REVIEW ARTICLE

Trade-offs and synergies between agricultural production and biodiversity conservation in socio-ecological landscapes of South-western Ethiopia: A Review

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ABSTRACT

Food security and biodiversity conservation are among the core issues of the UN sustainable development goals, and also of the development agenda of the African Union. Achieving these important goals also constitutes the top critical challenge of the 21st century. As an effort towards achieving these goals, the discourse about the need to transform the widely recognized trade-offs between agricultural production and biodiversity conservation into overlaps or synergies is also receiving top attention from different actors at various levels in recent times. This paper is, therefore intended to make a literature review of empirical studies on the nexus between agricultural development expansion and biodiversity conservation; and thereby identify the trade-offs and synergies between them, with special emphasis on socio-ecological landscapes of coffee production systems in South-western Ethiopia. The review focused on the synthesis of the competitions and overlaps between provisioning and regulating ecosystem services represented by agricultural production and biodiversity conservation respectively. The review made indicated that there are different types and levels of trade-offs between provisioning and regulating ecosystem services that vary according to the multiple factors operating in the multi-functional socio-ecological landscapes. Creating synergies and harmony between these trade-offs, therefore, requires a sound landscape governance system designed based on multi-criteria analysis. These criteria include socio-economic and demographic aspects; ecological aspects; as well as effective policy systems and institutional set-ups. Management interventions, such as natural or organic coffee certification; and promotion of climate-smart agriculture (such as agroforestry systems) can be used for reconciliation of the competing interests in the ecosystem services.

Keywords: food security, green development, multi-criteria analysis, sustainability goals

INTRODUCTION

Among the global sustainability goals, achieving food security and biodiversity conservation goals represent the top critical challenges of the 21st century (Jan *et al*., 2017). Despite some improvements in global food production, many people (about 800 million people) are undernourished (FAO, 2015). On the other hand, efforts made to ensure food security through the conventional approaches of agricultural expansion and intensification are identified to be the major drivers of biodiversity losses. As a result, the challenges of achieving food security and conserving biodiversity usually do not complement each other as they lack synergy; they rather compete with each other due to the trade-offs involved, with pronounced magnitude in the context of developing countries like Ethiopia. The trade-off is a situation where the use of one ecosystem service directly decreases the supply of, or benefits derived from, other services; while synergy is the case where the use of one ecosystem service directly increases the supply or benefits of another (Turkelboom *et al*., 2016).

The majority of African people (about 70%), and nearly 75% of the continent's poor people live in rural areas (Shilomboleni, 2017). Although agricultural activities are the major economic activities for these poor rural people, they are unable to satisfy their basic food requirements.

Agriculture is identified as a major contributor to land transformation and hence, in most cases, it is identified as a threat to biodiversity conservation and other ecosystem services (EESs), which are vital to human well-being and from which agriculture itself benefits (Schmitz *et al*., 2014). Deforestation, on the other hand, is a major threat to biodiversity and many ecosystem services, and it is closely linked to agricultural expansion. It is evident that the major underlying cause for deforestation, especially in the context of developing countries like Ethiopia, is the rapid and continuous human population growth. With a total population of more than a hundred million, Ethiopia is the second-largest populous country in Africa and the 14th-largest in the world. If current trends hold with the annual population growth rate of 2.6%, it will become the world's 10th most populous country by 2050, with a population reaching 167 million (Olson and Piller, 2013).

On the other hand, since the 1990s, the Ethiopian government has developed a long-term economic development strategy called Agricultural Development Led Industrialization (ADLI), which is the government's overarching policy response to the country's food security and agricultural productivity challenges. The strategy focuses primarily on the expansion of large-scale commercial farms and improving productivity in smallholdings (Degife and Mauser, 2017). However, pieces of evidence from different parts of the country indicate that the expansion of large-scale commercial farms has not been well aligned with the local socio-economic development and biodiversity conservation needs (Degife and Mauser, 2017).

