional level changes in climate-related variables and Gobena (2010) noted that large-scale land acquisition has worsened the magnitude of deforestation in Ethiopia; Rulli *et al.* (2013) estimated the volume of irrigation water appropriated globally due to ‘land grabbing’; Lazarus (2014) documented the effects of global ‘land-grabbing’ on rivers’ sediment flux; and Rabalais *et al.* (2010) analysed the effects on coastal water bodies of run-off from farmlands rich in nitrogen and phosphorus petrochemical fertilizer.

To date, research about the effects of land-use changes due to large-scale farming on vegetation cover change, soil related environmental parameters such as soil carbon stock, soil bulk density (porosity) and soil micronutrients in Ethiopia has been minimal. And yet, the effects on the soils are important and should be taken into the equation when valuing land-use changes due to large-scale farming. As a result, among the different elements that constitute the natural environment, this study examined the effect on large-scale farming on vegetation cover change and on soil quality.

Globally, the organic soil pool is estimated at 2,500 billion tons, of which soil organic carbon constitutes more than three times the atmospheric carbon pool (Lal 2004a). CO_2 emissions due to land-use change are estimated to have averaged 5.9 billion tons annually in the 1990s (IPCC 2007). Soils with a high level of organic matter increase biodiversity (Pimentel *et al.* 2006) and serve as a carbon sink. Piccolo (2012) argued that cultivation accelerates the release of organic compounds into the atmosphere by exposing top soils to surface drying and oxidation that makes farms sources of carbon to the atmosphere rather than carbon sinks. When properly managed, agricultural soils could serve as a carbon sink and play a vital role in reducing GHG emissions (Lal 2004b; Janzen 2004).

Cultivation also changes the soil's aggregation/porosity, which determines the circulation of air and water in the soil. Water-holding capacity of soils vary considerably across undisturbed natural environments and cultivated lands. This has a direct effect on groundwater availability and surface run-off (Gomiero *et al.* 2011). Undisturbed soils retain moisture better than cultivated soils.

Furthermore, Lazarus (2014) noted, without in-depth analysis, that the recent 'land grab' introduced industrial farming practices that could result in soil depletion around the globe. While soil macronutrients such as nitrogen (N), phosphorus (P) and potassium (K) are very important in crop production and could be affected by intensive large-scale farming, this study did not examine them because adding inorganic fertilizers (N, P, and K) is commonly practised by large-scale farms and we considered it less important.

Researchers who conducted soil analysis for micro-nutrients in Ethiopia found that zinc (Zn) and copper (Cu) are deficient in several locations in Ethiopia (Desta 1983; Asgelil *et al.* 2007 as cited in, Abera & Kebede 2013) and iron (Fe) and manganese (Mn) are deficient in Verisols of Central highlands of Ethiopia (Abera & Kebede 2013). Mn soil plays an important role in photosynthesis and chlorophyll production, both of which have a strong association in crop yields (Mousavi *et al.* 2011). Similarly, Fe soil serves as a catalyst in chlorophyll formation and it is an essential element in the formation of plant protein, plant respiration and photosynthesis. Plants need zinc for protein synthesis and plant metabolism (Uchida 2000). This calls for an in-depth study on the impacts of the recent large-scale land acquisition on land-use changes and soil related environmental parameters, notably the effects on micro-nutrients in Ethiopia.

This chapter, therefore, aims to address the following objectives: (1) to examine the changes in vegetation cover induced by large-scale land acquisition using spatio-temporal remote sensing imagery; and (2) to estimate the effects of land-use changes induced by large-scale land acquisition on soil organic carbon, soil micro-nutrients and soil bulk density. The results are based on data generated from spatio-temporal satellite images, soil data, perceptions of households affected by large-scale farms, key informants' interviews and focus group discussions. Details of the data collection and data analyses methods are already presented in Chapter 1.

6.2 Results

6.2.1 Vegetation cover change induced by large-scale farms in Ethiopia

Inevitably, cultivation brings change in vegetation cover. The land allocation to large-scale farming in Ethiopia predominantly targeted grazing lands, shrub/fallow lands and open to closed forests that are assumed by the government to have less socio-economic impacts. In some limited cases, farmlands cultivated by local people, often through customary ownership, and lands that were under state farms are transferred to large-scale farming companies. Our spatio-temporal satellite image analysis revealed that the large-scale farms studied as the subject of this research cleared closed forests and open-to-closed forests for farmlands. Out of the total land developed by Karuturi Agro Products PLC at its Ilia farm station of Gambella Regional State (2,435 ha), 18.6% and 80.2% of the lands were previously covered by closed and open-to-closed forests, respectively (Table 6.2 and Figures 6.2a and 6.2b).

Table 6.2: Vegetation cover change induced by large-scale farms in Gambella and Benshanguel Gumuz Regional States

From:	**To: Current land uses (ha)**		
Previous land use (ha)	Karuturi's maize plantation Ilia site Gambella	Basen's cotton plantation Gambella	S&P's pongomia and annual crop plantation Benshanguel Gumuz
Cropland	29.6	107.1	145.0
Open to closed forest	1952.5	1607.5	1026.5
Closed forest	452.8	849.6	630.2
Shrub/fallow	0.0	632.4	61.6
Existing plantation	0.0	372.8	0.0
Total	**2434.9**	**3569.4**	**1863.3**

