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SOIL & CROP SCIENCES | REVIEW ARTICLE

Enset farming system – a resilient, climate-robust production system in South and South-Western Ethiopia

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Abstract: With the ever-increasing global problem of food insecurity, climate-robust and resilient indigenous farming systems are getting increased attention. The enset [*Ensete ventricosum* (Welw.) Cheesman] farming system is one of the most sustainable indigenous farming systems in Ethiopia. The present study uses observations and literature to review the ecosystem services of enset, the resilience of the farming system to global change, and the implications of replacing it with cereals and cash crops. From a sustainability point of view, enset is a multipurpose crop; and delivers provisioning services (food, feed, fuel, fiber, mat, wrapping, fencing, traditional medicine), cultural services (identity, homegarden ornament, and greenery), regulation services (carbon and nutrient sequestration, soil protection and control of local microclimate) and supporting services (soil formation and water cycle). It is a staple food for over 20 million people in the south and southwestern part of Ethiopia. The crop is resistant to drought, flood and frost, and can be harvested and stored for food over long periods of time. Unlike annual crops, enset requires less tillage and few off-farm inputs. In enset-coffee homegarden, the enset shade improves soil moisture availability and moderates the effect of climate change on coffee. The broad leaves of enset intercept heavy rain, reduce soil erosion and facilitate groundwater recharge. However, in most parts of Ethiopia, enset is hardly known as a food source or considered as a hardship crop. Finally, we suggest disease prevention, improvement of processing technology and farm income helps to avert the current trend of transitions from enset farming system to cash crops.

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PUBLIC INTEREST STATEMENT

In line with the publisher's policy, I, the corresponding author, confirm that this paper has no potential conflict, and no direct funding was received for writing the paper. Further, both collaborators, Getachew Sime (PhD) and Paul Struik (Professor) have played a significant role in completing this paper for publication. More specifically, I, the corresponding author, was responsible for writing the original draft, and other authors played a supervisory role in writing, reviewing, and editing the paper.

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Keywords: Climate robust agriculture; ecosystem services; Ensete ventricosum; resilience; Ethiopia

1. Introduction

The links between agriculture and climate change have been well documented, and these links are bidirectional (Paustian et al., 1997). Agricultural activities emit greenhouse gases (GHGs) from cropping to harvesting. This is particularly true for modern agriculture, which is characterized by intensive use of agrochemicals and high levels of GHG emissions. Climate change also affects agriculture through degrading ecosystem services and results in other unintended consequences on agro-ecosystems (Gaba et al., 2015). Soil sequesters about 1500 Gt of carbon, which is equivalent to as much as three times the quantity of carbon stored in world's vegetation and twice the amount stored in the atmosphere (Bernoux et al., 2006). As such, farming systems have a potential to sequester GHGs, especially when these systems are characterized by little soil tillage and long lasting canopy cover. Climate smart agriculture (CSA) tries to create synergies and reduce trade-offs by increasing agricultural productivity and farm incomes, building resilient agricultural systems, creating food security, and reducing and/or removing greenhouse gases emissions (Faurès et al., 2013; Lipper et al., 2010).

Agriculture is the economic pillar and the single largest livelihood means of an overwhelming majority of Ethiopian people. It accounts for 43% of the GDP, 85% of all employments and 90% of the exports (FAO, 2011). Yet, the sector is subsistent, rain fed and highly sensitive to seasonal and interannual climate variability factors that consequently affect the food security of the country (Conway & Schipper, 2011; Deressa, 2007; Deressa & Hassan, 2009; Di Falco et al., 2012; Kassie et al., 2015; Senbeta, 2009). In the past, the agricultural sector has been hard hit by climate change calamities and as a result the country has become one of the net importers of agricultural products and lined among major food aid recipients in Africa. The vulnerability of the country to food insecurity may continue to exacerbate with increasing frequency and intensity of climate change variables, rising population, land fragmentation and degradation, and reduced adaptive capacity (Van Ittersum et al., 2016).

