AGROECOSYSTEM ANALYSIS OF FINCHA SUB BASIN, BLUE NILE RIVER BASIN, ETHIOPIA†

[ANÁLISIS DE AGROECOSISTEMAS DE LA SUBCUENCA DE FINCHA, CUENCA DEL RÍO NILO AZUL, ETIOPÍA]

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SUMMARY

Agro-ecosystems are ecological systems modified by human beings to produce food, fiber or other agricultural products. It is an intersection of a set of agriculturally relevant climatic factors; soils and physiographic variables relevant to crop production; and a prevailing set of cropping practices. The biophysical diversity and associated socioeconomic condition of the community necessitate multiple strategies for augmented the resilience and adaptation to climate change. The objective here is to support site-specific and climate resilient development activities in a changing environment. Hence, the pattern, productivity, and sustainability analysis of the agro-ecosystems found within the sub-basin analyzed. Primarily, agro-ecosystem analysis conducted in collaboration with experts, development agents, and local communities; and four distinct agro-ecosystems (Highland, Midland, Wetland, and Lowland) identified. Then, the identified agro-ecosystems examined in light of their potential for agricultural production and the challenge presented by climate change. The diverse agro-ecosystem offers the potential for the production of equally varied diversified agricultural products with a notable demarcation in terms of production orientation and socioeconomic uniqueness of the community among the agro-ecosystems. This feature provides an opportunity in addressing the adaptive capacity and resilient development options to climate variability and change based on specific requirement of each agro-ecosystem.
Keywords: Agro-ecosystem; adaptation strategy; pattern analysis; Fincha sub-basin; Ethiopia.

RESUMEN

Los agroecosistemas son sistemas ecológicos modificados por el ser humano para producir alimentos, fibras u otros productos agrícolas. Es una intersección de un conjunto de factores climáticos relevantes para la agricultura; suelos y variables fisiográficas relevantes para la producción de cultivos; y un conjunto prevaleciente de prácticas de cultivo. La diversidad biofísica y las condiciones socioeconómicas asociadas de la comunidad requieren múltiples estrategias para aumentar la resiliencia y la adaptación al cambio climático. El objetivo aquí es apoyar actividades de desarrollo específicas para cada sitio y resistentes al clima en un entorno cambiante. De ahí el análisis de patrones, productividad y sostenibilidad de los agroecosistemas encontrados en la subcuenca analizada. Principalmente, se realizó un análisis de agroecosistemas en colaboración con expertos, agentes de desarrollo y comunidades locales; y se identificaron cuatro agroecosistemas distintos (Tierras Altas, Tierras Medias, Humedales y Tierras Bajas). A continuación, se examinaron los agroecosistemas identificados a la luz de su potencial para la producción agrícola y el desafío que presenta el cambio climático. La diversidad de los agroecosistemas ofrece el potencial para la producción de productos agrícolas igualmente variados y diversificados, con una notable demarcación en términos de orientación de la producción y de la singularidad socioeconómica de la comunidad entre los agroecosistemas. Esta característica ofrece una oportunidad para abordar la capacidad de adaptación y las opciones de desarrollo resistente a la variabilidad y el cambio climático sobre la base de los requisitos específicos de cada agroecosistema.
Palabras clave: Agroecosistema; estrategia de adaptación; análisis de patrones; subcuenca Fincha; Etiopía.

† *September 28, 2018 – Accepted April 30, 2019.*
ISSN: 1870-0462

INTRODUCTION

Agro-ecosystems are agricultural systems as to the representation of phenomena and situations with multiple components where different inter-definable processes converge (García, 2006). This definition aims at highlighting the fact that systems are not a given but are built (conceptually) through observation and linking. Agro-ecosystems are fundamentally different from natural ecosystems because they are human constructs and as such managed for agricultural goals (Rapport, 2004). In its general sense, it is a way of perceiving agriculture from a systems perspective that emphasizes the connections between the environment and production (Xu and Mage, 2001).

The concept of a system defined in various ways depending on the objective and interest of the individual researcher. The system, here, is an assemblage of elements of the system that delimited by a boundary. The elements within each system have a strong functional relationship with each other but restricted, weak or nonexistent relationships with elements in other assemblages of the system. An essential element of a system approach to agriculture is its effect of spatial scale (Conway, 1985). Based on the hierarchical theory of system analysis, agro-ecosystem defined at different scales ranging from field plots to the entire globe (Kast and Rosenzweig, 1972; Conway, 1985; King, 1993).

Climate and agricultural are highly interconnected, and one influence the other in many ways. Climate variability and change affects agriculture through changes in average temperatures, rainfall, and weather extremes (drought and heavy rains); changes in pests and diseases conditions; changes in sea level; and changes in ecosystem services (benefits humans derive from ecosystems) at many scales among other (Niang *et al*., 2014; MEA, 2005; Tscharntke *et al*., 2005). On the contrary, Agriculture contributes to climate change on a global scale through emission of greenhouse gases (GHGs) (Niang *et al*., 2014). The observed effects of past climate trends on crop production are evident in several regions of the world, with negative impacts being more common than positive ones (Porter *et al*., 2014).

Spatially, the tropical highland regions are among the areas most vulnerable to climate change (IPCC, 2014; Porter *et al*., 2014). The climatic and biophysical conditions of the Ethiopian highlands, where the study sub-basin is located changes so dramatically over short distances. As a result, climatic parameters like temperature, precipitation, and others change accordingly. The changes in climatic parameters affect the type of crop to be grown and the socio-economic condition of the people residing in different agro-ecosystems. It also creates a challenge for policy-relevant implementation of the LVI-IPCC framework in all places of the nation (Simane *et al*., 2013).

In Ethiopia, of the different sectors, the impact of climate change worse on agriculture, as the sector heavily relies on seasonal rainfall, and where adaptive capacity is perceived to be low (World Bank, 2008; NMA, 2007; IPCC, 2007a). The sector also has unique potential contribution to stabilize the world's climate, through better management of crops, land and livestock, in a way that reduces emissions and increases carbon sequestration in plant biomass and soils (FAO, 2016; CRGE, 2011).

Like other sub-Saharan African countries, agriculture is by far the most important sector of the economy in Ethiopia; accounting about 42% of the GDP, 85% of the employment, 90% of the export earnings, and 90% of the poor depend on the sector for its livelihood. It is also the major source of food for the population and hence the prime contributing sector to food security (World Bank, 2008; NMA, 2007; MoFED, 2010).

However, this sector has been threatened and being affected by climate variability and change. In the last 50 years, the average annual minimum temperature has shown an increasing trend of 0.2^{0}C per decade (Tesfaye *et al*., 2015b). NMA/National Metrological Agency (2007) also revealed that temperature has been warming by about 0.37 ^{0}C every ten years over the past 55 years. The nation's rainfall characterized by seasonal and inter-annual variability (Tesfaye *et al*., 2015b; Seleshi and Zanke, 2004; Conway, 2000).

According to Kindie *et al*. (2016), the annual rainfall variability in most part of the country remains above 30%. The part of the nation that experiences higher rainfall variability also has relative higher probability of crop failures. The Belg season is suffering from greater rainfall variability, unreliable onset of the season, and frequent crop failures than the Kiremt season (Kindie *et al*., 2016).

Considering the importance and susceptibility of the sector, to climate variability and change and accordingly to avert the situation, it is crucial to study the sub-basin spatially. Since climatic and biophysical conditions change so dramatically over short distances in the Ethiopian highland regions, where the study sub-basin located, and creates a challenge of identical policy recommendation to avert the situation (Simane *et al*., 2013). Therefore, this study attempts to bridge the gaps of knowledge in Fincha sub-basin of the Blue Nile basin of Ethiopia.