Source: Analysis based on spatio-temporal satellite image

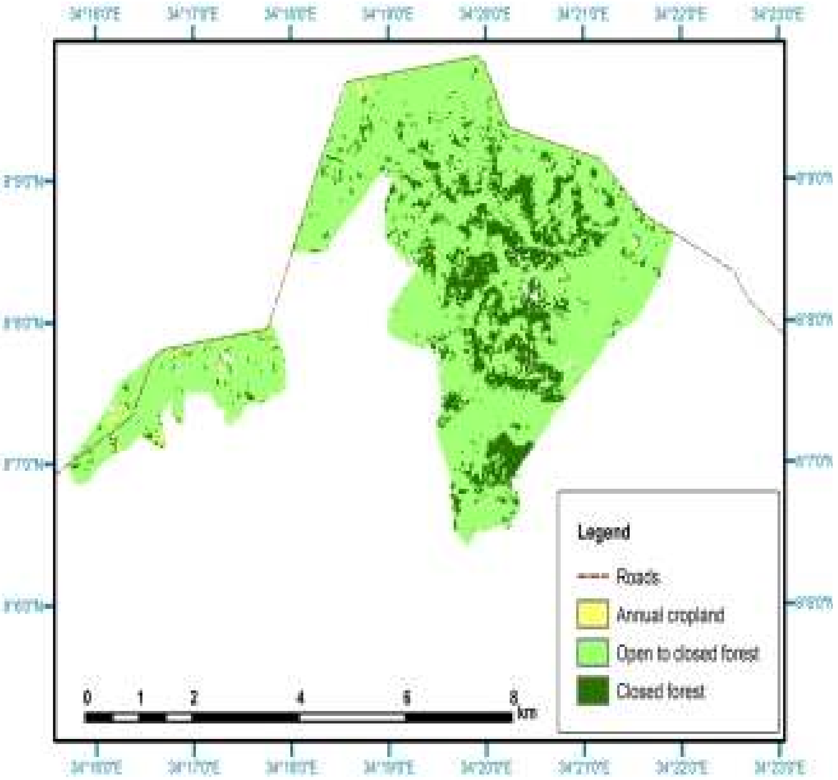

Figure 6.2a: Land use by Karuturi (Ilia site, Gambella) in 2008

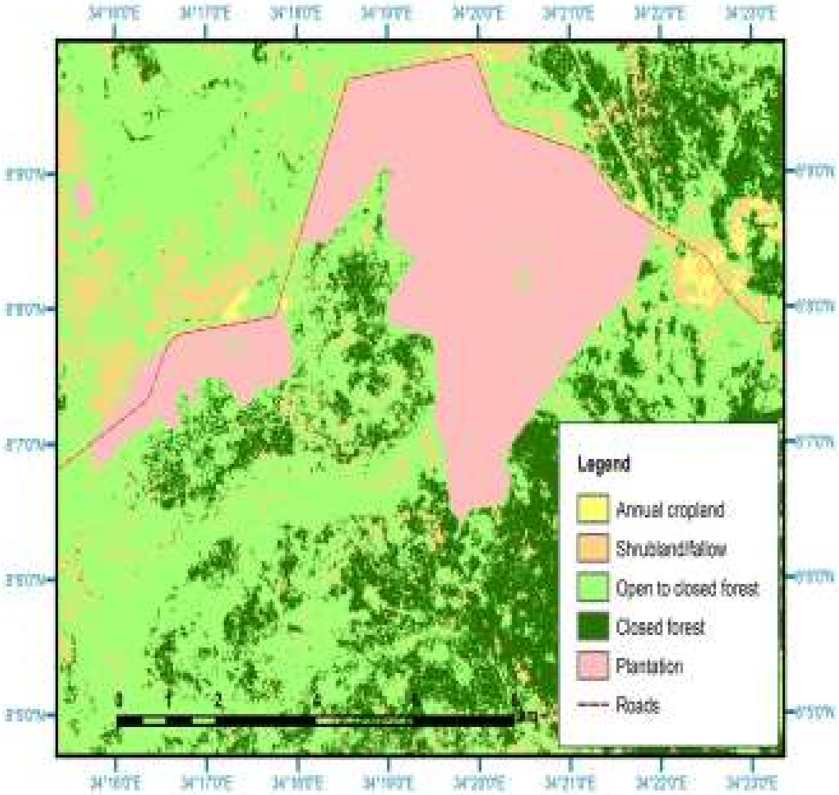

Figure 6.2b: Land use by Karuturi in 2015

A site visit to Karuturi's farm in Ilia village in 2012 and 2013 also confirmed that Karuturi bulldozed indigenous trees that have important ecological roles and socioeconomic values. In the same vein, although we have not analysed satellite images, we observed that Karuturi converted 2,800 ha of grassland in Jikawo and close to 3,000 ha of grazing land in Bako Tibe into maize farms.

In Benshanguel Gumuz Regional State, the S&P Energy Solution acquired 50,000 ha of land for the plantation of different food crops and pongomia trees. The spatio-temporal satellite data analysis indicated that the company developed 1,863 ha of land out of its total leasehold concessions. The magnitude of open-to-closed forests and closed forests cleared by S&P was substantial and accounted for 55.1% and 33.8% of the total land covered by maize and pongomia in 2014, respectively (Table 5.1 and Figures 6.3a & 6.3b). Pongomia belongs to the *Leguminaceae* family. It is an ever-green and oil rich tree adapted to a wide ranges of temperature conditions (1–38^{0}C) and tolerant to alkaline and saline soils (Meher *et al.* 2004). The seeds are estimated to contain 30–40% of oil. The oils have low density property and are suitable for biodiesel production. The S&P farm cultivated pongomia and pigeon pea intercropping on parts of its leasehold concessions and maize mono crop in some of its plots. In the forthcoming discussion, the impacts of the land-use change from natural forest to an economically beneficial tree and maize mono crop will be presented.

Similarly, out of the total land developed and planted with cotton by Basen Farm (3,569 ha), 23.8% and 45% of the lands were converted from closed and open-to-closed forests respectively. The company also cleared bushes and cultivated cotton, which accounts 17.7% of the total cultivated land of the company. Part of the land covered with cotton by Basen was previously owned by Abobo state farm and this accounted for 10.4% of the total land developed by Basen in 2014. This was also confirmed in our ground truthing field visit to Basen's farm in 2012 and 2013 (Table 6.1 and Figures 6.4a & 6.4b).