The population of Ethiopia is projected to increase to 188 million in 2050 (216% increase from 2010) compared to 237% increase for cereal crop demand during the same period (Van Ittersum et al., 2016). It was suggested that yield increase via land area increase is limited by availability of new land, competing claims for other uses and the trade-offs with greenhouse gas emissions and other unintended impacts of the food system on the environment (Giller et al., 2008; Gregory et al., 2002). Therefore, reducing the yield gap of crops via agroecological intensification that integrates ecological principles, social and cultural concepts into farming systems with the aims of increasing farm productivity, reducing dependency on external inputs, and sustaining/enhancing ecosystem services was presented as a viable options (Garbach et al., 2017; Struik & Kuyper, 2017).

In Ethiopia, four distinct agricultural systems were distinguished: the seed farming complex, the enset farming complex, shifting cultivation and the pastoral complex (Westphal et al., 1975). Among the agricultural systems the enset-farming complex has the largest crop diversity of which enset is considered as the key-stone species (Bizuayehu, 2008). According to the criteria set by Campbell et al. (2014) the enset farming complex of Ethiopia can be considered as one of the best successful climate smart indigenous agroecological intensification case studies. Yet enset farming system is under severe threat and the cultivated land is declining from time to time (Gebrehiwot, 2013). Therefore presenting the extensive ecosystems services of enset from ecological perspective, its resilience and recovery after climatic shocks, and exploring the main challenges of enset farm at the time of global change is crucial for maintaining the existing farmland

and for future potential expansion. Although there exists papers on multiple benefits (Borrell et al., 2020; Sahle Mesfin & Demissew, 2021), there is a continued need to structure the explicit ecosystem services of enset farming system in Southern Ethiopia and present the main challenges. In fact, Borrell et al. (2020) conducted an extensive review on enset covering wide aspects of enset, and several other studies are undergoing for diversity assessment and molecular characterization (Birmeta, 2018; Yemataw, 2018). The present review sought to present enset farming system as a resilient, indigenous, sustainable farming system, and discusses the extent to which it contributes to the objectives of CSA, including (i) increased productivity (provisioning services); (ii) improved resilience and adaptive capacity; and (iii) other ecosystem services including regulation services (decreasing greenhouse gas emissions and increasing carbon sinks; FAO, 2011). Multiple sources of evidence were used including literature review, personal observations and research experience in Southern Ethiopia. The literatures used are mainly collected from online sources using Google Scholar http://scholar.google.com [from November 2020 to May 2022]. The focus was on ecosystem services and challenges of the farming system, and the key words used for selection are "enset", "ecosystem services", "challenges and opportunities". The review paper is structured into five parts. The first part presents enset crop as an endemically cultivated plant in Ethiopia. The second part discusses the ecosystem services of enset farming. The third part presents the resilience of enset farming system to climate change. The fourth part looks at challenges and food security implications of replacing enset farming systems with systems based on cash and cereal crops. Finally, future study directions and policy implementations was presented.

2. Enset: an endemically cultivated plant

Enset [*Ensete ventricosum* (Welw.) Cheesman] is a perennial banana-tree-like herbaceous plant belonging to the family *Musaceae* and has leaves, a pseudostem, a large underground corm, roots and suckers. The detailed description of the plant can be found in Brandt et al. (1997). Enset has fruits similar to banana but the fruits are not edible and hence it is called the false banana. However, for best quality and quantity of its food products, the crop must be harvested before the flowering stalk is produced. The germination rate of enset seed from domesticated landraces is poor, and, therefore, farmers manage propagating enset vegetatively by using suckers. Enset grows at an altitude between 1600 and 3000 m above sea level. Wild enset is widely distributed in Central, Southern and Eastern Africa but it is domesticated and endemically cultivated as an important staple food crop in the southern and south western parts of Ethiopia (Brandt et al., 1997; Shack, 1963; Spring et al., 1997). Enset has a high radiation use efficiency, prolonged canopy cover, stable dry matter allocation, high storage capacity for starch, high harvest index, easy vegetative propagation, drought resistance and soil fertility improvement through nutrient cycling and reduced erosion soil (Struik, 2018).