The rationale behind for mapping agro-ecosystem as a unit of analysis is because AES is an intersection of a set of agriculturally relevant climatic factors; soils and physiographic variables relevant to crop production; and a prevailing set of cropping practices. In addition, the classification provides a background for adaptation analysis that takes into account the geographical differentiation (climate, topography, soils, farming systems) as well as the socio-economic stratification of the agricultural sector of the study area. The result of the analysis inevitably revealed a remarkable degree of differentiation in terms of constraints, opportunities, production orientation and socio-economic characteristics of farmers residing in different agro-ecosystem.

BACKGROUND

Bio-Physical Setting

Fincha Sub-basin is one of the eighteen sub-basins of the Blue Nile River basin. The Ethiopian part of Blue Nile River basin also called Abay River Basin and is located in the northwestern region of Ethiopia between 7^0 40’ N and 12^0 51’ N latitude, and 34^0 25’ E and 39^0 49’ E longitude. The Abay River Basin has sixteen sub-basins, which covers a total surface area of about 199,812 sq km. The study sub-basin specifically located in the south-central part of the Abay River Basin, western-central Ethiopia (Figure 1).

Fincha’a sub-basin specifically located between 9^0 10’ N and $10^0$00’ N latitude, and $37^0$00’ E and $37^0$40’ E and has an area of about 3,781 km^2. The altitude of the sub-basin ranges approximately between 970 masl, in the lowland of the Abay gorge located in the northern part of the sub-basin, and 3230 masl, in Guddene mountain of Jima Geneti District. The highlands in the western and southern part of the sub-basin are higher in altitude, greater than 2300 masl up to 3230 masl. The lowlands have lower altitude less than 1500 masl in the northern parts of the sub-basin.

Rainfall shows bimodal distribution, with the main rainy season between June and September, known as Kiremt or also Genna season, and a short rainy season between March and May, known as Arfasa season. The sub-basin has an annual rainfall ranging between 1367 mm and 1842 mm. Lower annual rainfall observed in the northern lowlands of the sub-basin and higher rainfall greater than 1500 mm observed in the western and southern highlands of the sub-basin. About 73% of the annual rainfall of the sub-basin falls during the Kiremt or Genna season. The annual maximum and minimum temperature in the sub-basin varied between 21.2˚C – 27.1˚C and 9.9˚C – 12.8˚C, respectively.

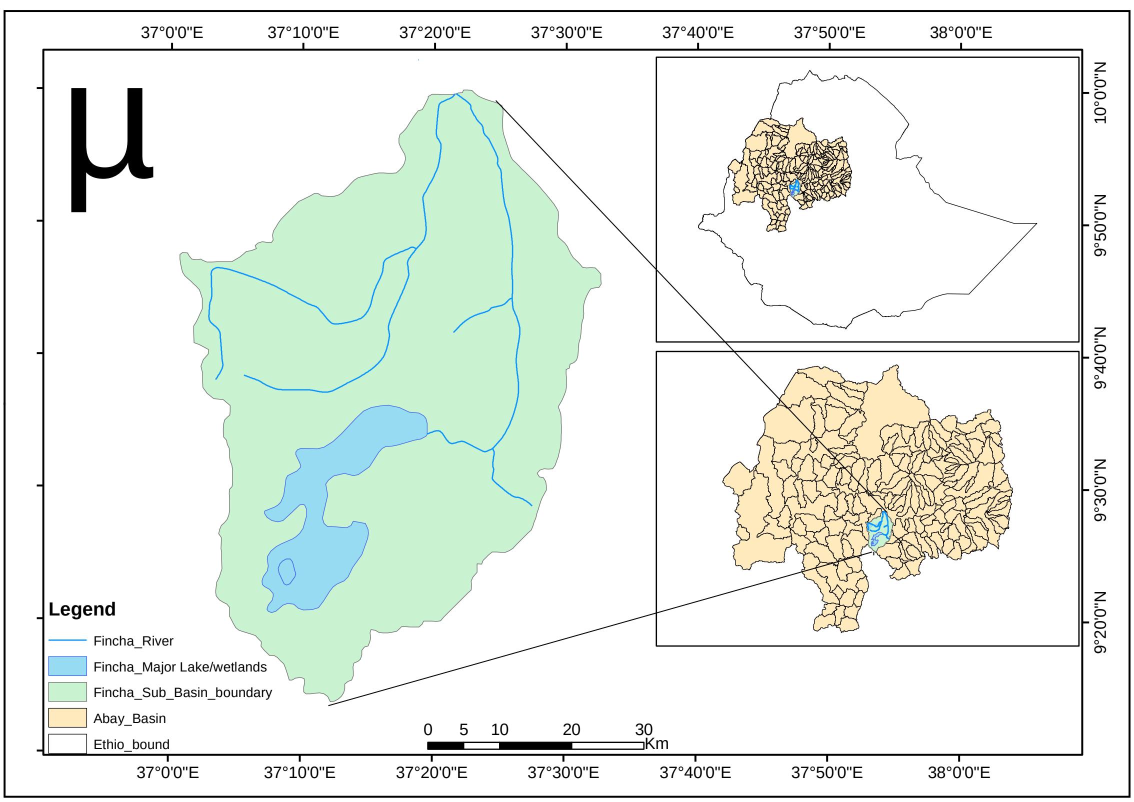

Figure 1: Fincha'a (Study) Sub- Basin Location

Agro ecologically, the sub-basin is characterized by tepid to cool and sub-humid mid highlands and moist mid highlands, and the lowlands in the northeastern parts of the basin being hot to warm moist lowlands. Potential Evapotranspiration (PET) in the sub-basin is generally between 1365 mm and 1970 mm per year. PET is higher greater than 1800 mm/yr, in the lowlands where high temperature is observed. The highlands in the western and eastern parts of the basin show lower PET, less than 1600 mm/yr (Denekew and Bekele, 2009).

Geologically, the sub-basin predominantly underlies by Mesozoic sedimentary formations consisting of horizontally bedded sandstones and shales of the Adigrat Formation. Alkaline Olivine Basalts underlie the upper ridge of the sub-basin. Below the ridge on the plateau and in the upper gorge are the Adigrat sandstones. The Adigrat Formation is composed of a transgressive series of alternating sandstone and shale layers (Denekew and Bekele, 2009).

According to FAO soil classification of Ethiopia, the prevailing soil type in the steep slopes of the sub-basin ridge underlies by Leptosols. It is unattractive soil for rainfed agriculture due to their shallowness and often gravelly with low water holding capacity. They are very prone to erosion. The dominant soils in the basin are Alisols, and Cambisols, and Nitosols, with the occurrence of Arenosols and Luvisols.

The most widespread land cover is rain-fed cultivation covering 57 percent of the Sub-basin. Wetland, open woodland and grassland make up 15, 12 and 10 percent of the area respectively. The remaining 6 percent of the area covered with water with a very small area of forest (MoWIE, 2014). The water cover is the result of the three hydroelectric dams constructed by the government for power generation: Fincha hydroelectric dam constructed in 1975, Amerti dam constructed in 1987 to increase the capacity of Fincha hydroelectric power generation by diverting the water through the tunnel, and the Neshe hydroelectric dam constructed in 2014.

Because of the construction of the dams major land use land cover change happened in the sub-basin. The Fincha Hydroelectric Dam alone inundated 120 km^2 of the swamp, 100 km^2 of grazing land, 18 km^2 of cropland and 1.2 km^2 of forest. Apart from the extensive water body, the most important changes in land use were the loss of grazing land and the increase in cropland. Grazing land occupied 555 km^2 in 1957, but only 332 km^2 left in 2001. In the same period, the area of cropland went up from 403 km^2 to 607 km^2, indicating large-scale conversion of grazing land into cropland. This expansion of cropland in the Fincha watershed was much greater than the changes found in several studies conducted elsewhere in Ethiopia, where population growth was the main reason for the observed land use changes (Bezuayehu and Sterk, 2008).