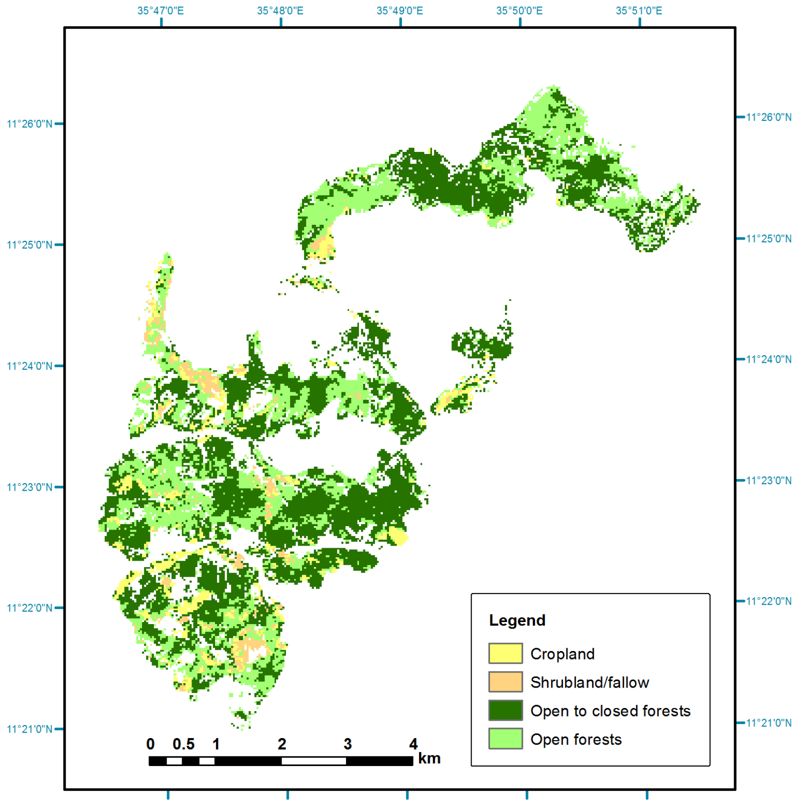

Figure 6.3a: Land use map of S & P farm in 2009

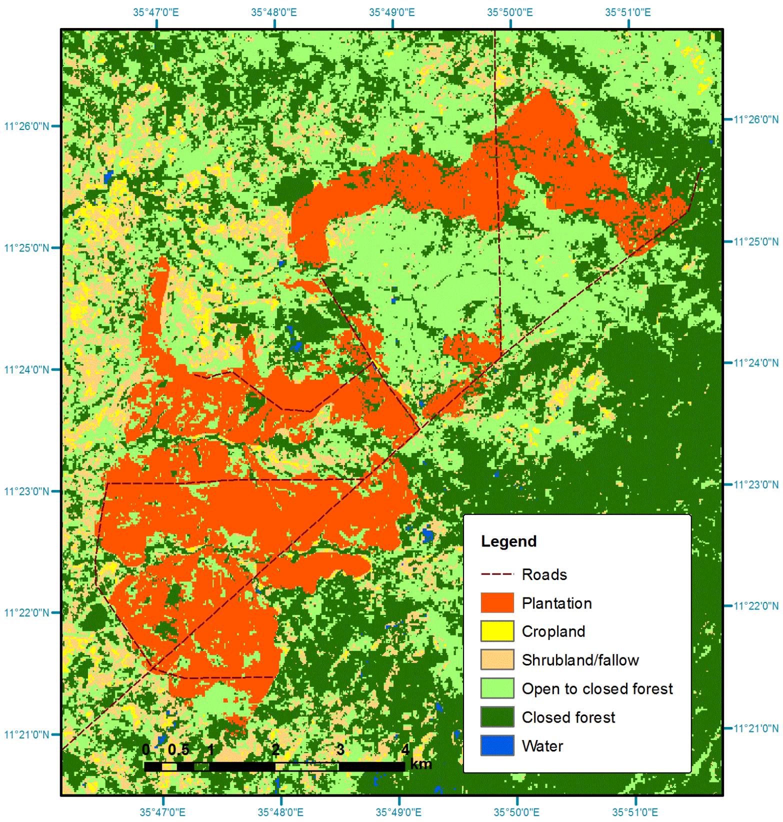

Figure 6.3b: Land use map of S & P farm in 2015

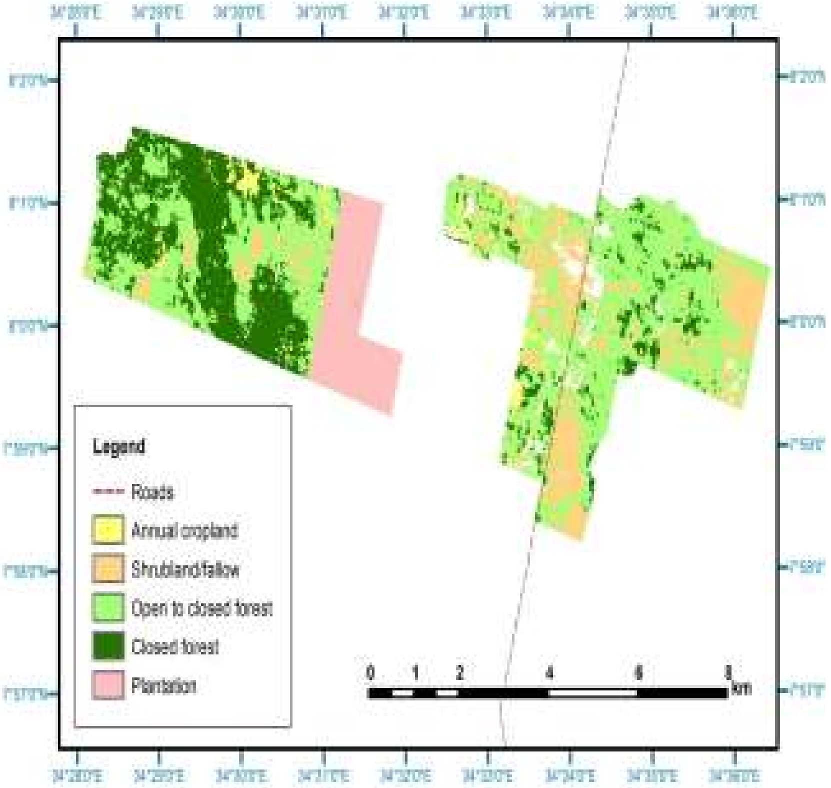

Figure 6.4a: Land use of Basen Farm in 2003

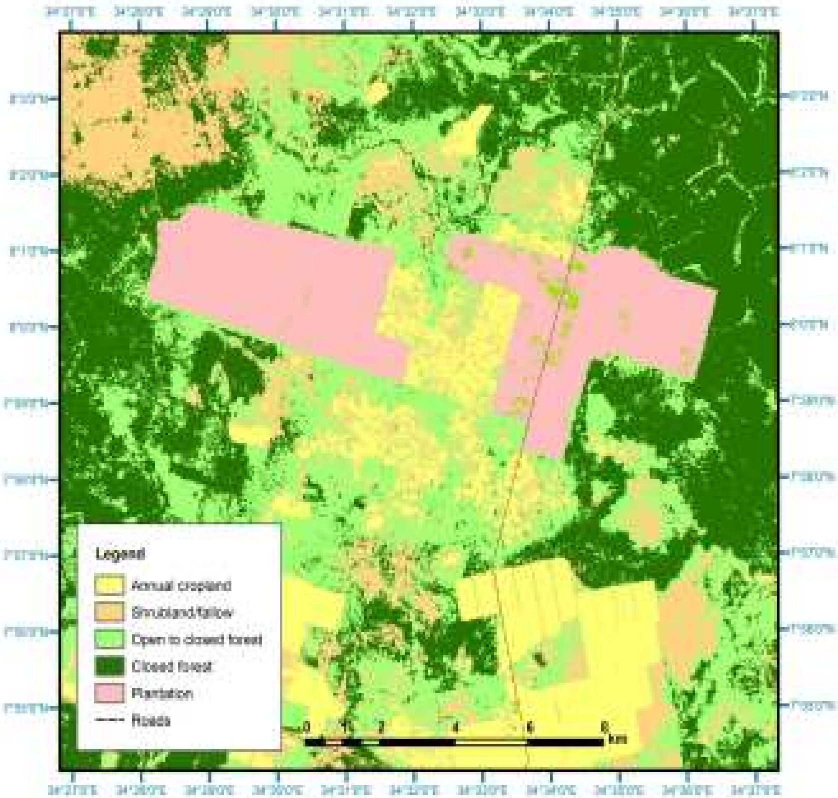

Figure 6.4b: Land use of Basen Farm in 2015

6.2.1 Impact of large-scale farming on soil carbon stock

As discussed in the aforementioned section, the large-scale farms examined as case studies for this research brought dominant changes in vegetation cover. Changes in vegetation cover induced by these farms, *inter alia*, have a direct effect on the soil's organic matter. The analysis of soil carbon levels on the large-scale farms operating in Oromia, Benshanguel Gumuz and Gambella Regional States confirmed the hypothesis that the farms sequestrated less organic carbon compared to the control. In Oromia, the soil carbon-stock at Karuturi Farm declined by 17.7% compared to the control. An exceptional result was observed in Benshanguel Gumuz Regional State at S&P Farm where pongomia was intercropped with pigeon pea. The plot covered with these crops – both crop types fix atmospheric nitrogen into the soil – improved the soil's organic carbon by 19%, implying that the type of land-use determines the effect on soil organic carbon. This is perhaps due to the nitrogen fixing characteristics of pongomia and pigeon pea. On the other hand, the plot of S&P Farm planted with maize was found to reduce soil's organic carbon by 6% compared to the control plot, which is covered by scattered trees (Table 6.3). The maize and sugar cane fields of Karuturi Farm in Gambella sequestrated 61% and 40% less organic carbon than the natural controls, respectively. Basen Farm in Gambella sequestrated 16% less organic carbon compared to the forest control. The changes in soil carbon-stock due to the land-use changes caused by the farms in Oromia, Benshanguel Gumuz and Gambella regional states are all statistically significant either at $p<0.05$ or $P<0.01$ (Table 6.4).

6.2.2 Impact of large-scale farms on soil compaction

The large-scale farms in Gambella, Benshanguel Gumuz and Oromia Regional States resulted in changes in soil-bulk density (BD). In Oromia, the change in land-use from grazing land to maize farm and the use of heavy machinery on Vertisols has increased the soil's BD by 9.5% (significant at $p<0.01$). The intercropping of pigeon pea with pongomia by the S&P Farm significantly improved the soil's bulk density in Benshanguel Gumuz Regional State. This is associated to the fact that the roots of pigeon pea and pongomia penetrate different zones of the soil and both improve the soil organic carbon by fixing atmospheric nitrogen through their root nodules. In its maize mono cropping, however, S&P Farm worsened the soil's bulk density by 7% (Table 6.3).

In Gambella, the conversion of grazing land to maize and sugarcane plantations increased the soil-bulk density by 28.5% and 46.7%, respectively. The increase in soil compaction is significant at $P<0.01$. This is due to a loss of organic carbon (OC) and an increase in soil compaction as a result of using heavy farm machinery for cultivation. The company burnt the sugarcane fields in 2013 when the soil samples for this study were being taken. This reduced the soil's OC and increased its BD. Although we observed that agro-pastoralists also burn grazing lands to encourage re-growth of fresh grass, this does not change the soil's BD. This might be because the loss of OC through burning is compensated for by animal dung. At Basen Farm the soil's BD has increased by 16% when compared to the uncleared forest, which was significant at $P<0.01$ (Table 6.4).