The southern and south western part of Ethiopia, where enset is the main staple food crop for a population of 20 million people, is one of the centres of diversity and origin for enset (Borrell et al., 2020). Enset represents about 65% of the total crop production in the southern region of Ethiopia (Assefa & Fitamo, 2016), and plays an important role in household food security. Hundreds of clonal varieties were identified in the region and many are yet to be identified. For instance, the Sidama botany recognizes 103 enset varieties of which 79 are actually grown (Bizuayehu, 2008), and varieties identified in other areas were summarized by Borrell et al. (2020) and Yemataw et al. (2018). The south-western Ethiopia was called the enset culture complex area, due to the existence of various culture traits associated with enset (Shack, 1963). The dominantly representative enset growing tribes in Ethiopia are the Gurage, Gedeo, Hadya, Kambata and Tambaro, Sidama, Wolayta, Darassa, Alaba, Konso, Gamo and Gofa (Doda, 2006; Struik, 2018). The Oromo people bordering the Sidama and Southern Nations and Nationalities also use several enset varieties as food and feed. For instance, in the Kofele district of Oromia region, where pastoralism has been the dominant form of livelihood, the role of enset increases with increasing altitude.

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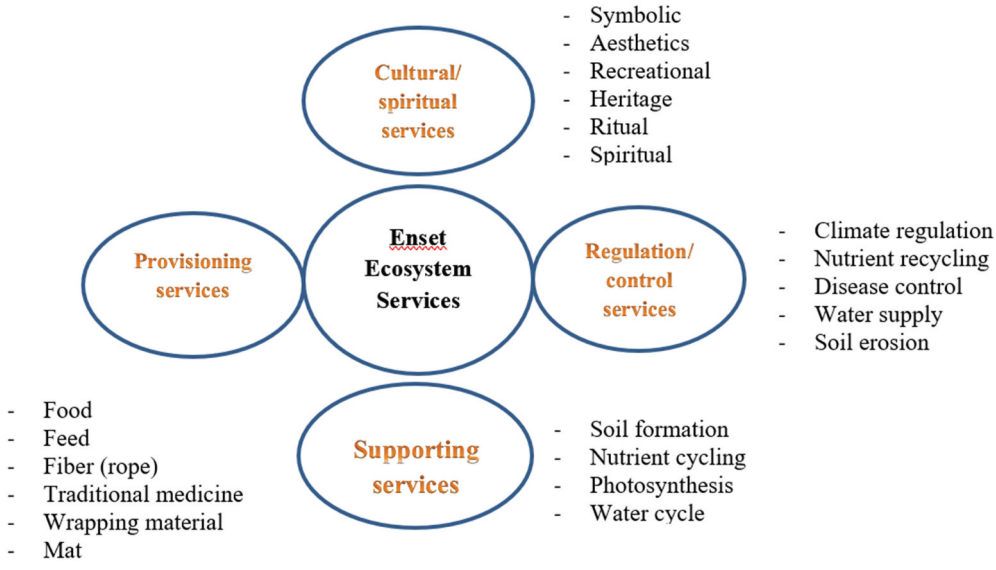

Figure 1. Ecosystem services of enset (*Ensete ventricosum*).

3. Ecosystem services of enset

Ecosystem services are defined as the desired benefits and life supporting services provided by ecosystem to human well-being. Agricultural ecosystems are modified by humans to enhance the production of specific services of food, fiber, and fuel (Bennett et al., 2009; Zhang et al., 2007). Enset farming system provides multiple interdependent web of ecosystem services (Figure 1). In the context of this study, the four ecosystem services of enset farming system (provisioning, regulating, supporting, and cultural ecosystem service) were discussed based upon literature research.

3.1. Provisioning services

In the face of global crisis such as climate change the priority of the agricultural sector in developing countries like Ethiopia should focus on improving provisional services and adaptive capacity (Campbell et al., 2014). Enset is a multipurpose crop and provides provisioning services such as starchy food products, animal feed, fiber, wrapping material, and traditional medicine. Enset support high population density compared to other crops and cropping systems in the same agroecology and with the same input (Shack, 1963; Spring et al., 1997). It has high yield per unit land and sustainable intensification with low off-farm input is possible. Yet, the productivity of enset per pseudostem or per hectare of land depends on the agro-ecology, landrace, and age of the plant.