Due to the conversion of grazing land to cropland and permanent water body, the community of the area is languishing due to lack of pasture. According to Bezuayehu (2006), livestock numbers have decreased in the area due to the shortage of permanent grazing land and farmers forced to use the swamp as pasture, which frequently results in the drowning of animals. In addition, farmers relocated from their farmland for Fincha Dam without any compensation had resettled themselves in the hilly areas of the watershed, owning 23% less land and 24% fewer livestock units (Bezuayehu, 2006). The resettlement of farmers towards the higher and steeper parts of the watershed may have further aggravated the soil erosion problems that are a serious problem in the Ethiopian highland areas, threatening the agricultural sector (Hurni, 1993) and causing increased sedimentation of reservoirs and lakes. Similarly, Lamessa (2003) argued that because of the Amarti dam project, the community in the watershed confronted with a decline in crop and livestock production and even recently with famine. Other similar problems surfaced currently in the area include; the decline in agricultural productivity, environmental degradation, deforestation, loss of wild animals and soil erosion are some to mention.

Phytogeographically, the ecoregion mapped as Afromontane vegetation and considered part of the Afromontane archipelago-like regional center of endemism (White, 1983). In the Warm Semiarid AES below 1500 masl., the main vegetation type is dry woodlands savannah, with bush land on the steeper slopes and riverine vegetation near the watercourses. The identification of trees and shrubs species found in the sub basin conducted during the field survey. Species-level identification made using expert knowledge and by means of local names provided by people in the area. The local names then checked against the lists presented in various publications, particularly Flora of Ethiopia, Volume 3. Even though it is not exhaustive, some of the trees and shrubs found in the sub-basin include the following. *Acacia abissinica, Acacia nilotica, Albizia gumifera, Aningaria adolfifredericii, Carissa edulis, Celtis africana, Combretum spp., Cordia africana, Croton macrostachyus, Dodonaea angustifolia, Ekebria cafensis, Eucalyptus globules, Eucalyptus camaldulensis, Ficus sycomorus, Ficus vasta, Hygenia abissinica, Juniperus procera, Maytenus arbutifolia, Nyrica salicifolia, Olinia rochetiana, Olea africana, Osyris lanceolata, Phoenix reclinata, Podocarpus falcatus, Prunus africanus, Rosa* *abyssinica, Salix subserrata, Syzygium guineense and Vernonia amaygdalina.*

Socioeconomic Setting

The Fincha sub-basin administratively located in Oromia regional state, Horo Guduru Wollega Zone of Horo, Guduru, Hababo Guduru, Abay Chomen, Jima Geneti, Jima Rare, and Jardega Jarte Districts. According to CSA (2013) of Ethiopia population projection of 2014 – 2017 the total population of the sub-basin assumed 577,467 and the average density of the population is about 153 people per km2. Densities are highest on the plateau and ridges of the sub-basin.

Agriculture is the main economic stay of the people residing within the sub-basin. The diversified agro-climatic zones with distinct climatic, soil and altitude differences give an opportunity for growing a varied range of crops like cereals, oilseeds, pulses, and vegetables. Agriculture in the sub basin is predominantly crop-livestock mixed systems, practiced by subsistence farmers on small plots. The major crops grown are teff (*Eragrostis abyssinica*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare),* sorghum (*Sorghum bicolor*), maize (*Zea mays*), and oats (*Avena spp.*) are among cereals. Faba beans (*Vicia faba*), field peas (*Pisum sativum*), mung beans (*Vigna mungo*) and haricot bean (*Phaseolus vulgaris*) are among food legumes. Noug (*Guizotia abyssinica*), linseed (*Linum usitatissimum*), rapeseed (*Brassica napus*), and sesame (*Sesamum indicum*) are among oil crops. Potato (*Solanum tuberosum*), onion (*Allium cepa*), and garlic (*Allium sativum*) are among horticultural crops grown in the sub basin. Cereals, food legumes, and oil crops are crops grown in descending order of area coverage.

The farming system in the sub basin dominated by cereal production that accounts for about 75% of the total cultivated area. From cereals: teff, wheat, and maize account 30.9%, 23.6%, and 19.9% respectively. Most cereal crops particularly teff and wheat are planted on fine seedbed and provided little groundcover during the most erosive storms in July and early August. This combined with steeply sloping upland area and poor land management practices contributes to land degradation currently observed in the area.In the sub basin, the cropping system is dominantly mono cropping of the first three major kinds of cereal, i.e., teff, wheat, and maize whereas intercropping, and double cropping practiced to a limited extent. Crop rotation practiced almost by the entire farmers of the sub basin. In the sub basin, farmers follow rotations like cereal-pulse-cereal or oil crop-cereal-pulse or cereal-cereal-oil crop or root crops-cereals-pulse or cereal-cereal-pulse.

Farmers of the sub basin use different agricultural inputs (fertilizer, improved seed, pesticide, and herbicide) to increase their level of productivity. In 2014/2015 cropping calendar alone about 87,864 Quintals of DAP and 51,083 Quintals of Urea fertilizers distributed to 58,491 and 48,418 beneficiaries respectively in the sub basin. During the same period, 18,967 improved seed (Maize) distributed to 48,418 participated farmers. In the same year, 9453 liters of 2-4D herbicide and 1846 actinic pesticide distributed to 9306 and 11998 participant farmers respectively (Horo Guduru Wollega Zone Agriculture and Natural Resource Office). Farmers in the sub-basin mostly practice hand weeding to control weeds. Weeding frequency can range from one to four depending upon the level of infestation and the crop type. They give priority to teff, maize, wheat, and potato. It is obvious weed cause damage at an early stage of crop growth but farmers unable to exercise timely weeding due to labor shortage because of overlapping of agricultural activities.

Of the major crops grown in the sub-basin, mainly niger seed, sesame, mung bean, and teff are cash crops and the others used for home consumption while also sold. Oxen used as traction power for land preparation. Land preparation, weeding, and harvesting are the most laborious agricultural activities and they are activities that wealthier households will pay for. Ball worm, termites, and stock borer are the main pests that affect crop production. Ball worm affects Niger seed, termites affect all types of crops and stock borer affects maize. Niger seed ball worm is a pest unique to the sub-basin. Even though overall crop productivity in the sub-basin is increasing, the average productivity of different crops is much less than the potential productivity (Table 1). The agricultural year begins with preparing and clearing the land for planting of maize in the month of May. The consumption year begins in October with the green harvest of maize. Genna (June to September) rains are used for planting short cycle crops (teff and wheat) while Arfasa (March to May) rains are used for land preparation and planting of long cycle crops (maize and sorghum). Maize planted in May and harvested in December and January. The planting, weeding, and harvesting periods of teff and wheat crops are in July, September to October, and December respectively. Cattle, sheep, goats, horse, donkey, mule and chickens are the main types of livestock raised in the sub-basin. Horo Guduru cattle breeds are one of the most productive breeds in Ethiopia. Animals free graze on bushes, shrubs, leaves, grasses and crop residues.

Table 1: Comparison of the average yield and the potential attainable yield of major crops in the sub-basin

Crop	Proportion (%)	Current Yield (T/ha)	Potential yield (T/ha)	Yield Gap (%)
Maize	15	3.11	4.5	30.9
Teff	23.3	0.90	2.0	55
Wheat	17.7	1.83	3.5	47.7
Barley	9.0	1.6	2.2	27.3
Niger seed	7.4	0.55	0.6	8.3
Faba bean	5.9	1.02	2.0	49
Average		1.5	2.5	40

Source: Survey result; Zonal & District agricultural Offices; EIAR bulletins

METHODOLOGY

Agro-ecosystem Analysis

In this application, the Agro-ecosystem Analysis (AEA) methodology of Simane *et al*. (2013) tailored to the conditions of the communities and research relationship in Fincha Sub-basin. According to Simane *et al*. (2013), the structure of an agro-ecosystem is a consequence of its environmental setting (e.g., climate, soil, topography, various organisms in the area), agricultural technologies and practices, and farmers' social setting (e.g., human values, institutions, and skills).

We used a participatory, interdisciplinary approach to landscape mapping that makes extensive use of objective data but recognizes that the definitions of system boundaries and functional relationships necessarily involve subjective, locally specific judgments about the defining elements of the agro-ecosystem.