Table 6.3: Effects of land use change on soil bulk density and organic carbon in Oromia and Benshanguel Gumuz Regional States

Parameters	Land use of Karuturi Farm in Oromia region		Land use of S&P Farm in Benshanguel Gumuz region		
	Karuturi's maize farm	Grazing land (Control)	Pongomia intercropped with pigeon pea	Maize farm	Scattered tree (Control)
Bulk Density in gm/m3					
Mean ± SEM	1.39 ± 0.015	1.27 ± 0.007	1.37 ± 0.003	1.49 ± 0.02	1.39 ± 0.01
Std. Dev.	0.064	0.028	0.01	0.05	0.03
t statistics (Std. Error)	0.12 (9.45%)***		4.9 (0.01)	5.99 (0.02)	
Mean difference (%)	7.2 (0.02)		-0.03 (-1.4 %)***	0.1 (7.2%)***	
Organic Carbon in %					
Mean ± SEM	2.05 ± 0.022	2.49 ± 0.028	2.22 ± 0.03	1.74 ± 0.02	1.86 ± 0.03
Std. Dev.	0.09	0.12	0.06	0.05	0.12
t statistics (Std. Error)	-0.44 (-17.7%)***		9.0 (0.04)	2.8 (0.04)	
Mean difference (%)	12.2 (0.04)		0.36 (19.4%)***	-0.12 (6.4%)**	

Source: Survey data (2013 & 2014); ***Significant at p<0.01; **Significant at p<0.05

Table 6.4: Effects of land use change on soil bulk density and organic carbon in Gambella Regional State

Parameters	Land use of Basen in Abobo		Land use of Karuturi at Ilia site		Land use of Karuturi at Jikawo site		
	Basen's cotton farm	Forest/bush (Control)	Karuturi's maize farm	Forest/bush (Control)	Karuturi's maize farm	Karuturi's sugar cane farm	Grazing land (Control)
Bulk Density in gm/m3							
Mean ± SEM	2.01 ± 0.03	1.73 ± 0.03	2.09±0.05	1.90±0.01	1.76 ± 0.01	2.01 ±0.02	1.37 ± 0.01
Std. Dev.	0.11	0.13	0.22	0.04	0.038	0.07	0.024
Mean difference (%)	0.28 (16.2%)***		0.19 (10%)***		0.39 (28.5%)***	0.64 (46.7%) ***	
t statistics (Std. Error)	7.10 (0.04)		3.73(0.52)		32.26 (0.01)	35.38 (0.02)	
Organic Carbon in %							
Overall Mean ± SEM	2.35 ± 0.01	2.79 ± 0.01	0.82±0.01	1.04±0.01	1.49 ± 0.01	2.29 ± 0.01	3.82 ±0.01
Std. Dev.	0.05	0.04	0.01	0.03	0.017	0.033	0.028
Mean difference (%)	-0.44 (-16.1%)***		0.22 (-21.2%)***		-2.3 (-61%)***	-1.5 (-40.1%)***	
t statistics (Std. Error)	29.11 (0.02)		28.71(0.01)		225.13 (0.01)	119.68 (0.01)	

Source: Survey data (2013); ***Significant at p<0.01

6.2.3 Impact of large-scale farms on soil micro-nutrients

Soil nutrient uptake by plants, unless checked and treated through the application of deficient soil nutrients, will lead to soil nutrient imbalance. Land conversion from natural vegetation to crop production, as witnessed in the large-scale farms in Oromia, Benshanguel Gumuz and Gambella Regional States, is anticipated to result in exploitation of soil micro-nutrients. Sims and Johnson (1991) and Kparmwang *et al.* (2000) indicated that the critical levels of available Fe and Mn required for plant growth are 2.5–4.5 mg/kg and 1.0 mg/kg, respectively. Similarly, McKenzie (2001) argued that soils that have greater than 1.0 mg/kg of Cu, 1.0 mg/kg of Zn, 4.5 mg/kg of Fe and 1.0 mg/kg of Mn are classified as adequate for this micro-nutrient.

The land-use change from grazing land to maize farming by Karuturi Agro Products PLC in Bako Tibe District (Oromia) resulted in the reduction of the soil's Fe, Cu, Zn and Mn levels by 38%, 36%, 66% and 63%, respectively. The declines in these nutrients are statistically significant at $P<0.01$. In absolute figures, we discovered that the area was generally deficient in Zn (0.76 mg/kg) and Cu (0.44 mg/kg) compared to the minimum level (1 mg/kg for both Zn and Cu) needed for a healthy plant growth. The stock of Zn and Cu were further declined to 0.26 mg/kg and 0.28 mg/kg, respectively, due to the land-use change induced by Karuturi Farm. Although the declines of Fe and Mn due to the land use change were significant, the stock of these micro-nutrients in the soil are well above the minimum amount required for plant growth, and hence they are not yield limiting factors at the moment (Table 6.5). Tilahun (2007) also found a decline of soil micro-nutrients due to land-use change from grazing and forest land to cultivation in Ethiopia.

The analysis revealed that Bako Tibe has an adequate stock of soil Fe and Mn, although the land-use change brought a statistically significant reduction of these micro-nutrients. The company cultivated maize year after year. Although this study did not examine the effects of mono cropping on the soil's biodiversity, cultivation of same crop without crop rotation for four consecutive years by Karuturi resulted in the mining of important soil micro-nutrients.

Table 6.5: Effects of land-use change on soil micronutrients in Oromia and Benshanguel Gumuz Regional States

Soil micronutrients (mg/kg)	***Land use of Karuturi Farm in Oromia***		***Land use of S&P Farm in Benshanguel Gumuz***		
	Karuturi's maize farm	Grazing land (Control)	Pongomia intercropped with pigeon pea	Maize plot	Scattered tree (Control)
Iron (Fe)					
Mean ± SEM	10.42 ± 0.09	16.7 4± 0.08	8.67 ± 0.19	8.83 ± 0.05	8.89 ± 0.03
Std. Dev.	0.40	0.33	0.56	0.15	0.11
t statistics (Std. Error)	5.2 (0.12)		1.66 (0.13)	1.14(0.05)	
Mean difference (%)	-6.32 (-37.75%)***		-0.22 (-2.5%); NS	-0.06 (-0.6); NS	
Copper (Cu)					
Mean ± SEM	0.28 ± 0.002	0.44 ± 0.008	1.53 ± 0.01	1.55 ± 0.01	1.58 ± 0.01
Std. Dev.	0.009	0.035	0.03	0.04	0.05
t statistics (Std. Error)	19.1 (0.01)		3.2 (0.02)	2.24 (0.02)	
Mean difference (%)	-0.16 (-36.36%)***		-0.06 (-3.2%)***	-0.04 (-1.9%)**	
Zinc (Zn)					
Mean ± SEM	0.26±0.002	0.76±0.008	0.44 ± 0.01	0.45 ± 0.01	0.47 ± 0.01
Std. Dev.	0.008	0.034	0.01	0.01	0.03
t statistics (Std. Error)	6.5 (0.01)		2.86 (0.01)	1.95 (0.01)	
Mean difference (%)	-0.05 (-65.8%)***		-0.025 (-6.3%)**	-0.021 (-4.25%)*	
Manganese (Mn)					
Mean ± SEM	4.41±0.003	11.94±0.046	32.45 ± 0.16	32.56 ± 0.13	32.58 ± 0.12
Std. Dev.	0.01	0.19	0.50	0.39	0.52
t statistics (Std. Error)	16.1 (0.05)		0.46 (0.2)	0.03 (0.18)	
Mean difference (%)	-7.53 (-63.06%)***		-0.09 (-0.4%); NS	-0.006(-0.01%); NS	

Source: Survey data (2012 & 2014); NS= Not Significant; ***Significant at $p<0.01$; **Significant at $p<0.05$; *Significant at $p<0.1$

In Benshanguel Gumuz Regional State, S&P cleared the natural vegetation and cultivated some of the plots with maize mono crop and some with pongomia-pigeon pea intercropping. Cultivation resulted in a significant decline of Cu by 2–3% and Zn by 4–6%. However, there was no significant reduction in the soil's Fe and Mn. The area under cultivation by S&P's farm was generally deficient in Zn (0.47 mg/kg) compared to the critical minimum needed for plant growth (1.0 mg/kg) even before the land-use change induced by S&P. The land-use change by the S&P Farm further reduced the soil's Zn to 0.44–0.45 mg/kg (Table 6.4). The soils of S&P Farm have a slightly acidic reaction (pH 6.1–6.9) with high contents of Ca ions (20.3–24 cmol(+) kg). Acidic soils are reported to have high Mn and Fe since these micro-nutrients are less available with an increase in soil acidity (Lindsay 1979). This explains the insignificant decline of the soil's Fe and Mn in Benshanguel Gumuz region compared to the control plot.