3.2. Enset as food

Three starch-rich food products are produced from the enset: *kocho, bulla,* and *amicho. Kocho* is the bulk of the fermentation product of scraped pulp of pseudostem and pulverized corm (underground stem base). *Kocho* fermentation is carried out through two phases: first phase with 15 days of surface fermentation, and followed by second phase of at least 15 days of pit fermentation (Karssa et al., 2014). The underground pit is usually prepared in the enset homegarden and the pit is lined with enset leaves. During fermentation some landraces are selected to be used as starter to speed up the fermentation process. The fermented *kocho* can be consumed after a month of fermentation and can stay in pit storage for several years. The *kocho* fermentation time varies depending on ambient temperatures of incubation. To fill food shortage gaps two enset fermentation pits are commonly prepared per household, one is consumed while the other is in the process of fermentation. From the enset products *kocho* has the largest share and the yield of *kocho* per hectare or per pseudostem depends on agro-ecology and landrace.

Bulla is the by-product of *kocho* and results from squeezed scrapings and pulp. It has high-quality starch and can also be sold at high market price. *Bulla* has also other applications such as alternative starch in pharmaceutical, paper and textile industries (Yematow et al., 2018). *Amicho* is the fleshy inner portion of the corm, which is boiled and consumed. The enset plant can be harvested for food at any time of the year starting from as early as two years up to the early flowering stage, and few pseudostems can feed a household for months.

3.3. Enset as feed

Livestock mortality associated with feed scarcity is a common phenomenon during the drought season in Ethiopia (Desta & Oba, 2004). Drought events are challenging for farmers in all agroecology and causes forage deficit and increase vulnerability to livestock disease (Senbeta, 2009). During droughts livestock physical deterioration due to heat stress and long distance travel for water and pastures is a common phenomenon. The vulnerability of livestock was exacerbated by restricted mobility of pastoralists, hiking feed price, low livestock price, drying water sources, and depletion of grasses and crop residues. Market imbalance *aggravates the problem of pastoralists by shifting the terms of trade in favour of their purchases rather than their sales* (Futterknecht 1997 as cited in Ahmed et al. (2002). The price of feed: *fagulo* (oil by-product), *atela* (residue of local drink) and *geleba* (crop residue) increased by more than four-fold during past drought periods as compared to normal time. The household study in West-Arsi zone by Senbeta (2009) indicated that 31% livestock per household died during the 2006/07 drought season.

Figure 2. Dairy cow feeding on enset leaves.

However, the presence of enset at homegarden improved the adaptive capacity of households to climatic shocks. Enset remains green throughout the year and serves as a suitable feed when other feeds are scarce. The use of enset as livestock feed during the dry and a wet season is a common practice in enset producing areas (Figure 2). Desta and Oba (2004) showed that about 85% of the farmers in the Bale highlands of Ethiopia provide enset leaves, corm, pseudostem, fluid and processed by-products to livestock during the dry season. Similarly the Kofale highland people of Oromiya region use enset as a feed and the superiority of the plant in withstanding climate change events was observed (Senbeta, 2009). The inter-linkages and complementarities between livestock and enset production are strong. The livestock provides easily available animal manure which farmers consider very essential for enset cultivation and the enset, in turn, provides feed for animals. Moreover, the presence of legume trees in enset agroforestry system such as acacia leaves also serves as best feed for small ruminants to increase milk yield, body weight, and increase farm income.

3.4. Non-food provisioning services

Enset provides many other non-food products. Enset provides fiber, packaging material, bedding mat and medicine. The fiber is extracted from the pseudostem as a by-product of *kocho* production. The fiber is largely used to produce sacks, ropes, sieves and mats. The dried leaf is also used to make traditional fencing and for thatching houses. The leaf and leaf sheaths are used as packaging and wrapping material. Enset leaves are used for lining of *kocho* fermentation pits, wrapping bread during baking, making mattresses, and cushions, serves as sitting/bedding mat, wrapping *kocho, khat*, butter, and honey, and serves as fuel when dry. Enset has also medicinal value. Boiled corm (*amicho*) cures fractured or broken bones, facilitates placental discharge in humans and animals, cures diarrhoea or venereal diseases (Bizuayehu, 2008). *Mocha* (squeezed watery product of *kocho*) is used to treat a person intoxicated with poisonous mushrooms (Senbeta & Ayele, 2020). Enset also serves as an indication of prestige and is included in household wealth classification criteria in Kofale highlands (KofaleARDO, 2009).