The majority of smallholder-dominated landscapes of south-western Ethiopia are home to a unique remnant of biodiversity having national and global conservation values (Schmitt, 2006; Mittermeier *et al*., 2011; Aerts *et al*., 2015). Despite the importance of the biodiversity of these landscapes for local livelihoods and the country's economy (Petit, 2007; Moat *et al*., 2017), they are under severe pressure due to increasing human land use. These uses mainly involve the conversion of forests to farmlands, forest degradation, and a shift in smallholder farmland management practices towards more intensive agriculture (Hundera et al., 2013; Kassa *et al*., 2017). According to the country's second Growth and Transformation Plan (GTP II: 2015/16-2019/20), it has been well recognized that following the conventional development paths, including the competing land uses between biodiversity conservation and agricultural production would result in many adverse effects. Some of these major effects include a sharp increase in greenhouse gas (GHG) emissions and unsustainable use of natural resources (Planning commission of Ethiopia, 2016). The Ethiopian government has, therefore, developed a Climate Resilient Green Economic (CRGE) development strategy to avoid such negative effects. Implementing the strategy would offer important co-benefits, which include improving public health through better air and water quality, and promoting rural economic development by increasing soil fertility and food security. For realizing these benefits, the strategy recognizes the need of maintaining healthier and well-functioning natural ecosystems.

According to the country's CRGE development strategy, agriculture and forestry are among the important pillars identified and planned to support the implementation of the strategy. In connection with the agricultural development sector, improving crop and livestock production practices for ensuring food security and enhancing farmers' income while reducing GHG emissions are being emphasized (Planning commission of Ethiopia, 2016). On the other hand, the forestry sector is targeting protecting and re-establishing forests for their contribution to economic development, biodiversity conservation, and ecosystem services, including carbon stocks. This means that the CRGE development strategy of the country requires that the trade-offs between agricultural development expansion and biodiversity conservation activities should be transformed into synergies so that they would complement each other than competing one another. This review paper, therefore, aims at making a critical review of research findings of previous studies on the nexus between agricultural development expansion and biodiversity conservation; and thereby identify the trade-offs and synergies between them, with special emphasis on the socio-ecological landscapes of coffee production systems in South-western Ethiopia. The review involves an in-depth analysis of the levels of competition and overlaps among various ecosystem services (such as provisioning and regulating services) under different coffee-based production systems.

METHODOLOGICAL APPROACH

A review of various published literature of empirical studies on the nexus between provisioning ecosystem services (mainly represented by coffee production) and regulating services (represented by various ecosystem services resulting from biodiversity conservation) was made. The review mainly focused on identifying different kinds of trade-offs and options for creating synergies between agricultural production and various kinds of regulating ecosystem services. Special emphasis was given to the review of empirical evidence in the specific context of socio-ecological landscapes in south-western Ethiopia with different coffee production systems (forest coffee, shade-grown coffee, and more intensified sun-coffee) (Hundera et al., 2013; Kassa *et al*., 2017). These coffee production systems were purposively considered as coffee represents the major product in these ecosystems, and it is also an important agricultural commodity both for the national economic development and also for smallholder farmers' socio-economic well-being. Coffee is also the country's most important export commodity. According to the Global Agricultural Information Network GAIN (2020), coffee accounted for about 29% of the value of all exports in 2018/19. From an ecological perspective, the different coffee production systems represent different levels of trade-offs among various ecosystem services depending on the management regimes of these socio-ecological landscapes (Elmqvist *et al*., 2011). The review, therefore, focuses on the comparison of the trade-offs among these production systems with the ultimate purpose of suggesting possibilities of creating overlaps and synergies between economic interests and ecological sustainability.

Nexus between Agricultural production and Biodiversity conservation

Globally, and in Sub-Saharan African (SSA) countries in particular, agricultural expansion has been identified as the most significant direct driver, or immediate cause of ecosystem degradation and biodiversity loss (Sandra Díaz, 2019). In SSA, the area of land covered by natural forests, or by woodlands classified as forests declined by nearly 10% between 2000 and 2010 (Franks *et al*., 2017). Three-quarters of this decline was caused by forest conversion for agriculture, which was mainly to serve the rapidly growing domestic food demand.