In Gambella, Basen Farm mined 34% and 74% of Cu and Fe, respectively, and these results are significant at $P<0.01$. The analysis also showed that Zn and Mn declined on the farm, but they are not statistically significant. Nevertheless, the four micro-nutrients are available in adequate amounts, which are above the critical levels needed for plant growth and they are not growth limiting factors for the farm. Karuturi's Ilia maize farm in Gambella mined 36% of Fe, 12% of Cu, 30% of Zn and 4% of Mn and the reductions were statistically significant at $p<0.01$. Similarly, Karuturi's maize and sugar cane plantations at Jikawo farm station reduced all the four soil micronutrients significantly ($p<0.01$). Compared to the control, the maize plantation at Jikawo reduced the soil's Fe, Cu, Zn and Mn by 57%, 80%, 74% and 41.5%, respectively. The sugar cane plantation at Jikawo station has also mined the soil's Fe by 75%, Cu by 76%, Zn by 71% and Mn by 5%. At Ilia farm station, all micro-nutrients but Cu are found in sufficient amounts. Before the intervention of Karuturi, the availability of Cu was, on average, 0.5 mg/kg, which is below the critical level (1.0 mg/kg) needed for plant growth. This further declined by 12% after the land-use change induced by Karuturi Agro Products PLC. In the other two stations (Jikawo/Karuturi and Abobo/Basen), all the four micro-nutrients are found in sufficient amounts and they are not plant growth limiting factors (Table 6.6).

Table 6.6: Effects of land-use change on soil micro-nutrients in Gambella Regional State, the case of Basen and Karuturi farms

Micronutrients (mg/kg)	***Land use of Basen in Abobo***		***Land use of Karuturi at Ilia site***		***Land use of Karuturi at Jikawo site***		
	Basen cotton farm	Forest/bush (Control)	Karuturi's maize farm	Forest/bush (Control)	Karuturi's maize farm	Karuturi sugar cane farm	Grazing land (Control)
Iron (Fe)							
Mean ± SEM	8.42 ± 0.26	32.09 ± 0.11	4.22 ± 0.02	6.60 ± 0.01	8.51 ± 0.01	9.64 ± 0.06	19.7 ± 0.06
Std. Dev.	1.1	0.46	0.09	0.04	0.02	0.16	0.25
Mean difference (%)	-23.7 (-73.8%)***		-2.37(-36.1%)***		-11.2(-56.8%)***	-10.1 (-51.2%)***	
t statistics (Std. error)	8.4 (0.28)		9.69 (0.02)		13.27 (0.08)	10.89 (0.09)	
Copper (Cu)							
Mean ± SEM	19.06 ± 0.37	29.03 ± 0.08	0.44 ± 0.01	0.50 ± 0.01	12.51± 0.01	14.82 ± 0.05	62.8 ± 0.03
Std. Dev.	1.6	0.34	0.01	0.01	0.019	0.15	0.11
Mean difference (%)	-9.97 (-34.3%)***		-0.06 (-12%)***		-50.3 (-80%)***	-48 (-76.4%)***	
t statistics (Std. error)	26.36 (0.38)		16.17 (0.01)		13.46 (0.04)	864.07 (0.06)	
Zinc (Zn)							
Mean ± SEM	4.81 ± 0.072	4.9 ± 0.034	1.05 ± 0.01	1.5 ± 0.01	2.28 ± 0.01	2.57 ± 0.005	8.81 ± 0.023
Std. Dev.	0.31	0.15	0.01	0.01	0.028	0.015	0.097
Mean difference (%)	-0.09 (-1.8%); NS		-0.45 (-30%)***		-6.54 (-74%)***	-6.25 (-71%)***	
t statistics (Std. error)	1.09 (0.08)		110.40 (0.01)		19.9 (0.03)	189.73 (0.03)	
Manganese (Mn)							
Mean ± SEM	4.3 ± 0.06	4.36 ± 0.02	10.90 ± 0.01	11.34 ± 0.01	3.3 ± 0.004	5.91 ± 0.023	5.64 ± 0.01
Std. Dev.	0.23	0.066	0.05	0.04	0.013	0.069	0.044
Mean difference (%)	-0.07 (-1.4%); NS		-0.45 (3.9%)***		-2.3 (-41.5%)***	0.28 (4.8%)***	
t statistics (Std. error)	1.25 (0.06)		25.84 (0.02)		15.26 (0.02)	12.54 (0.02)	

Source: Survey data (2012 & 2013); NS=Not significant; ***Significant at $p<0.01$

6.2.4 Farmers' perceptions of the environmental effects of large-scale farming

Social surveys were also conducted in 2012, 2013 and 2014 to identify the perceptions of the local people towards the environmental changes that have been observed as a result of large-scale farming. A total of 538 households (100 from Itang, 100 from Makuey, 100 from Abobo, 96 from Dangur and 142 from Bako districts) were selected by a systematic random sampling technique from the villages that have experienced the effects of land-use changes. The exploratory surveys that were conducted in 2011 helped to identify the villages that experienced the effects of land-use change by large-scale farms and to investigate locally relevant environmental variables that should be included in the household survey.

Households were interviewed using a structured questionnaire that constituted 14 items on environmental components expected to change because of land-use change induced by the operation of large-scale farms. The questionnaire was developed using a five-point Likert scale to make the instrument sensitive to the possible responses. Households were asked to rate their perceived impacts as: 1=Highly declined/worsened; 2=Declined; 3=No change; 4=Improved/Increased; and 5=Highly improved/increased. The responses were analysed using mode and median scores. In addition, focus group discussions with key informants – such as elders who have lived in the villages for many years and are knowledgeable about the changes in key environment variables – were conducted to substantiate the household survey. The perception of the local people towards impacts of land-use changes induced by the large-scale farms on various environmental variables are expected to be different due to the relative perceived differences of the values of natural resources to their livelihood (read Chapter 1 for the description of livelihood portfolio of the local people in the three regional states).

In the case of Karuturi in Bako (Oromia), the land-use change affected the local people's access to land for cattle grazing and food crops cultivation, access to water and trees for various purposes. The land-use change in Abobo (Gambella) by Basen Farm changed access to resources such as land for cultivation, grazing land for cattle and trees for different uses. In the case of Karuturi (Gambella), the land-use changes affected the local people's access to pasture, water and fish resources, and forest foods. Availability of pasture and water for livestock are important resources for the Nuer and access to forest foods is important to the Anuak. For the Gumuz in

Benshanguel Gumuz Regional State, foods from the forest are important. To capture these variations, respondents from each local population were represented. The perception of land-users was analysed using descriptive statistics (median and mode scores) and presented in Table 6.7.

Generally, the overall perceived modal value for the 14 items in Oromia, Gambella and Benshanguel Gumuz Regional States was 2, which indicates the declining/worsening of socioeconomic and environmental variables due to the changes in land uses induced by the large-scale farms. The perceived median score for several of the items showed that environmental good/services are declining due to the interventions, which is consistent with the perceived modal values. Availability of pasture land, trees for firewood and charcoal, water for livestock, and wildlife, are all declining due to the change in land-use by large-scale farms.