The definition of agro-ecosystems based on the overlay of three inputs: an agro-climatic zoning based on precipitation and temperature, a soil and terrain analysis, and a map of the distribution of farming systems.

Specifically, the agro-ecosystem zones of the Fincha sub-basin defined using the temperature and precipitation ranges associated with the traditional Ethiopian agro-ecological zones (Table 2). Soil and terrain analysis performed using the FAO (2006) soil classification in combination with local soil survey. Farming systems defined based on the dominant type of resource base and livelihood pattern of the farm households (FAO, 2007) as determined by local agricultural experts and confirmed during the focus group discussion. In most cases, we found that there is a gradual transition from one system to another, so the boundaries between them not actually as sharply defined as they appear on generalized agro-ecosystem maps (Figure 4).

Finally, these three sources of information (agro-climatic zoning, soil and terrain analysis, and farming systems) combined to define the major agro-ecosystems within the sub-basin. Secondary literature used to develop a preliminary structure and criteria for differentiation. There are five traditional agro-ecological zones in Ethiopia (Table 2). The traditional zones further elaborated into 33 agro-ecological zones based on temperature, elevation, and length of growing period. Afterward, the differentiated structure refined in collaboration with experts and farmers during my focus group discussions with the communities. This resulted in the distinction of four major agro-ecosystems.

Table 1: Agro-ecological zones and their physical characteristics.

Traditional Zone	Climate	Altitude (m)	Average Annual Temperature (^{O}C)	Average Annual Rainfall (mm)
Bereha	Hot arid	<500	>27.5	<200
Kola	Warm semiarid	500-1500	27.5-20.0	200 - 800
Weyna Dega	Cool sub-humid	1500-2300	20.0-17.5	800 - 1200
Dega	Cool and humid	2300-3200	17.5-11.5	1200 - 2200
Wurch	Cold and moist	Above 3200	<11.5	Above 2200

Source: Agro-ecology zones of Ethiopia, Ministry of Agriculture, Addis Ababa, 2000

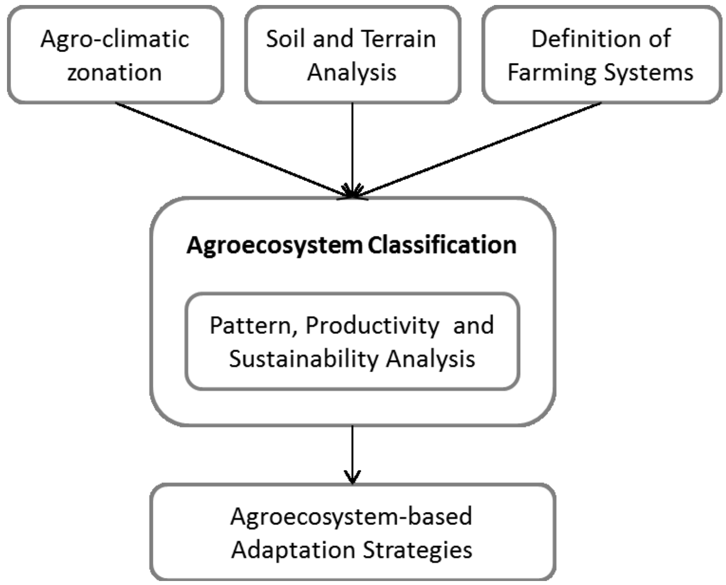

Figure 2: Conceptual framework for agro-ecosystem analysis and adaptation planning.

After defining the agro-ecosystems; pattern, productivity, and sustainability assessment performed. Pattern analysis is the identification of constraints and opportunities for the management of the system, while productivity and sustainability assessment focus on key questions about the functioning of the system, especially with respect to possible ways to overcome constraints to enhance productivity and sustainability to urge possible research and development options.

These analyses began with an objective productivity potential assessment based on soil and terrain conditions conducted using the FAO revised Framework for Land Evaluation (FAO, 2007). Then, a full pattern, productivity, and sustainability assessment performed through a series of questionnaires and focus-group discussions (FGD) in consultation with local agriculture experts and complemented by field observations. The assessment includes physical and realizable productivity potentials and existing production constraints used to suggest future adaptation intervention.

RESULTS AND DISCUSSION

Definition of Agro-ecosystems

The analysis of the study identified four major agro-ecosystems within the study sub-basin. The identified AES show a notable difference in terms of agro-ecological zones, dominant sources of livelihood, production potentials, constraints, and production orientations. The variety of agro-ecosystem grants both an opportunity and challenge for adaptation to climate change (Simane *et al.*, 2013). The multiplicity of climate conditions suggests that variety of farming techniques, growing different crops, and strategies are active within the region, providing a broad foundation for adaptive efforts, but that same diversity makes it difficult to establish climate change projections and adaptation strategies that targeted to address to these highly localized specific conditions.

The four identified agro-ecosystems are the Highland with sloping terrain AES, the Midland with rolling plateau AES, the Wetland with the artificial lakes AES and the Lowland AES and each of them discussed below.

The Highland with sloping terrain AES

This AES confined to the watershed ridge above 2,300masl in the Dega Agro-ecological Zone. Typically, the AES experiences cool and humid type of climate. It is characterized by steep (15% to 30%) to very steep (> 30%) slopes. In terms of area coverage, it accounts 21.9 % of the sub-basin. Formerly, the area is known for its overall high production potential, fertile soil, and producing surplus food. However, the high rate of deforestation, soil erosion, and landslide are the major environmental problems that jeopardized the overall productivity of the AES.

Temperature ranges from a minimum of 10-15^{0}C (June to August) and maximums of 15-25^{0}C (January to March). Agriculture dominated by rain-fed production system and takes place only during the Genna (Kiremt) season. Previously Arfasa production of Barley known in the area but now such production is minimal or even non-existence in the area due to changes in climate.

The main crops grown in this AES are barley, wheat, pulses, and potatoes. In terms of area coverage, wheat and Barley accounts 35.1% and 26% respectively. Previously, some 20 to 30 years back, crops like Teff, Maize, and Nuge not grows in this AES, but now the community started to grow these crops. As verified during focus group discussion, this is one indicator of climate change (temperature increase). Wheat, barley, pulses, and potatoes are used both for home consumption and sold. Land prepared using oxen plows and by hand digging. The most laborious agricultural activities are weeding and harvesting.

The main crop pests and diseases are ball worm, leaf blight, and smut. Crops affected by ball worm are barley, wheat, and teff; crops affected by leaf blight are potatoes and teff; smut attacks wheat, barley, and maize. Timely weeding reduces the impact of leaf blight. Removal of affected plants is a treatment practiced reducing the impact of smut. Households use fertilizers (urea and DAP), improved seeds and compost. Farmers widely prepared compost to manage the fertility of their soil.

The main types of livestock owned are cattle, shoats, and equines. Animals free graze on browse and fed crop residue. Rivers are the major source of water for both people and livestock in dry and wet seasons.