Agriculture, on the other hand, has been the primary source of livelihood for millions of smallholder farmers since the early development of civilization until now. It is a key economic sector to overcome household livelihood challenges, especially for the poor and also it is a backbone to the growth of many developing, agriculture-based national economies (FAO, 2012). Despite the adverse impacts of human modifications of agricultural land uses on biodiversity, traditionally managed agricultural lands, especially those by smallholder farmers can harbor rich biodiversity with high intrinsic and instrumental conservation values (Scherr and McNeely, 2012). Agricultural land use is, therefore, a critical interface to ensure both food security and the conservation of valuable biodiversity, the success of which depends on how these land uses are managed.

It has been widely reported that major ecosystem degradations and simultaneous failures in multiple ecosystem services are highly connected to each other (Carpenter et al. 2006). For example, many parts of the dry lands of sub-Saharan Africa demonstrate many instances where these multiple failures of ecosystem services have resulted in many consequences: crop failures, declining quality and quantity of fresh water, and loss of vegetation cover. On the contrary, a synthesis of many cases (roughly, over 200 cases) of investments in organic agriculture indicated that the application of various modern agricultural interventions could result in substantially reducing trade-offs among ecosystem services in several developing countries throughout the world (both dry lands and non-dry lands), even under situations of increased crop yields (Pretty et al., 2006, cited in Elmqvist *et al*., 2011). This implies that, through the appropriate combination of knowledge, and incentive systems coupled with the right institutional setups, multiple failures can be avoided and synergies can be created between agricultural production and biodiversity conservation. As a result of the synergies created, other regulating ecosystem services such as climate regulation, water regulation, biological control, pollination, and maintenance of soil quality can be improved.

Figure 1 illustrates a range of possible trade-offs between provisioning and regulating ecosystem services (Elmqvist *et al*., 2011). There are different trends (rates of decline) of regulating services (represented by type A, B, and C responses) for the same level of provisioning service (Fig. 1). For type 'A' response, there is a steep decline in regulating services; while there is a linear relationship in type 'B' response; and in type 'C', before there is a decline in regulating services, levels of provisioning services may increase to very high levels. Therefore, depending on the type of ecosystem management responses, the supply of regulating ecosystem services can be low, intermediate, or high for a similar level of provisioning services.

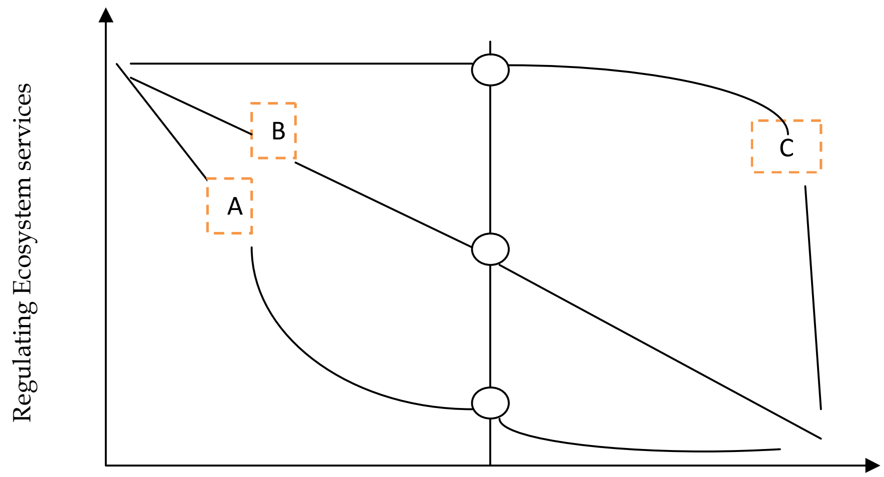

Figure 1. Possible trade-offs between production/provisioning services (e.g. food, timber) and protection/regulating services (e.g. soil quality maintenance, pollination, biological control, and water regulation, etc.; which are described below) (Elmqvist *et al*., 2011).