3.5. Regulation services

Enset farming system plays a role in the regulation of climate, water supply and nutrient recycling. In the enset-coffee home garden agroforestry enset and coffee are considered as key-stone species, where enset serves as important food and feed source, and the latter is an important cash income source (Abebe, 2005). It was reported that climate change affects the quality and quantity of coffee by affecting crop physiology, land suitability and emergence of disease (Laderach et al., 2011). The presence of enset creates a good micro-climate for sun-sensitive plants such as coffee. Enset and trees acts as a coffee shade and modifies the agro-ecology of coffee by reducing air temperature, improving bean size, reducing overproduction and dieback, reducing coffee leaf rust, improving cup quality, and conserving soil moisture (Alemu & Dufera, 2017). Moderately shaded *Coffee arabica* has photosynthetic rates three times higher than coffee leaves under full sunlight (Davis et al., 2012).

As a perennial crop enset fields generally do not require tilling and off-farm input, and it is usually cultivated by vegetatively and by using manures derived from livestock (easily available and affordable fertilizer). Therefore, it is a sink and decomposition site for livestock manure, and sequesters GHGs. The CSA interventions on soil carbon stock in the southern Ethiopia after 14 years has shown that the agroforestry system with an enset plantation had the highest mean soil carbon stock compared to crop land, conventional forest and grassland (Tadesse et al., 2018). The enset and coffee field are most sustainable and less degradable in terms of soil organic carbon and CO_2 emitted into the atmosphere (Laekemariam, 2020). The large enset leaf surfaces and the presence of trees and other crops in the system further prevents the risk of soil erosion through below ground root system. The study by Woldesenbet et al. (2020) in Meki watershed showed that enset based land use system reduces significant amount of soil loss and contribute in sustaining water bodies from sedimentation problem. Mulching soil with enset leaves in enset farm also prevents soil erosion and enhance nutrient cycling (Figure 3).

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Figure 3. Heavy mulching with enset leaves to prevent soil erosion and enhance nutrient cycling.

3.6. Supporting services

Enset plays role in supporting ecosystem services. The supporting services of enset are soil formation, nutrient cycling, photosynthesis and water cycle (Woldesenbet et al., 2020). Enset farming system has the highest biodiversity and terrestrial carbon pool as compared to other farming systems (Tadesse et al., 2018). Enset can be intercropped with trees, coffee, cereals, pulses, root crops, fruits, and vegetables (Abebe, 2005).

3.7. Cultural services

Enset has social and cultural services among ethnic groups (Egziabher et al., 2020). The cultural services of enset in the southern and southwestern Ethiopia include symbolic, aesthetics, and spiritual values. It is the identity of people and indicator of the wealth status of households. The role of enset among ethnic groups is also expressed in folklores and sayings (Doda, 2006; Egziabher et al., 2020). It is a house yard ornament and make individual home plot look to like a *botanical garden* (Rahmato, 1995) (Figure 4a).

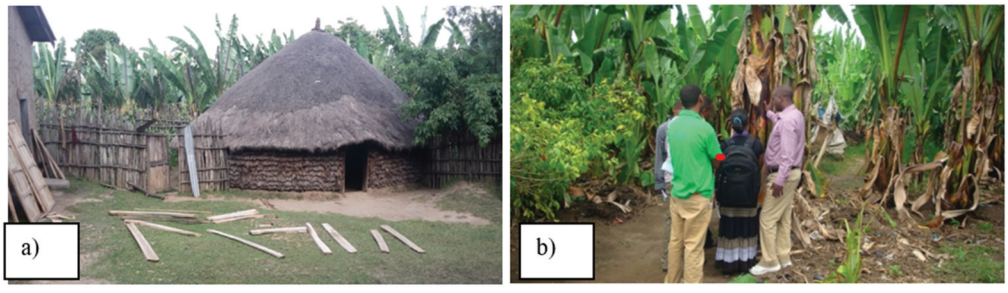

Figure 4. Enset home-garden agroforestry system in Sidama region. (a) typical enset home-garden surrounding the back-yard of living place; (b) Hawassa Zuria woreda development agent explaining importance of enset to Hawassa University students visiting homegarden agroforestry: as food, shade for coffee, erosion prevention, requiring less tillage, and livestock manure.