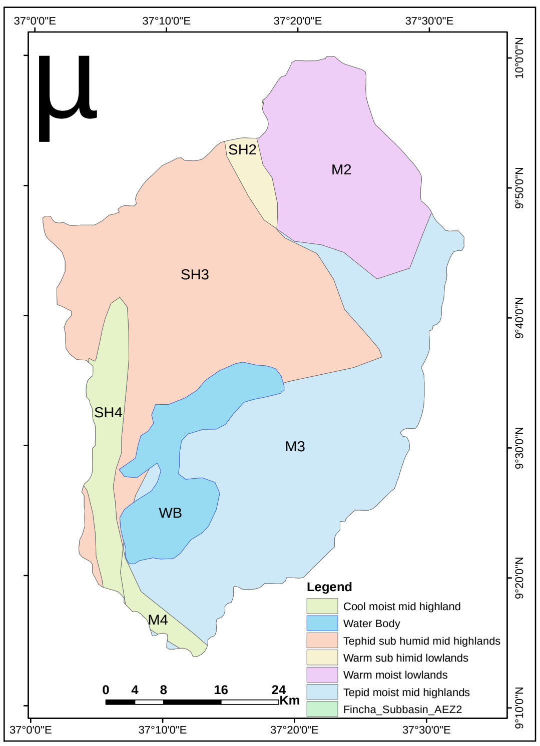

Figure 3: Elaborated Agro-ecological Zones of Fincha Sub-basin

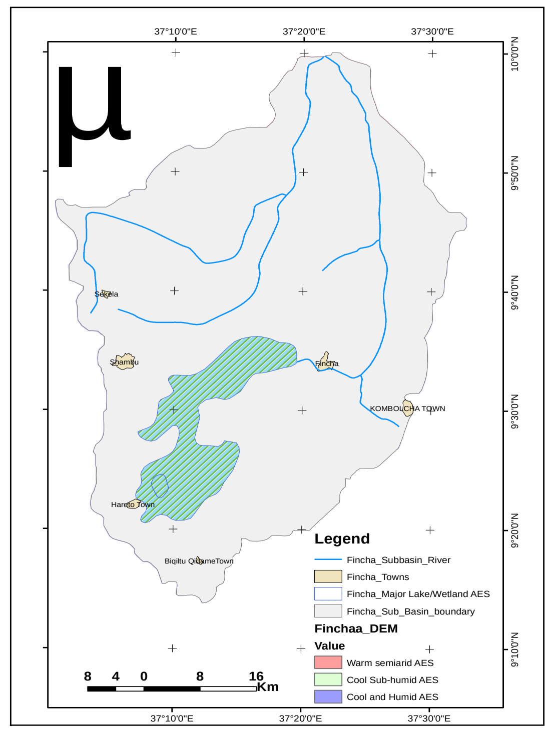

Figure 4: Agro-ecosystems of Fincha Sub-basin

Table 2: Sub-basin Agro-ecosystems and their characteristics

Agro-ecosystem (AES)	Farming Systems	Traditional Climatic Zone	Major Soils	Major Crops
Highland	Semi-intensive Barley-Wheat based	Dega	Leptosols Luvisols	Barley, Wheat, Fave Bean
Midland	Intensive Tefff-Maize-based	Upper Weyna Dega	Leptosols Nitosols	Teff, Maize, Niger seed
Wetland	Intensive Tefff-Maize-based	Lower Weyna Dega	Nitosols	Teff, Maize
Lowland	Sorghum-based extensive	Upper Kola	Luvisols Vertisol	Sorghum, Teff, Sesame

There is no payment for water. Cows are the only animals milked in this AES. Shoats older than one year, cattle older than two years, butter and eggs sold to generate income. Boys are responsible for looking after livestock. The main diseases affecting livestock are anthrax (cattle, shoats), blackleg (cattle), Pasteurellosis (cattle, shoats) and African horse sickness (equines).

The Midland with rolling plateau AES

This agro-ecosystem dominantly characterized by midlands or Weina dega areas with an extensive rolling plateau, ranging in altitude between 1500 m and 2300 m.a.s.l. The topography is predominantly undulating land and plains. Coupled with opportunities for market access, this livelihood zone is food self-sufficient. It covers 44.7% of the total area of the sub-basin. The main rainy season extends from early May to the end of September. Average annual rainfall ranges from 1200mm-1800mm. Maximum temperatures of 23-27 ^{0}C reached from January to March. Minimum temperatures of 7-15 C^{0} are normal from October to November. Soil types are dominantly loam and silt, sand and clay, which are fertile. Generally, the AES can be considered as a very high potential area and annually produce a food surplus.
Teff, Niger seed, Maize, Wheat, Barley, and Beans produced very well in this AES. In terms of area coverage teff, wheat and Niger seed account 26.2%, 25.7%, and 18.5% respectively. Households grow teff, maize, and wheat for consumption and sale while Niger seed grew as a cash crop. Land preparation, weeding, and harvesting of cereal crops are the most labor-intensive activities. The main crop pests and diseases are ball worm, leaf blight, and smut. Crops affected by ball worm are barley, wheat, and teff. Crops affected by leaf blight are potatoes and teff; smut attacks wheat, barley, and maize. Timely weeding reduces the impact of leaf blight. Removal of affected plants is a treatment practiced reducing the impact of smut. Households use fertilizers (Urea and DAP), improved seeds and compost. Mostly, improved seeds, fertilizers and insecticides/herbicide obtained from the farmers' cooperative and Bureau of Agriculture and Rural Development (BOARD). This agro-ecosystem utilizes more agricultural inputs such as improved seed and inorganic fertilizer than the adjacent AES.

Cattle, goats, sheep, and chickens are the main types of livestock raised. Animals free graze on grasses, bushes, leaves and crop residues. Water sources for the animals include springs, minor rivers and seasonal ponds in wet seasons and major rivers during the dry season. Water sources for humans include springs, dug wells, rivers, and hand pumps. Cows are the only animals milked. Men and boys are mostly responsible to take care of livestock's. Trips, internal parasite, and pasteurellosis are the main pests and disease affecting livestock.

The key sources of income are crop sales, livestock and livestock product sales, agricultural labor and petty trade. Cereals like maize, wheat, and teff sold as well as used for consumption whereas crop like Niger seed grew exclusively for sale. Wealthier households also sell barley and pulses (beans and field peas). The honey production also earns income for some households. All wealth groups sell cattle, sheep, and chickens. Middle and better-off households also raise and sell fattened oxen. Livestock product sold by all wealth groups refers to eggs and butter.

The Wetland with the artificial lakes AES

This agro-ecosystem includes the wetlands and the associated artificial lakes constructed for the generation of hydroelectric power. According to Ramsar wetlands definition of (1997), Wetland is an ecosystem that occurs when the water table is at or near the surface of the land, or where the land covers by shallow water. Therefore, it includes areas of marsh, fen, peatland or water, whether natural or artificial, static or flowing, fresh, brackish or salt including areas of marine water the depth of which at low tide does not exceed six meters. Crops like Tefff, Maize and horticultural crops grow best in this agro-ecosystem by draining the water. In terms of area coverage, teff and maize account for 43.2% and 36% respectively. Households grow Teff, Maize and horticultural crops for consumption and sale. The main crop pests and diseases are ball worm, leaf blight, and smut. Households use fertilizers, improved seeds, insecticide/herbicide and compost. Mostly, improved seeds, fertilizers and insecticides/herbicide obtained from the farmers' cooperative and Bureau of Agriculture and Rural Development (BOARD). Land preparation, weeding, and harvesting of cereal crops are the most labor-intensive activities.

Recession farming is another important activity exclusively carried out in this agro-ecosystem. Recession farming is a crop production system carried out by residual soil moisture that is stored in the subsurface after annual inundation of floodplains, lake margins or seasonal wetlands. This farming system practiced at the floodplains and associated artificial lakes constructed for the generation of hydroelectric power using the residual moisture retained when the lake's water recedes.

Cattle, goats, chickens, sheep, and equines are the main types of livestock raised. Animals free graze on bushes, shrubs, leaves, grass, and crop residues. Water sources for the animals include minor rivers and seasonal ponds in wet seasons and major rivers during the dry season. There is no payment for livestock food or water. Water sources for humans include springs, dug wells, rivers, and hand pumps. Cows are the only animals milked. Livestock products sold include eggs, butter, and skins. Taking care of livestock is left mostly to men and boys. Trips, internal parasite, and pasteurellosis are the main pests and disease affecting livestock.

The wetland agro-ecosystem generally accounts for about 15% of the sub-basin (MoWIE, 2014). These ecosystems act as an interface between land and water and have a wide socioeconomic and ecological function. However, communities are complaining about the construction of the artificial lakes constructed for hydropower generation that has taken their grazing and farmland. As compared to the other agro-ecosystem found in the sub-basin the households in this AES holds relatively small land holdings.