In Oromia, local people revealed that, except for the items that enquired about quality of soil change, all the environmental variables such as availability of trees (for firewood and shade), water (for human and livestock use), quantity and quality of pasture for cattle grazing have all declined, and the extent of flooding has worsened due to the land-use change by Karuturi Farm. The company dug 22 boreholes and started to irrigate its farm from the Aboko River. Previous access to water for livestock from the Aboko River has been completely blocked for downstream users since the company started using the river for dry-season cultivation. Shortage of water for cattle was mentioned as a serious problem for the livelihoods of the local people (FGD held with five youths on 2 April 2012 and five farmers on 3 April 2012 in Goromitti village, and five farmers on 3 April 2012 in Oda Gibe village on 3 April 2012). The members of the FGDs explained that farmers in the villages used the Aboko River as a source of water for their cattle before their access to the river was completely blocked by Karuturi. Now, they trek their cattle three hours every day to the Gibe River that resulted in, not only body weight loss of the animals, but also spending few hours on farming. Both have brought negative effects on their agricultural production and overall livelihood. The rush for African farmland is reported by Olanya (2012) to have a hidden strategy of securing water access for large-scale commercial agriculture.

Table 6.7: Local people's perception of the impacts of large-scale farms on socioeconomic and environment variables in Oromia, Gambella and Benshanguel Gumuz Regional States

Socioeconomic and environmental variables	Gambella region						Oromia region		Benshanguel region	
	Karuturi Farm/ Anuak Case (n=100)		Karuturi Farm/ Nuer Case (n=100)		Basen Farm/ Settlers case (n=100)		Karuturi Farm/ Highlanders case (n=142)		S&P Farm/ Gumuz case (n=96)	
	Mode (%)	Median	Mode (%)	Median	Mode (%)	Median	Mode (%)	Median	Mode (%)	Median
Availability of trees for firewood	2(100%)	2	2(63%)	2	2(78%)	2	2(100%)	2	2(93.7%)	2
Availability of trees for shade	2(100%)	2	2(63%)	2	2(52%)	2	2(100%)	2	3 (100%)	3
Availability of trees for NTFP	2(100%)	2	3(61%)	3	3(74%)	3	NA	NA	2(100%)	2
Availability of trees for medicine	2(90%)	2	3(58%)	3	2(69%)	2	NA	NA	2(89.6%)	2
Availability of water for humans	2(97%)	2	2(89%)	2	2(82%)	2	2(100%)	2	3 (100%)	3
Availability of water for livestock	NA	NA	2(82%)	2	2(74%)	2	2(100%)	2	NA	NA
Availability of fish resources	2(94%)	2	3(53%)	3	3(97%)	3	NA	NA	NA	NA
Quality of water for human use	2(84%)	2	2(84%)	2	2(75%)	2	2(96.5%)	2	3(100%)	3
Quality of water for livestock	NA	NA	2(94%)	2	2(74%)	2	2(96.5%)	2	NA	NA
Amount of pasture available	NA	NA	2(94%)	2	2(82%)	2	2(100%)	2	NA	NA
Quality of pasture	NA	NA	2(94%)	2	2(63%)	2	2(100%)	2	NA	NA
Quality of soil	3(72%)	3	3(98%)	3	2(70%)	2	2(75.4%)	2	2(83.3%)	2
Wildlife resources (Bush meat)	2(84%)	2	2(88%)	2	2(65%)	3	NA	NA	2(89.6%)	2
Flooding/Water logging	2(92%)	2	2(94%)	2	2(86%)	2	2(100%)	2	NA	NA
Overall mode (%)	**2 (93.4%)**		**2 (84.5%)**		**2 (74.4%)**		**2 (96.8%)**		**2(91.2%)**	

Note: NA= Not Applicable/Important; Mode (%)=Calculated from valid responses; Overall mode (%) =Calculated based on the average percentage of most frequent responses

Source: Survey data (2012, 2013 and 2014)

In Bako, Karuturi converted grazing land with scattered fig and acacia trees into maize cultivation. The perception of the local people was that the clearing of the trees brought significant changes to the micro-climate of the area. Participants of the five FGDs in the four villages mentioned above said that the scattered figs and acacia trees over the grazing fields were used for ritual purposes, shade for humans and cattle and served for community gatherings. After the trees were cleared by Karuturi, the local people complained about a rise in daily temperature and lost shade for ritual and community gatherings. The negative effects of large-scale farming are also reported by Shete (2011).

In Gambella, Karuturi is also blamed for significant environmental damage. It bulldozed indigenous tree species at the Ilia site. Pasture land was cleared to make way for a maize and sugar cane farm at the Jikawo site. It diverted water from Baro River to its sugar cane farm, aggravating flooding in the area. Elderly respondents who were interviewed in Bildak village raised the negative environmental impacts of Karuturi's operation. They said that flooding is aggravated in their village due to the construction of diversion canals, and they are afraid of more flooding that will pose serious environmental problems in the future. Their perception is consistent with the soil bulk density analysis result discussed earlier.

Another environmental concern in Gambella is the likely conflict of large-scale farming with wildlife resources. Gambella National Park, which has not been officially gazetted, partly overlaps with the lease concession of Karuturi Farm. The Park is known to be home to the endangered shoebill stork, the Nile lechwe antelope and the white-eared kob antelope. The world's second largest mammal migration is found here with hundreds of thousands of animals crossing the South Sudanese border through the Boma-Jonglei landscape and returning to Gambella when the weather is right (HoAREC 2013). The local people revealed that wild animals are observed in large-scale farms and their flock is declining (mode value 2) since Karuturi started farming here. Three scouts working for the Gambella National Park who were interviewed on 27 March 2013 also supported the views of the local people saying that "wild animals are seen in the Karuturi Farm and we expect conflict between the farm and the wildlife resources."

In Benshanguel Gumuz Regional State, the Gumuz rely heavily on natural resources for food and incomes. The S&P Farm converted natural forest to plantation, and the local people perceived that the impacts of land-use change by S&P Farm on different environmental variables are negative. The quality of the soil is perceived as having deteriorated due to the shortening of the fallow period after the land transfer to the S&P Company. The practice of applying fertilizers is not common among the Gumuz indigenous population. They rejuvenate the fertility of their parcels through fallowing, instead. Availability of non-timber forest products is perceived to have declined. Harvesting of honey from the forest for household consumption and sale, hunting of different wild animals for bush meat and gathering of different foods from the forest/bush are important among the Gumuz population, but perceived to have deteriorated due to the intervention. Although these variables are more to do with food security issues, the local population mentioned the decline of these products from the forest in connection to the clearing of trees by the large-scale farm (Table 6.7).

6.3 Discussion

6.3.1 Environmental Impact Assessment (EIA) and large-scale farms in Ethiopia

This section discusses the institutional mechanisms available to mitigate the negative effects of large-scale farming on the environment. The Constitution of Ethiopia (see Articles 43, 44 and 92) incorporated important phrases that address environmental issues in development projects (FDRE 1995). The Environmental Protection Authority (EPA) in Ethiopia, an agency mandated to oversee environmental issues, has developed policies, laws, regulations and administrative frameworks to ensure that environmental issues are taken into account before any project is launched (EPA 2012). To this end, different proclamations pertinent to environmental issues[65] were promulgated. As with any development project, the preparation of Environmental Impact Assessment (EIA) documents are compulsory for all large-scale farming projects in Ethiopia. The mandate to oversee EIA was given to the EPA under Proclamation No. 295/2002 (FDRE 2002b). The EPA, however, transferred its mandate of monitoring the EIA of large-scale agricultural farms to the Agricultural Investment and Land Administration Agency (AILAA) in 2009

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[65] Proclamation No. 299/2002 (the Environmental Impact Assessment Proclamation), Proclamation No. 541/2007 (the management and utilization of wildlife resources), Proclamation No. 300/2002 (the Environmental Pollution Control Proclamation), Proclamation No. 513/2007 (the Solid Waste Management Proclamation) and Proclamation No. 197/2000 and Regulation No. 115/2005 (the conservation, utilization and development of water resources in the country), which aimed to reduce the negative impact of development projects on natural resources and the environment, are promulgated following the recognition of environmental issues by the Constitution.