4. Resilience of enset to climate change

Resilience is an ecological term and is defined as the ability of a system to absorb disturbance without shifting to an alternative state and without losing important functions and services (Côté & Darling, 2010). The term also refers to the speed and degree to return to the system's original state after perturbation. Resilience is widely used in global change management such as climate change. The term again has come to the forefront as a useful organizing principle in the light of COVID-19 pandemic crisis to study food system transformations (Gillespie, 2020). In 2020, East Africa is hit by drought, flooding, locust swarm and COVID-19 pandemic. In light of multiple crises facing the region the resilience of local farming system, in terms of resistance to a shock and recovery after disturbance, needs to be explored.

4.1. Enset farm resistance to disturbance

The resistance of enset to climate change has been witnessed since long time. Enset's resistance and adaptability to environmental change has earned it the name "The Tree Against Hunger" by Portuguese priests who explored northern Ethiopia in the 1600s (Spring et al., 1997). The name suggested that "anyone who has this food never suffers." The Wolayta people of Ethiopia grow enset as precaution against famine during drought (Rahmato, 1992). The Wolaytic name for enset is *utta* or *utea* which means "self-rescue" or "security against disaster" (Rahmato, 1992). Similarly in many areas of Oromiya region enset is called *worqe*, an Amharic word that literally translates to "my gold," to indicate the preciousness of the plant in resisting climatic change.

Enset has high drought, flood, and frost withstanding capacity, and can be harvested for food over long periods of time and the fermented product can be stored for several years. The farmers mix enset age groups and clonal varieties to ensure continued food supply through time, enhance yield and quality of food, maintain garden structure and achieve permanent production, safeguard against pests and disease (Bizuayehu, 2008). To improve drought resistance farmers' use methods such as mulching, bending enset leaves during rainy season to increase water holding capacity, cutting older leaves and covering the exposed root of the plant using soil. In terms of food and nutritional security, the presence of other component plants (cereals, fruits, root crops, and trees) as intercrop in the enset farming system increases farm diversity, nutritional diversity and serves as insurance during shortage of food and income.

4.2. Enset farm recovery after climatic shock

Farmer recovery from climatic disturbances is always a challenge in cereal production systems. After disturbance, like in other natural ecosystems, farmers face another new stable state with less adaptive capacity and higher vulnerability. This is because aftermath of climatic disturbances cereal farmers face shortage of food and farm inputs such as fertilizer and new varieties). Drought agents (oxen) also die by drought events or get very much weaker (Senbeta & Olsson, 2009). The situation is aggravated by the absence of social institutions providing credit systems and other supports. Therefore the option available for poor farmers is renting their land to rich farmers with low price and for long years, which makes the recovery very difficult. In enset farming systems, recovery is easy and rapid. The plant is easy for vegetative propagation and requires easily available farm inputs. The farmers get the propagules for free, exchange with other enset clonal varieties or for a cheap price.

5. Implication of replacing enset farming with growing cash and cereal crops

Enset production has been decreasing alarmingly in terms of area coverage, production and clones diversity grown (Gebrehiwot, 2013; Tenaye & Geta, 2008; Tsegaye & Struik, 2002). Trends in enset plant cultivation as a food source has been changing so that in some formerly enset-dominated areas cereal crops are dominating (Doda, 2006). **Figure 5** indicates typical farm in one of the kebeles in Sidama region where transitions to *khat* system is occuring at rapid rate. Farmers in enset cultivation zones are not considering enset as a more important crop than other cash crops such as *khat*, sugarcane, eucalyptus trees or cereals, and the latter are becoming a major source of livelihood for farmers (Gebrehiwot, 2013; Gebrehiwot et al., 2018). The transition from agroforestry