In this AES, there are also villages that are isolated from the land mass due to the inundation of the Fincha reservoir. These islands have very poor boat transport to go to the nearby towns like Fincha wuha. The boat transport system is very expensive particularly to school boys and girls who are paying two Birr every day to reach their schools. Communities also get all market and health services by crossing the water with the boats.

Another important problem associated with this AES is the problem of wetlands degradation that includes siltation due to soil erosion, and overexploitation of wetlands to farming activities due to dwindling of farmland (shortage of land). The siltation of the reservoir inundated the adjacent land that also escalated the grazing land shortage, and communities consider this ecosystem as a lost land. The implications of wetland degradation resulted in Flooding, declining water quality, declining wetland biodiversity, declining water table and water recharges. There are also opportunities to halt the situation by controlling soil erosion in upland areas, improve productivity in dry land agriculture, practicing rice cultivation in the seasonally flooded plains, strengthen policy for protection/conservation of wetlands, protecting water sources and benefiting the communities from such development activities.

The Lowland AES

The warm semiarid AES confined to the lower parts of the sub-basin along the Blue Nile gorge with an altitude range less than 1500 m.a.s.l. in the Kola Agro-ecological Zone. Typically, the AES experiences a hot type of climate. This specific AES accounts 18.4% of the sub-basin. Landslide and high rate of soil erosion are the major environmental problems of this AES.

The production of sorghum, maize, teff, sesame and mung bean (Masho) crops best known in this agro-ecosystem. In terms of area coverage, sorghum is the first and accounts 35.8%. Households grow Sorghum and Maize for home consumption while Sesame and Mung bean grows as a cash crop. Termite, Stock borer, and Smut are pests affecting crop production in this agro-ecosystem. Land prepared using oxen plows and by hand digging. The most laborious agricultural activities are weeding and harvesting.

The main types of livestock owned are cattle, shoats, and equines. Animals free graze on browse and fed crop residue. Rivers are the major source of water for both people and livestock in the dry and wet seasons. Cows are the only animals milked in the AES. Shoats older than one year, cattle older than two years, butter, and eggs sold to generate income.

According to the data obtained from the Hababo Guduru Woreda, there are five investors in this AES with a total capital of 5,687,000 Birr. The investors are engaged in agricultural activities and owned a total of 606 hectares. The job opportunity created by the investors includes 11 permanent and 186 temporary peoples.

Apart from other AES, the upper part of this agro-ecosystem utilized for commercial sugarcane plantation. The source of irrigation water for the sugarcane plantations are Fincha and Neshe dams after generating the hydroelectric powers. According to sources from Fincha Sugar Factory, the command area of the farm is 67,098 hectares. In 2017, sugarcane production carried out on 19,559 hectares of land.

Pattern analysis

Pattern analysis deals with the identification of Constraints and Opportunities for the management of the system.

Constraints of the Fincha Subbasin

The Natural resource degradation namely degradation of land, water and vegetation resources and environmental concerns are the most pressing issues in Fincha Sub-basin that affecting the livelihood of its population. One of the root causes of land degradation assumed to be deforestation. The extent of the forest degradation especially severed in the

Ethiopian highlands to which Fincha Sub basin belongs (Hurni *et al*., 2010). As identified during the FGD the underlying causes of deforestation or decline of forest coverage are poverty, ill-defined forest tenure and use right system and low level of awareness. The proximate causes, however, are extensive land use change from forestland use to cultivation and grazing land use system. The land degradation problem caused on-site and off-site effects on agriculture and water reservoirs found in the sub-basin. It also challenges the desire of farmers to meet the basic food requirements of the growing population currently let alone the food demand of the future generations.

The sub-basin also characterized by rapid population growth, environmental degradation, and poverty. Agriculture is predominately rain-fed. An insignificant amount of land is currently under irrigated agriculture whereby traditional irrigation schemes have the dominant share. Rainfall variability is the dominant phenomena that affect agricultural activities.

Furthermore, erosion, unreliable rainfall, unimproved agricultural technology, small size land holding and fragmentation, insufficient supply of agricultural inputs (fertilizers, improved seeds, and pesticides), lack of sufficient feed (fodder) for livestock, low performance of local breeds, inadequate veterinary service & high prevalence of animal diseases are some of constraining factors that adversely affect agricultural productivity. Similarly, the inconvenience of rural feeder roads to access input-output market is also a problem.

Partial lists of agro-ecosystem specific constraints include the following:

Land degradation/ Soil erosion is a phenomenon that endangers the livelihoods of rural farmers' ability to produce crops, livestock, and products from other natural resources. The effect of soil erosion not limited to onsite effects like yield reduction, soil depth reduction, soil water holding capacity reduction, etc but also offsite effects such as sedimentation and pollution. Land use practices in the sub-basin are resulting in the land, water, and forest degradation, with significant repercussions for the sub-basins' agriculture sectors, natural resource bases, and ecological environmental balances. The problem is observed in all AES but severe in the Highland and Lowland AES.

The farming system in the sub-basin entirely dominated by annual crop production system that accounts more than 95% of the total cultivated area. Soil erosion by water is very high from annual crops than perennial crops (Hurni, 1990). Most cereal crops particularly teff and wheat are planted on fine seedbed and provided little groundcover during the most erosive storms in July and early August. This combined with poor land management practices contributes to land degradation currently observed in the sub-basin.

Deforestation: Forests have tremendous present and future values to human beings' existence. Forests are important for maintaining ecological balance and preserving the life supporting system of the earth. They are the largest ecosystems and have the following generalized functions viz. production function (economic function); protective or amelioration function (ecological function) and development function (MEA, 2005). However, forests of the sub-basin threatened by many factors majorly conversion to agricultural land use, and land and water intensive development activity carried out in the sub-basin by the government (Bezuayehu and Sterk, 2008). Even though the problem of deforestation is a common practice in the sub-basin the recent practice to obtain agricultural fields for the production of sesame in the Lowland AES, cause a devastating impact in the forest resources of the AES.

Water logging: The Wetland AES is prone to water logging problem. Such problems are hindering the full productivity of the land. Appropriate technology capable of utilizing the water logging of the soil recommended for practice.

Crop residue burning: such a practice common in the cool sub-humid AES of the sub-basin. The practice has a negative effect on soil microorganisms.

Disease and Pests: The main crop pests and diseases are ball worm, stock borer, leaf blight and smut. Crops affected by ball worm are barley, wheat, and teff. Crops affected by leaf blight are potatoes and teff; smut attacks wheat, barley, and maize; Ball worm affects maize and Niger seed. Niger seed ball worm is a pest unique to the sub-basin. Timely weeding reduces the impact of leaf blight. Removal of affected plants is a treatment practiced reducing the impact of smut. Regarding Animal disease in the sub-basin, the most important diseases affecting the livestock resources are Trypanosomiasis, Internal and external parasites, Infectious diseases and blood urine that entirely attack domestic animals especially the ruminant animal.

Limited access to improved seed technologies: The use of improved seeds has multitude advantages to increase productivity, produce a large amount of biomass, increase resistant to diseases, pests and weeds, and fasten vegetative growth and provide early land cover. However, due to limited access, the use of improved seeds crop varieties is extremely low which is less than 20% of the total cultivated land. Other than maize, the coverage of other crops in terms of improved seeds utilization is almost nothing. All AES are suffering a lot due to lack of poor supply of improved seed.

Climate change: Agriculture, particularly rain-fed agriculture, is extremely sensitive to climate change (Ramay, 2011). The main direct effects of climate change will be through changes in factors such as temperature, precipitation, length of growing season, and timing of critical events related to crop development (Agarwal *et al*., 2000). Like other rain-fed dominated agricultural systems, Fincha Sub-basin agricultural system is also highly vulnerable to the negative impact of climate variability and change. Participatory agro-ecosystem analysis indicates that sensitivity to climate variability and change is a major concern in all defined AES. Especially, the Lowland AES have faced on average 3.6 years drought and 3 years flooding in the past 20 years.