(Rahmato 2011). This was done with the justification that the EPA was too weak to monitor large-scale farms while the AILAA was considered to have the needed capacity and opportunity to closely monitor large-scale farms. Stebek (2012, p. 115) also argued that the EPA is 'disempowered' due to the delegation of its duties and responsibilities to sectoral environmental units of different ministries, such as the Ministry of Agriculture, the Ministry of Water and Energy, and the Ministry of Mines, whose major activities involve the utilization of natural resources in one way or another.

Table 6.8: Environmental impact assessment of major large-scale farms in Ethiopia

Large-scale farm	Land size (in ha)	Date land-deal concluded (DD/MM/YY)	Date EIA prepared (DD/MM/YY)	Date project began operation
Karuturi (Gambella site)	100,000	25/10/10	14/12/11	2010
Karuturi (Oromia site)	11,700	2008	no EIA	2008
S&P Energy Solutions	50,000	01/03/10	no EIA	2010
BHO	27,000	11/05/10	30/11/11	Unknown
CLC (Spentex)	25,000	25/12/09	no EIA	2009
Ruchi	25,000	05/04/10	no EIA	2010
Hunan Dafengyuan Agric.	25,000	25/11/10	no EIA	2010
Saber Farms PLC	25,000	10/05/11	no EIA	2011
HORIZONE Plantation PLC	20,000	01/09/12	no EIA	2012
Adama	18516	24/08/10	no EIA	2010
Whitefield	10,000	01/08/10	30/01/11	2010
Sannati	10,000	01/10/10	03/05/11	2010
Saudi Star Agri. Dev. PLC	10,000	25/10/10	31/05/11	2010
Basen Farm	10,000	2008	no EIA	2008
Toren Agro Industries PLC	6000	18/09/11	no EIA	2011
Access Capital	5000	08/10/10	no EIA	2010
Tracon Trading PLC	5000	18/03/10	28/11/11	2010
Mela Agric. Development PLC	5000	12/03/10	12/03/12	2010
Daniel Agri. Dev. Enterprise	5000	26/08/09	19/03/12	2010
State-owned sugar mills[66]	175,000	Not Applicable	no EIA[67]	2011
Green Valley Agro PLC	5000	25/01/12	no EIA	Unknown
Lucci Agric. Development PLC	4003	08/11/09	no EIA	2010

Source: AILAA and agricultural company's documents (2014); Note: The shaded are the cases examined in this study

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[66] This includes Omo Kuraz, Tendaho, Arjo-Dedessa, Tana Beles, Kessem Sugar Mills. EWCA (2011) mentioned that the effects of Omo Kuraz sugar plantation on wildlife resources of the area were not studied.

[67] EWCA (2011).

While an EIA is prepared to mitigate any possible negative effects of projects on the environment, evidence to date shows that 63.6% of the large-scale farms that received land for investment have not yet prepared EIA documents. Others (36.4% of the large-scale agricultural projects) prepared EIA documents after project implementation started, which is contrary to the recommendations set out under Proclamation No. 299/2002 (FDRE 2002c). Considering the case studies selected for this study, Karuturi Agro Products PLC prepared an EIA document for its Gambella site in 2011 after it started operation in 2010. The company did not prepare an EIA for its Oromia site (Table 6.8).

Although policies, proclamations and regulations that aimed at reducing the environmental costs of agricultural projects are developed by the EPA, an assessment of EIA document preparation by large-scale farms in Ethiopia revealed that the majority of the companies did not have environmental impact mitigation strategies. Those large-scale farming companies that prepared the EIA document sometime after they started clearing the land might have developed the document as a rhetorical device to silence critiques forwarded by various groups, rather than to mitigate the negative environmental effects of their operations.[68] In this regard, we can argue that the AILAA failed to live up to the expectations of the Ethiopian government to monitor the activities of the large-scale farms to devise and implement environmental impact mitigation strategies. Rahmato (2011) also noted that the AILAA is too weak to accomplish its duties of monitoring large-scale farms in the country related to environmental protection activities. It is, therefore, important to understand the subsequent discussion on the site-specific environmental effects of the large-scale farms in Oromia, Gambella and Benshanguel Gumuz Regional States against this background information.

6.3.2 Implications of the loss of soil organic carbon

Loss of Soil Organic Matter (SOM) is one of the detrimental effects of removal of vegetation cover. It is well documented that SOM is very important for soil quality and soil functions (Campbell 1989; Baldock & Nelson 2000). Among other things, it improves soil aggregation and structure, enhances absorption and water retention capacity, increases soil fertility, improves soil biodiversity, and serves as sink and source of soil carbon. Because of the high content of organic carbon, SOM is often used as a proxy indicator for measuring Soil Organic Carbon (SOC). Soils as a sink for atmospheric carbon, improving SOC, is considered as one of the climate-change

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[68] See Deininger *et al.* 2011, Oakland Institute 2011 and Rahmato 2011 for the critiques.

mitigation strategies (FAO 2008). Soil organic carbon improves overall soil functions such as soil structure, water retention capacity, aeration, and soil's resistance to compaction (Liddicoat *et al.* 2010). Therefore, a decline in soil organic carbon implies a decline in the quality of soil (Van Camp *et al.* 2004). For this reason, the established literature suggests increasing the input rates of organic matter with the aim of enhancing the amount of SOC (see Post & Kwon 2000).

The organic carbon that was previously sequestrated in the soils declined by 16–61% because of the land-use changes induced by the large-scale farms. This release is a challenge to the environment. Farming practices that result in a decline in soil's organic carbon-stock below 2% are considered to be unsustainable, since they disrupt the structural stability of soil (Spink *et al.* 2010). Thus, they pose problems to the environment. With the current rate of soil carbon decline due to the land-use changes, most importantly in Gambella and Oromia but also in Benshanguel Gumuz Regional State, the sustainability of the large-scale farms and the functioning of the natural ecosystem might be affected negatively in the years to come.

Land-use change that depletes the soil's carbon pool and accelerates the release of organic carbon into the atmosphere, as in the case of the large-scale farms, has wider implications for climate conditions. Our log-linear analysis, based on metrological data obtained from Bako Agricultural Research Centre for the Bako area, revealed that the maximum mean daily temperature increased, on average, by 1.23°C between 1961 and 2011 ($t= 3.66$, $p<0.001$) and relative humidity decreased by 1% every year ($t= -2.7$, $p<0.01$). Although it is very difficult to associate the rise in temperature and the decline in relative humidity to the land-use changes occurring in Bako because of the large-scale farming, local people linked the rise in daily temperature in their village to the land-use changes induced by Karuturi Farm. Gambella is also a region frequently affected by climate variations such as abnormal flooding (Woube 1999). Unless relevant mitigation strategies are taken, the decline in soil carbon stock due to the land-use changes by the large-scale farms will eventually contribute to the worsening of climatic factors in the region.

Although climate change has both local and global effects, farmers in developing countries, like Ethiopia, with the lowest capacity to cope with the effects of climate change are more vulnerable to it (ILRI 2006; Stige *et al.* 2006). Cheru (2008) also contended that, although Africa has contributed little to climate change, it is one of the regions that has experienced the negative effects of climate change most intensely. Limited capacity of national governments to invest in climate change adaptation measures exacerbates the negative effects of climate change. We believe that the absence of strategies developed by the large-scale farms to mitigate negative environmental impacts of their farming operations will exacerbate the removal of soil organic carbon, which is also associated with SOC.