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Figure 5. *Khat* cultivation in homegarden in Yuwo kebele of Wondogenet woreda, Sidama region.

homegardens towards *khat* monoculture is due to higher financial income generated in short time, improved market network for cash crop transportation and distribution, year round access to irrigation for multiple cropping, farmland fragmentation, and intensive labour for enset processing. Enset takes a longer period to generate income and it has low price and hence has the lowest sale rate compared with other crops (Borrell et al., 2020). Whereas cash crops such as *khat* can be harvested twice a year and generate up to four-fold income per harvest (Gebrehiwot, 2013). The government is also encouraging *khat* honouring and encouraging *khat* traders for the sake of foreign currency earning (Dessie et al., 2013). The shift to such cash monocrop has caused socio-economic changes, household food and nutrition insecurity, declining biodiversity and high agro-chemical and water requirement (Gebrehiwot, 2013).

The current replacement of enset by other crops has short and long term social, environmental and food security implications. *Khat* is a banned drug in many countries containing cathinone and cathine, and *khat* addiction has socioeconomic and health effects (tooth loss, gastric disorders, heart disease, blood pressure, male impotence, sleeplessness, and several mental health problems; Akalu et al., 2020; Balint et al., 2009). The recent COVID-19 pandemic crisis is one of the relevant events one can learn from. It has affected the lives and livelihood of the poor, and it became a major challenge to developing countries in general and to smallholder farmers in particular. The lockdown, physical distancing, and restrictions on transport and movement to counter the effect of diseases affected all activities from cropping to marketing of agricultural products. The local and international restriction on transport has led to value chain breakdown of agricultural commodities and damaged perishable products such as *khat*. An article published by BBC on 14 May 2020 had the title "Somalia's coronavirus *khat* bans leaves chewers in a stew." The news highlight the glimpse how the banning of international flight affected the livelihood of *khat* farmers and traders in Kenya and Ethiopia.

The food security implication of replacing enset by other introduced grains in central and northern Ethiopia is another lesson for government, researchers, farmers and extension workers. Farmers in central and northern Ethiopia abandoned enset during the eighteenth and nineteenth century under the influence of colonial preferences for bread and other foods made from grains, put greater economic value on growing drought-sensitive grain crops imported from Europe (Brandt et al., 1997; Spring et al., 1997). According to Brandt et al. (1997), the replacement of enset by other crops may be one of the reasons why the 1980s famines resulted in devastating effects, killing millions of people. The suggestion of Brandt et al. (1997) can also be supported by Rahmato (1992) who indicated that enset areas suffered only one major famine in 1984/85 in a century in contrast to Wollo and Tigray, part of the *tef* (*Eragrostis tef*) culture of the north, which suffered more than five major famines in the same period. He attributed the triggering factor for the 1984/1985 famine in the enset zone not to the effect of drought *per se* but to the effect of bacterial wilt disease that destroyed enset.

The trend of land use change from enset-complex homegarden to cash crop and cereals will also contribute to the impact of climate changes and soil fertility decline through reduced soil organic carbon, increased emission and soil erosion. Enset is called a "women crop" since the processing and income gained from selling the products is controlled by women. The replacement of enset by cash crops also snatches women right over the control and decision making on the farm (Gebrehiwot et al., 2018; MacEntee et al., 2013).

6. Future directions

The Ethiopian government drafted policies and strategies on adoption of agricultural systems with high productivity, reduced reliance on external inputs, and increased soil carbon sequestration and reduce emissions (CRGE, 2011; Tanner et al., 1994). However, the government of Ethiopia seems practically ignored the existing traditional farming practices and gave more emphasis to modern agriculture and high yielding varieties with the aim of producing enough food for ever increasing population. Consequently, the synthetic fertilizer use per hectare is expected to grow from 65 kg/ha in 2010 to 247 kg/ha in 2030, constituting the largest source of soil-based emissions in 2030, increasing from 4.3 Mt CO_2e in 2010 to 35 Mt CO_2e in 2030 (CRGE, 2011). To sustain the existing enset farming system, we suggest more emphasis to be given to enset farm income improvement, attention for enset disease prevention, and processing technology improvement.