Opportunities of Fincha Sub-basin

The opportunities found in the sub-basin for the management of the system includes but not limited to the following:

Diversified Agro-climatic zones: There are diversified agro-climatic zones in the sub-basin with distinct climatic, soil and altitude differences, which allow growing of various crops.

The practice of using Agricultural Input: Agricultural inputs believed to be the most important factors to increase agricultural productivity. In terms of using agricultural inputs (fertilizer, improved seed, pesticide, and herbicide), farmers of the sub-basin have a long tradition.

Rice-based production system: In some of the seasonal waterlogged or flooded areas, especially in the Wetland AES, rice can be an important crop to grow. However, the utilization of such potential not currently practiced in the area that has the potential to increase the crop production potential of the specific AES.

Introducing temperate fruits and cool season vegetables: The temperate fruits are adapted to temperate zones. However, there are some varieties grown very well in the tropics under certain climatic condition. The most important fruits in this group are apples, pears, plums, nectarines, and strawberry. Furthermore, low chilling requiring varieties found adaptable at Holetta, an area with a similar climatic condition like the study area, are available (Gebre, 2004). The high-altitude parts of the sub-basin or the Highland AES are convenient for temperate fruits and cool season vegetable production. Since low temperature experienced in some months (October-January) of the year satisfies their chilling requirement. Therefore, it is possible to utilize this untapped potential for the benefit of the community as well as the nation. Currently, in Ethiopia temperate fruits are grown at an altitude of 2200 masl and beyond up to 3000 masl (Gebre, 2004).

Indigenous Sustainable Land Management Practice (SLM): For generations' farmers in the sub-basin practiced indigenous SLM practices to halt land degradation, improve soil productivity and for woody biomass production. In Ethiopia, as population increased, some of the indigenous practices such as fallowing, manuring, crop residue management, and leaving trees on farmland declined due to high demand for fuel wood, feed and house construction (Zeleke *et al*., 2006). However, in the sub-basin, there are still indigenous knowledge practices practiced by farmers that can assist to manage the natural resources including land sustainably.

In the subbasin one traditional unique practice that not common elsewhere is the practice of <<Chichessu>>. Chichessu is analogous to fertilize with manure. It is a local name given to the traditional soil fertility management prevailing in the sub-basin. Another important common SLM practice in the sub-basin is the traditional agro-forestry practices in the form of scattered trees on the farmland and home garden. Peoples used to plant both indigenous and exotic tree species for such purposes.

Productivity and sustainability issues

At the production level, agricultural productivity measures the value of output for a given level of inputs. To increase agricultural productivity, the value of output must increase faster than the value of inputs. Gains in overall agricultural productivity can, therefore, come from changes in the production process that produce more output per unit of land or labor, or from changes in production and market costs and hence the increased profitability for farmers. Generally, increasing agricultural productivity not only relies on improved production efficiencies; but also, on factors such as adequate access to productive resources, well-functioning markets and infrastructure, and policy promoting economic and social stability (Simane *et al*., 2013).

In this subtopic, to determine the productivity potential of each agro-ecosystem, we conducted the land suitability evaluation that represents the suitability of different AES for crop production. Suitability is then ranked on a scale from one (least suitable) to five (most suitable) (Simane *et al*., 2013). Here we hypothesized that vulnerability increases with a decrease in crop productivity potential, as household livelihoods are more at risk from substantial changes in climate. Then the suitability of soil characteristics and overall average suitability to agricultural production by AES done and presented in Table 5. The relative suitability of land areas for agriculture includes climate, soil (fertility & depth), and terrain conditions relevant to agricultural production.

The result of the analysis showed that the Highland AES is constrained with land degradation, Erosion, and steeply sloping terrain. While the Midland AES is only constrained with soil acidity and found relatively the most suitable land for agriculture, Wetland AES constrained with water logging (drainage problem), liability to flooding and siltation. The Lowland AES is constrained with rainfall variability, erosion, natural fertility declines due to leaching and acidity.

Although physical evaluation of productivity done is informative, the relative input utilization of each AES also reflected the potential and possible gap for agricultural crop production systems that observed in the sub-basin (Table 6). The observed production system is the result of ecological, socioeconomic and cultural factors found in the sub-basin. Relevant management considerations that influence realizable productivity potential in each AES listed in Table 7.

The result of input utilization confirms that most farmers of the sub-basin used local seed in combination with fertilizer as depicted in table 6. Out of the total land cultivated in 2017 cropping calendar 52.8%, 55%, 48.6% and 54.2% of the agro-ecosystems covered by (local seed and fertilizer inputs) in AES1, AES2, AES3 and AES4 respectively. The percentage share of improved seed and fertilizer inputs was 14%, 21%, 23.9% and 12.1% in AES1, AES2, AES3 and AES4 respectively. The result of the analysis revealed that the full productivity potential of the sub-basin not yet utilized.

The assumed intensity of management and the level of agricultural investment expected for physical, chemical and biological constraints on the productivity of each AES confirmed through the participatory approach in consultation with the community and experts presented in Table 7 below. Key properties and production potentials identified through agro-ecosystem pattern and productivity analysis carried out

Table 3: Analysis of the suitability of soil Characteristics and overall average conditions to agricultural production by AES.

AES	Depth*	Natural Fertility*	Drainage*	Texture*	Terrain*	Average Suitability**	Dominant Constraints
AES1	3	2	2	1	5	3	Land degradation, Erosion
AES2	2	2	1	1	3	5	Soil Acidity
AES3	2	3	5	2	1	4	Water logging, Siltation, liability to Flooding
AES4	3	3	1	1	4	2	Rainfall variability, fragmented and steep slopes with the highest degradation rate

AES1: Highland; AES2: Midland; AES3: Wetland; AES4: Lowland
For soil characteristics*: 1: not constrained; 2: slightly constrained; 3: moderately constrained; 4: constrained; 5: severely constrained.
For average suitability**: 1: not suitable; 2: least suitable; 3: suitable; 4: more suitable 5: most suitable.

Table 4: Input utilization currently practiced in the sub-basin.

AES	Improved Seed + Fertilizer (%)	Local Seed + Fertilizer (%)	Local Seed + Compost (%)	Local Seed only (%)	Total Percentage
AES1	14	52.8	20	13.2	100
AES2	21	55	13	11	100
AES3	23.9	48.6	14.2	12.3	100
AES4	12.1	54.2	7.1	28.6	100

Source: Survey result and District agriculture office
Key: AES1: Highland; AES2: Midland; AES3: Wetland; AES4: Lowland

Table 5: Realizable Potential of Fincha sub-basin Agro-ecosystems.

AES	Assumed Intensity of Management	Key properties and production potentials
AES1	Ecological based production system including highland temperate fruits. In addition, use of relatively high level of inputs for a crop like wheat.	Production for subsistence plus commercial sale is a management objective. Production based on the use of both traditional cultivars and improved high yielding varieties; labor-intensive techniques, and practice of application of nutrients for high yielding varieties. The high steeply sloping upland and consequent high erosion hazard prevail but minimum conservation techniques practiced.
AES2	Relatively high level of input & management practices	Production is based on improved high yielding varieties, mechanized, and uses optimum applications of nutrients and chemical pest, disease and weed control
AES3	High level of input & management practice including recession farming	practicing rice cultivation in the seasonally flooded plains, production based on improved high yielding varieties, labor intensive, & optimum application of fertilizer/inputs.
AES4	Relatively low level of input	Production mainly based on subsistence production system. The AES has a high potential for the production of sesame and newly introduced mung bean, which is a good cash crop.

Sustainable systems are systems those best use the environmental goods and services while not causing to these assets (Scherr and McNeely, 2008; MEA, 2005). Sustainability in agricultural systems incorporates concepts of both resilience (the capacity of systems to buffer shocks and stresses) and persistence (the capacity of systems to continue over long periods) and addresses many wider economic, social and environmental outcomes (Pretty, 2007).