6.3.3 The challenges of soil compaction

Soil-bulk density is an indicator of soil structure in general and soil compaction in particular. Land-use change affects soil porosity and compaction, which determines water infiltration, groundwater movements and surface water run-off (Conolly 1998). Cultivation with heavy machinery is one of the main reasons for soil compaction (Arvidsson *et al.* 2000). The analysis results for Gambella and Oromia revealed that the soil's BD increased with increasing soil depth. This was also true for the maize mono cropping of S&P Farm in Benshanguel Gumuz Regional State. Studies also confirmed the inverse relationship between soil BD and infiltration capacity (cf. Osuji *et al.* 2010; Getachew *et al.* 2012). Reduced soil infiltration capacity contributes to surface run-off (Conolly 1998; Alhassoun 2009) and tends to increase the likelihood of flooding (Sparovek *et al.* 2002; Alhassoun 2009). Infiltration also determines ground water storage and has an impact on the hydraulic cycle (Alhassoun 2009). In the dry season, groundwater level will be very low due to the limited amount of water infiltrated during the rainy season. Both effects (i.e. flooding and decline of ground water level) reduce the productivity of the farms and their sustainability.

The large-scale farms, especially in Gambella and Oromia Regional States, frequently experienced abnormal flooding and water-logging that substantially reduced their yields. For example, at the Jikawo site, Karuturi completely abandoned its maize harvest for two consecutive years (2012 and 2013) due to flooding. At Bako, Karuturi achieved only 15–20 qt/ha of maize yield due to water-logging, compared to 60–80 qt/ha maize harvested in the adjacent area. Similarly, the cotton yield level of Basen Farm, on average, declined by 66% (19.07 qt/ha in 2011 to 6.5 qt/ha in 2012) due to flooding and other related challenges. Normal flooding is common on the floodplains of Gambella and is actually required by the indigenous people for their agricultural activities. It brings moist, nutrient-rich soils to their farms. Abnormal flooding patterns are experienced when the same amount of precipitation causes excessive flooding due to land-use changes by human interference (Woube 1999). The key informants of this study also explained that abnormal flooding has posed a threat to their livelihoods. The findings of this study in Gambella are also consistent with the claim made by Woube (1999) and Getachew *et al.* (2012). Woube discovered that, due to the clearing of vegetation by the state-sponsored resettlement scheme in 1984 and the expansion of mechanized large-scale farms in Gambella, the infiltration capacity of the soils had reduced and flooding had increased. Getachew and his colleagues also documented the negative effects of land-use changes from forests and grazing lands to farmlands on soil's physical and chemical properties in South Ethiopia. In a nutshell, this study found a significant increase in the soil bulk density of the large-scale farms, which is one of the challenges that will hamper the sustainable agricultural production of these establishments.

6.3.4 Soil micro-nutrient decline and the sustainability challenge

Soil micro-nutrients are required by plants in small amounts but they are important in determining plant growth and crop yield (Foth & Ellis 1997). They are very important in sustainable agricultural production (Srinivasara & Rani 2011). Although the large-scale farms increase the application of inorganic macro-nutrients, crop yields will never increase if the availability of micro-nutrients falls below a certain threshold level. Presently, the available Fe and Mn in all the four large-scale farms are above the minimum threshold levels required by plants. But, with the current rate of nutrient uptake of these micro-nutrients (greater than 35%), the stock of these micro-nutrients might fall below the critical level in a few years and the sustainable agricultural production of the farms might be affected.

The plots of Karuturi at Ilia and Bako farm stations are generally deficient in soil Cu and the available stock is below the critical minimum needed for plant growth and development. The land-use change from forest land and grazing land at Ilia and Bako, respectively, to maize mono cropping significantly reduced the stock of Cu in the soil, further worsening the available stock of Cu in both locations. Uchida (2000) argued that Cu is an essential micro-nutrient for the formation of plant enzymes that are important in photosynthesis. The absence of this micro-nutrient in sufficient amount results in stunted and bushy plant growth that will eventually contribute to reduced plant yield. It is worth noting here that Karuturi's maize productivity is far less than the yield level under farmers' conditions, and that the company is bankrupted and closed its farm in Gambella. In the other cases, the plots of Basen and S&P did not exhibit deficiency in soil Cu. However, the land-use changes induced by these farms significantly reduced the stock of soil Cu, and the farms need to watch closely the stock of this micro-nutrient in the future.

Alloway (2008) reported that Gambella and Benshanguel Gumuz regional states are generally mapped for Zn deficiency. But, we did not find sufficient evidence that Zn is deficient in the large-scale farms we examined. However, with the exception of Basen Farm, Karuturi (both in Oromia and Gambella) and S&P farms have significantly further reduced the soil's Zn. This calls for large-scale farming companies to take precaution measures in their future farming.

In general, a decline in the availability of micro-nutrients below the required levels results in a diminishing marginal return to additional macro-nutrient application. This holds true in the short-run until large-scale farms realize the deficient micro-nutrients and treat the soil. Although it is possible to treat soils with deficient micro-nutrients, the large-scale farms considered in this study, however, operate without the correct mix of professionals who can take appropriate decisions on soil management practices. For instance, Karuturi's farm management is outsourced to Multiplex Company, which has very little experience in SSA agriculture. Basen is operated by a small group of young Ethiopian agriculturalists who have no specialization in soil/environmental sciences. Farms operate when they generate some profit margin. Once their productivity declines due to nutrient imbalances, they will operate below a break-even point, which eventually will force them to abandon operations. The local people will thus remain with unproductive lands paying the environmental costs incurred due to the mismanagement of farmlands by the investors. Hence, the environmental costs associated with the loss of micro-nutrients will be externalized to the local community. At macro level, if production is not sustained due to the continued mining of important micro-nutrients, the goals of the Ethiopian government to transform the agricultural sector will not be achieved.

The large-scale farms considered in this study practised mechanized agriculture with a mono-cropping system. Karuturi cultivated maize and sugar cane. Basen Farm cultivated cotton, and S&P Farm produced maize on some of its plots. Although this study did not analyse the effects of mono-cropping on other environmental parameters (e.g. biodiversity), the disadvantages of the system is documented in the literature. For example, Aggarwal (2006) stated that mono-cropping reduces the resilience of the ecosystems to shocks. He continued to argue that the flow of short-term external capital to the agricultural sector in developing countries targets short-term production goals and ignores the long-term effects on the ecosystem that results in ecosystems changing into an undesirable state. Once the resilience of the ecosystem is disrupted, external capital shifts to other profitable ventures. Therefore, the environmental costs associated with mono-cropping will also be externalized to the local communities.

6.4 Conclusion

Ethiopia is the second most populous country on the African continent. Promoting large-scale plantation farming is one of the strategies adopted by the Ethiopian government to improve the nation's food security and to promote agricultural modernization. Large-scale plantations were intended to increase availability of food grains at low prices for Ethiopia's large population and by improving the purchasing power of the local populations through waged employment on plantations. Despite the potential gains, the results of this study instead suggests that adverse changes in land use, vegetation cover, and soil quality, resulting from land conversion to plantation monocultures, undermine the long-term economic viability and sustainability of commercial agricultural production. Findings have shown that, with the exception of pongomia-pigeon pea intercropping, large-scale plantations reduce soil carbon stock and micro-nutrient concentrations. Moreover, the cultivation practices of the case study plantations have resulted in soil compaction, which has limited the water infiltration capacity of the soil. This worsens surface run-off and allows for abnormal flooding patterns.

Unless appropriate strategies are adopted to monitor and address issues related to soil micro-nutrient content, soil compaction and soil organic carbon and/or organic matter, large-scale plantations are unlikely to fulfil long-term food security objectives of the Ethiopian government since investments will fail, ecological functions will be disrupted, and land will become less productive for future generations. Therefore, environmental protection measures should extend beyond environmental impact assessments. More specifically, the government should (1) ensure that large-scale plantations have the right mix of professionals that can scientifically guide farming operations through appropriate land management, soil-testing and treatment of deficient soil nutrients; (2) establish a land allocation system that accounts for a wider diversity of environmental parameters such as soil properties and vegetation; and (3) ensure plantations retain a greater proportion of trees and vegetation on their concession and recycle crop-residues so as to improve soil organic matter and soil organic carbon.