According to a quantitative review of relationships between ecosystem services by Heera and Sven (2016), a dominant synergistic relationship was reported among different regulating services; while the relationship between regulating and provisioning services was trade-off dominated.

Minimizing the undesired trade-offs and enhancing synergies among ecosystem services requires a clear understanding of the relationship between the ecosystem service (Heera and Sven, 2016). The major task for the researchers in the contemporary disciplines of forestry and agriculture is, therefore, to design and undertake empirical research works, which can generate evidence on how the existing management system has strong negative effects on regulating services - type 'A' response, can be transformed into type 'B' or even type 'C'. Further explanations of these types of responses in connection with coffee production systems in south-western Ethiopia are given in the next section following descriptions of the major ecosystem services.

Major Regulating Ecosystem Services considered in the trade-offs

According to the classification by, 'The Economics of Ecosystems and Biodiversity, TEEB (2009, cited in Elmqvist *et al*., 2011)', the major regulating ecosystem services include climate regulation, water regulation, biological control, pollination, maintenance of soil quality and erosion prevention and hazard control. These services might show different thresholds in response to different kinds of external disturbances (e.g. land cover change); and ecosystems do have different capacities in providing the services, which are determined by the complex processes and interactions taking place within the ecosystems. A summary of the review of the current knowledge of the dynamics of these regulating services is shown below (mainly based on TEEB 2009):

Climate regulation: The roles of different ecosystems in climate regulation vary considerably. For example, forest ecosystems are known to store the highest amount of carbon stored in the biomass of the plants as compared to the amount stored in the soil. As a result, deforestation can substantially affect the climate regulation role of the forest ecosystem. On the other hand, agricultural ecosystems are currently characterized by low soil carbon stores due to the intensive production methods being applied. However, there is scope for enhancing those stores, which is determined depending on the agricultural practices being used. The climate regulation service provided by the terrestrial ecosystems, which occurs through a variety of mechanisms, is the real and the most substantial service of ecosystems (Maibritt, 2017).

Water quality regulation: Water regulation roles of ecosystems also vary with their types and qualities. Accordingly, a very good vegetation cover is a key factor that can enhance water quantity and quality (TEEB, 2009). For regulating water flow and improving water quality, wetlands and forest ecosystems with intact ground cover and root systems are considered to be very important conditions. Water quality encompasses different parameters, including nutrient levels, acid-base chemistry, organic pollutants, pathogens, pesticides, industrial and pharmaceutical products, and suspended sediments (Smith *et al*., 2013). In agricultural landscapes, for example, water quality issues include run-off of nutrients, pesticides, organic pollutants, pathogens from livestock, and suspended sediments from disturbed soils. Terrestrial ecosystems, therefore, contribute to enhancing water quality by regulating the diffusion of contaminants to surface waters, particularly through the infiltration and retention of pollutants into soils (Smith *et al*., 2013). There are a variety of routes through which water reaches freshwater stores (lakes, rivers, aquifers). These routes include direct precipitation, surface and subsurface flows, and human intervention. In almost all cases, the water quality is altered by the addition and removal of organisms and substances (TEEB, 2009).

Biological control: According to TEEB (2009), the densities of natural enemies and the biological control services they provide might not have linear relationships under every situation. However, certain levels of their diversities and distributions are important for effective biological control services. This means that there can be a substantial decline in the biological control function of ecosystems below a certain level of the diversity of the natural enemies. Biological control of pests by natural enemies is an important ecosystem service in agriculture as well as many other production ecosystems, which contributes substantially to worldwide crop production (Bengtsson, 2015).