6.1. Improving enset farming income

Enset farming system is a novel CSA approach in Ethiopia and its further intensification is possible if the concerned bodies give attention to the farming system. Improving farmer income and adaptive capacity is a key component of CSA (Lipper, 2010). Enset farmer capacity can be developed through diversifying income and services from enset farming, developing and disseminating improved processing technologies, controlling enset diseases and pests, arranging credit systems, agricultural insurance in cases of crop failure, and provision of credit service.

The price of enset is discouraging and one of the lowest, and it is one of the major reasons for replacing enset with other cash crops. Therefore, it is essential to improve and diversify enset farmers' income from enset farming products and services. For instance, enset fiber elongation and thermal stability is comparable with many other natural fibers (Blomme et al., 2018) and has the potential to be used for a range of novel applications beyond traditional uses (Borrell et al., 2020). Enset farming also contributes toward increasing soil carbon sequestration and it is a possibility to consider enset-coffee complex homegardens in a carbon trading scheme.

6.2. Attention for enset diseases

Enset can be attacked by diseases and pests. The most serious diseases are bacterial wilt disease (*Xanthomonas campestris)* and enset root mealy bug (*Cataenococcus ensete*; Spring et al., 1997; Tariku et al., 2015; Welde-Michael, 2000; Yemataw et al., 2018; Yirgou & Bradbury, 1968). Bacterial wilt kills enset and the only available options till today to reduce bacterial wilt disease is removing the infected plant from the farm (Egziabher et al., 2020). Enset landraces showed varied tolerance to the disease and farmers reduce yield loss from disease and pests by growing different varieties of enset in their homegarden (Yemataw et al., 2018, 2014). Bizuayehu (2008), for instance, found a mean of 8.2 enset varieties per household in Sidama home gardens. Farmers also intercrop other plants/trees to avoid total loss due to environmental change and as additional insurance during blink seasons. So far, extension workers support for farmers is on cereal crops and watershed management, and attention was not given with regards to enset diseases control. Enset disease and lack of attention from researchers, extension and government was mentioned as one factor for the decrease of enset production (Gebrehiwot, 2013; Rahmato, 1995).

6.3. Improving processing technology

Enset is also called a "woman's crop" because women undertake all activities during harvest and post-harvest management including the processing, cooking and selling of the products (MacEntee et al., 2013). Enset processing is laborious, tiresome, and time consuming. Several attempts were

carried out to improve the processing technology. For instance, Jimma University developed metal and wooden tools for enset processing (to scrap and squeeze enset parts) but the distribution of the technology was constrained by lack of funding (MacEntee et al., 2013).

6.4. Removing social and physical barriers

Enset is one of the neglected and underutilized or unknown crop in many parts of Ethiopia and abroad (Borrell et al., 2020). In most parts of the country, enset is a co-staple crop, hardship food, considered as food of the poor, or its use as food in many places is totally unknown. Coupled by acculturation and urbanization the current trend of enset replacement by other crops may result in disappearance of the crop from its current narrow zone of cultivation as it happened in the northern parts of the country. The social and cultural and biophysical factors that hindered the use of enset need to be investigated and addressed. Enset products such as "*Sidama bursame and chukame*" and *kocho* with "*Gurage kitfo*" are widely served in traditional Sidama and Gurage ethnic group restaurants respectively. Those foods can be used to promote enset plant and its products in other parts of the country.

7. Conclusions

The present review presented enset as a climate smart crop in terms of ecosystem services, resilience to global change and challenges of converting enset farming system with other crops. With respect to the objectives of CSA the enset based farming system in Ethiopia addresses the "lose–lose" outcome of food production and climate change simultaneously and holistically, and therefore can be considered as one of the most sustainable climate robust indigenous farming systems. Enset provides several ecosystem services and has important local CSA traits that render it excellent climate smart crop to adapt to climate change. However, the conservative eating behaviour, acculturation, urbanization, intensive labour requirement, and low farm income from enset is contributing towards rapid conversion of enset farming system to other cash and cereal crops. Therefore, we suggest more studies and policy makers attention toward maintaining the existing enset farming system in the country.

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