In terms of input use, the major external inputs used for crop production in the sub-basin includes inorganic fertilizer (DAP and Urea) and Chemical Pesticides (insecticides, herbicides, etc). From the crops grown in the sub-basin Teff, Wheat and Maize are the high external input users and Barley, Sorghum, Fava Bean, Field Pea, and Niger Seed are low external input users. The decision to use or not the external inputs requires proactive and conscious thinking. The inefficient use of external inputs can cause considerable environmental harm. In contrary, increased agricultural area by encroachment to the natural ecosystem to increase agricultural production contributes substantially to the loss of habitats, associated biodiversity and their valuable environmental services (MEA, 2005; Pretty, 2007; Scherr and McNeely, 2008).

In the study sub-basin, there are two inconsistent interventions carried out by the community. In one hand, you may find picturesque landscape due to the traditional agro-forestry practice dominant in the sub-basin. The practice contributes to the mitigation of climate change by sequestering carbon in the aboveground biomass and below ground in the soil. On the contrary, especially in the Highland AES, the practice of agriculture contributing to the change of climate through carbon emission by encroachments to the natural ecosystem and deforestation and inappropriate land use that aggravated soil erosion. Therefore, it is required to enhance the sustainable practice, recuperate the unsustainable practices and harnessing agro-ecological based production systems.

Adaptation Strategies

It is obvious that adaptation not only involves reducing risk and vulnerability but also seeks opportunities and building the capacity of the agricultural sector and the communities including the natural systems to cope as well as mobilizing that capacity to implement actions (Tompkins *et al.*, 2010). It is inevitable that the business as usual approaches to increase agricultural production no more feasible and requires a proactive approach that continually adapt to the changing environment. Compounding factors including climate variability and change are causing a significant impact on the study sub-basin. Therefore, designing adaptation strategies capable of withstanding the significant challenges in the whole of the sub-basin and specifically in each AES offers the opportunity to benefit from the existing resources and minimizes risks.

Agro-ecosystem analysis provides opportunities for designing adaptation strategies relevant to the specific AES that considers the spatial differences (Climate, topography, soil and farming system) including the socio-economic stratification of the agricultural sector of the study sub-basin. In addition to climate variability and change, the study sub-basin facing different challenges like land degradation, soil fertility decline, livestock feed and fuel wood that affects the livelihood of the farming communities.

AES specific strategies for climate resilient development in Fincha sub-basin as identified during the household survey, focus group discussion, expert judgment, and review of literatures includes:

Agronomic Sustainable Land Management (SLM) technologies: SLM is vital for enhancing and sustaining the productivity of food and fiber of agricultural systems. It also stated that the highly productive agricultural systems need sustained and made more efficient to reduce the impact on the environment (World Bank, 2006). The use of appropriate crop production technologies could contribute to the integrated effort to arrest land degradation and for sustained productivity. Beneficial farm-level land management practices designed to maintain the quality and long-term productivity of the land and to mitigate environmental damage from crop production.

According to IIRR (2002), Agronomic SLM technologies grouped in to; Conservation tillage (includes but not limited to contour plowing, ridging, minimum tillage, tied ridging); Conservation farming (includes crop rotation, intercropping, alternative crop varieties, fallows and area closure); Soil fertility management (includes manure application, compost application, green manuring, and biological nitrogen fixation). The technology is applicable to all AES based on the specific scenario. For example, out of the conservation tillage, technologies like contour plowing & minimum tillage more important to the Highland AES where soil erosion is severe and tied ridging is important in Lowland AES where moisture stress is a problem. Minimum tillage is good on sloping, well drained, and course and medium textured soils, but less effective on poorly drained soils or on soils that form surface crusts easily. Weeds may be a problem at first in minimum tillage. It is necessary to weed more or to use mulch to smother the weeds. It is possible to spray herbicides, but these are expensive and may harm the environment (IIRR, 2002). Generally, in the conservation agriculture approach three linked principles achieved viz. minimum soil disturbance, permanent organic soil cover, and diversification of crop species (FAO, 2011).

Bio farming: This is a system of establishing permanent agriculture (Permaculture) that draws from several disciplines including organic farming, agro-forestry, integrated farming, sustainable development, and applied ecology. It is an applicable strategy for Highland, Midland & Lowland AES, but with different technology packages in each. The intent of bio farming is to optimize agricultural outputs produced by the community while minimizing external inputs like chemical fertilizer (Simane *et al*., 2013).

Area closure /Farmer Managed Natural Regeneration: As the major problem in the sub-basin is land degradation, most lands, especially in Highland AES, are at the verge of losing their potential to render further service; so, it is better to manage & reclaim them and take some benefit out of it. By allowing severely degraded and eroded lands to rest and letting the natural vegetation to recover by itself with passive forest management practice, satisfactory soil conservation and forest product can be achieved at a rather slow rate but with almost no input. This procedure of closing off the highly degraded lands for conservation has been termed as area closure or hill closure (Chadhokar, 1992). Hill closure denoted as a protection system to improve degraded land with vegetation and/or soil through natural regeneration.

Introducing temperate fruits: Steep slopes characterize the Highland AES of the sub-basin. The high-altitude areas are convenient for temperate fruits production. Since low temperature experienced in some months (October-January) of the year satisfies their chilling requirement, seed production of cool-season vegetables achieved in such areas. In addition, due to population pressure and the consequent land shortage, farmers are cultivating steep slopes. The cultivation of such lands and planting to cereals degrades the land obviously due to severe soil erosion. In areas where steep slopes put under cultivation, it would be worth introducing fruit tree cultivation that could provide perennial vegetation cover to the soil. The introduction of fruit tree planting in this AES accompanied with intercropping technologies where farmers could produce other leguminous and/or cereal crops in the free space between the fruit trees.

Reduced sedimentation: The soil erosion problems happened because of the steepness of the slope, poor land use system and lack of SLM system that are creating damage to downstream reservoirs, wetlands, and waterways. It has also implications for flooding, decline water quality, declining wetland biodiversity, declining water table and water recharge. Therefore, by avoiding or reducing such problem we need to safeguard uses such as hydroelectric power generation and their implications on the wetland AES.

CONCLUSION

The agro-ecosystem analysis of Fincha sub-basin confirmed the considerable challenges posed on each AES. The compounding factors creating a challenge on the agro-ecosystems include environmental degradation, climate variability and change, population growth, deforestation and inappropriate land use practice are among some to mention. The widespread deforestation, cereal dominated production system that left the farmland without groundcover during heavy and erosive rainfall season (July and August) coupled with livestock free grazing makes the land of the sub-basin vulnerable to erosion and poses serious land degradation that could lead to significant productivity declines.

Furthermore, small sizes of land holding and fragmentation, insufficient supply of agricultural inputs (fertilizers, improved seeds, and pesticides), poor infrastructure to supply agricultural inputs to peasant holdings and to access agricultural products to the market and lacks of credit facilities are some of the constraining factors that adversely affect agricultural productivity in the sub-basin.

The challenges and opportunities found in each agro-ecosystem viewed from a system perspective as interlinked parts in creating specific adaptation strategy to increase the resilience of the system. AES is one method that provides the opportunity to delineate identical areas with similar challenges and opportunities of a landscape. Then the transformation of the agricultural system of each AES by fostering the sustainable intensification of the production has a paramount importance.

The agro-ecosystem analysis of Fincha sub-basin resulted in a classification of four AES. The potential adaptation strategy recommended for each agro-ecosystem in consultation with the local community and experts including but not limited to the following. Specifically, for Highland AES permaculture (biofarm system) that includes the temperate fruits; for Midland AES sustainable intensification by including relevant agronomic sustainable land management technologies; for wetland AES sustainable intensification by introducing rice-based production system including the wetland management system; and for Lowland AES extensive agriculture production system by including water retention techniques. Generally, greater integration of the most visible avenues by considering the specific potential to generate a sustainable solution to the development challenges required.

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