Pollination: Pollination services of ecosystems can become too scarce or too unstable if the pollinator species/functional diversity is below a certain threshold level. In a landscape context, such a tipping point might occur when the destruction of sufficient habitat can either cause a population crash in multiple pollinators; or it may lead to the collapse of particularly important pollinators, leading to a broader collapse in pollination services of the ecosystems (TEEB, 2009). Some estimates have indicated that over 75% of the world's crop plants, and also many plants that are source species for pharmaceuticals rely on pollination by animal vectors (Elmavist *et al*., 2010). According to Klein *et al*. (2007), animal pollination has contributed to an increase in fruit or seed numbers or quality of about 87 out of 115 leading global crops (representing up to 35% of the global food supply).

Maintenance of soil quality: The soil formation process can be governed by different factors, which include the nature of the parent materials, biological processes, topography, and climatic factors (TEEB, 2009). The major characteristic of the development of most soils is the progressive accumulation of organic materials, which in turn are influenced by microbial activities, plants, and other associated organisms. The major determinant of soil quality, which is occurring in all ecosystems, is nutrient cycling, with a key element being nitrogen. Nitrogen occurs in large amounts in the atmosphere and is converted to a biologically usable form by bacteria. On the other hand, as nitrogen fertilizer is becoming ever more expensive, especially to the smallholder poor farmers, more affordable nitrogen fixation by organisms has to be considered for sustainable agricultural systems. Nutrient cycling, which occurs in all ecosystems and is strongly linked to productivity, is an important factor in determining soil quality (Elmavist *et al*., 2010).

Erosion prevention: Vegetation cover contributes to soil erosion prevention through different mechanisms, such as interception of the raindrops by the canopies and through their root system. Forests, in steep terrains, for example, protect against landslides by improving the soil moisture regime. As compared to grasslands or herb-dominated communities, forests may be more effective in providing erosion prevention services (TEEB, 2009). Prevention of soil erosion represents an important factor for soil conservation as it improves soil fertility and enhances the capacity of soils to conserve and sustain above and below-ground biodiversity (Orgiazzi and Panagos 2018). In addition to affecting soil fertility, sediment removal and transport due to soil erosion can also have large and lasting off-site effects in rivers and channels, for example, by impacting fish stocks and reducing water quality (Kondolf et al. 2014; Rickson 2014; Kjelland *et al*., 2015). Reducing soil erosion, therefore, has not only positive local effects on soil biodiversity and soil ecosystem processes but also has the potential to have important cascade effects on other terrestrial and aquatic ecosystems (Powlson *et al*., 2011; Guerra *et al*., 2020).

It may generally be concluded from the above review about the regulating ecosystem services that, despite the high uncertainty, these regulating services may respond differently along the A, B, or C response curves in Fig. 1 above depending on the management of the ecosystems under specific spatial and temporal context. Therefore, designing strategies for the production of provisioning services and the socio-ecological landscape management that can shift type 'A' responses to type 'B' or even to type 'C' responses should get due attention. In the section below, the potential of such management is illustrated with an example of one important provisioning service, coffee, considering its different production systems in Southwestern Ethiopia.

Trade-offs between Coffee production as a Provisioning service and other Regulating services in south-western Ethiopia

The south-western Ethiopian Afromontane forests are known to be one of the most species-rich ecosystems and they are among the globally recognized priority areas for biodiversity conservation (Kassa *et al*., 2017). However, the increasing trends of cereal cropping, resettlement, and commercial agriculture are contributing to the deterioration of the natural forest cover of the region and are threatening biodiversity, land quality, sustainable and traditional farming practices, and the livelihoods of the local community. In addition, it is also evident that these forests are the center of origin of *Arabica* coffee, *Coffea arabica*; and still, wild coffee populations are found throughout these forests with different levels of management interventions for enhancing production levels (Woldemariam 2003; Schmitt 2006). The local people living in the surrounding agricultural landscapes of these forests and forest fragments utilize this coffee by picking the berries from scattered coffee plants in the natural forest ecosystems.

In addition, the local people also manipulate the natural ecosystems through various management interventions in certain areas within the forests to increase coffee productivity (Elmqvist *et al*., 2011). Therefore, clearing some forest understory and retaining some selected indigenous trees for increasing coffee density under their canopies by either planting or by allowing natural regeneration are commonly practiced activities in the area. As a result, there is a gradient in coffee density within the entire forest ecosystem from the natural forest coffee to modified or semi-forest coffee systems (where there has been a removal of most small trees and shrubs in favor of coffee production). Moreover, smallholder farmers also practice coffee production in home gardens below selected shade trees in addition to the practices in natural forest ecosystems with continuous canopy cover (Elmqvist *et al*., 2011).

The various land uses described above with coffee production systems exhibit different levels of both provisioning and regulating ecosystem services. These levels range from low yield/ ha in the natural forest ecosystem to very high yields in areas of intensive production with high inputs of fertilizers and pesticides in terms of provisioning service (coffee production). On the other hand, the regulating services are showing responses from type A to type C, meaning low for intensive (sun-grown coffee); intermediate for shade-grown coffee; and high for forest coffee (Fig. 2).

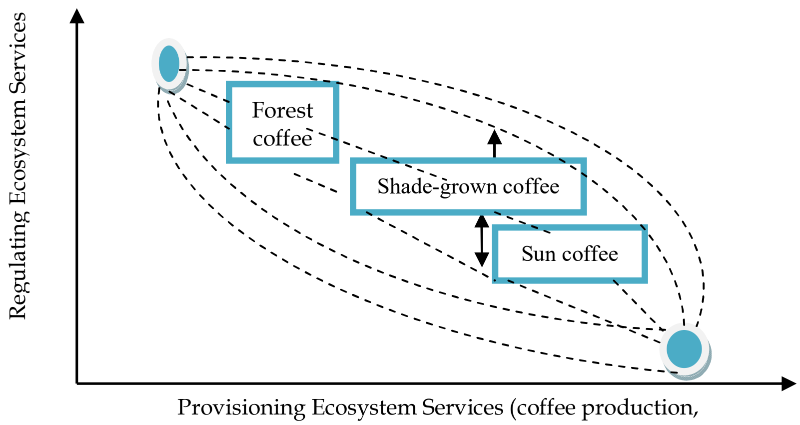

Figure 2. Different kinds of trade-offs in coffee production systems of South-western Ethiopia (Source: Elmqvist *et al*., 2011)

The low coffee yield per ha as a provisioning service is represented by unmanaged forest coffee; whereas regulating ecosystem services are largely maintained in such forested landscapes (Elmqvist et al., 2011) (Fig. 2). On the other hand, the intensive coffee production system (sun coffee) with the application of various inputs (e.g. pesticides and fertilizers) is associated with high coffee yield per ha, but with much-reduced biodiversity and other regulating ecosystem services in the landscape. The graph also shows that the shade-grown coffee, with some management of the shade trees, represents an intermediate kind of trade-off, where there can be different levels of regulating services (type A, B, and C-responses) for the same level of provisioning service (same coffee yield per ha) depending upon the management interventions of the landscapes. In this specific case, levels of regulating services are determined by the density and diversity of trees maintained for the provision of coffee shade. If the density and diversity of shade trees decline through the selective removal of certain species, which are not suitable for coffee shade, then the level of regulating services will also decline substantially. Therefore, different management interventions can be designed for achieving type-C response by enhancing the economic value of coffee (e.g. through coffee certification as an organic product) without further degrading the other ecosystem services. Another study by (Tadesse *et al*., 2014) on the prospects of forest-based ecosystem services in forest-coffee mosaics of southwestern Ethiopia indicated that most of the forest-based ecosystem services can be provided by semi-forest and garden coffee systems. The same study, on the other hand, also reported that the extent to which losses of forest-based ecosystem services can be substituted or complemented by coffee agroforests depends on different factors. These factors include the livelihood strategies and socio-cultural practices of local people, management intensity, and policy and demographic factors that affect agroecosystem intensification.

Synthesis and Discussion on Nexus between Agricultural production and Biodiversity conservation

Agricultural production and biodiversity conservation, which were traditionally addressed separately, have been identified as key challenges of the twenty-first century (Glamann *et al.*, 2017). However, according to the Millennium Ecosystem Assessment (2005), the existing perception of the role of biodiversity in food security has changed. As a result, the four pillars of food security, health, and nutrition (food availability; access to food; utilization of food; and, stability of food supply) are believed to be "inextricably linked" with the health of natural ecosystems and the biodiversity they contain. A landscape with healthier natural ecosystems and the associated biodiversity is, therefore, the foundation for the delivery of various Ecosystem Services (ESSs). Within the landscape, there is a mosaic of various ecosystem types (forests, croplands, water bodies, infrastructure, etc.) and their functions can be optimized to meet social, ecological, and economic demands. In such multi-functional landscapes, biodiversity is a critical component of ecological functioning resulting in the various ESSs that are vital for human welfare.

Biodiversity conservation and food security are now increasingly perceived as complementing each other although they were considered to be mutually exclusive in the past (Brussaard *et al.*, 2010; Tscharntke *et al.*, 2012). Therefore, in connection with food security being a top priority in the current development agenda, it is becoming necessary to design a strategy on how biodiversity can contribute to ensuring food security (Brussaard *et al.*, 2010). The narrow focus of many ecologists and conservation biologists, where the conservation of biodiversity is emphasized only in the natural ecosystems, fails to recognize the role of biodiversity conservation in the agricultural production system (Tscharntke *et al.,* 2012). The majority of biodiversity in the complex and multi-functional agricultural landscapes (especially in the tropics), which are managed by smallholder farmers and recognized to have their role in the food production system, are situated outside of the protected areas. The emphasis on conservation in agricultural systems provides novel insights into the functional role that biodiversity plays in the provisioning of various ecosystem services (DeClerck *et al.,* 2010).

According to Paul *et al.* (2017), despite the reported huge number of biodiversity species (nearly 7000 plant species and many animal species) that have been used in human history for food and medicine, only a few of them have been used to meet human requirements for food. Among these, only three crops- wheat, rice, and maize account for more than half of global energy consumption. This situation of increasing uniformity of agricultural production has resulted in the elimination of many wild relatives of crop and livestock species. A review on wild edible plants in Ethiopia by Ermias *et al.* (2011), for example, compiled information about 413 wild edible plants belonging to 224 genera and 77 families. However, according to IPBES (2019), many crop wild relatives that are important for long-term food security lack effective protection, and also the conservation status of wild relatives of domesticated mammals is worsening.

According to Myers *et al.* (2013), the increasing trade-off between food production and biodiversity is known to be the outcome of the inherent conflict between an ever-growing human population and finite natural resources. By raising production efficiency through intensification to meet the growing food demand, for example, biodiversity is being reduced, and this, in turn, reduces the degree of ESSs that support the food production system itself (Myers *et al.*, 2013). This can also have other dramatic consequences in addition to affecting sustainable food production. Pollination, for example, is just one of the ESSs that is provided by biodiversity, and the role of which is consistently underestimated. Efforts to replace pollination services with human activities are usually involving a very high cost. It is reported that the global economic value of pollination of the major food crops by some of the insects such as bees was estimated at $153 billion in 2005, which is approximately equivalent to 9.5% of the overall value of global agricultural food production of that year (Gallai *et al.*, 2008). Despite their huge economic importance, there has been a worldwide decline of pollinators due to various threats such as diseases, climate change, invasive species, habitat loss, and large-scale agro-industries based on the high input of chemicals (FAO, 2008).

Loss of biodiversity in different kinds of ecosystems (both in the human-influenced agro-ecosystems and the natural ones) can generally affect food availability and choices, as well as income and wealth creation as a result of diminishing provisioning ESSs (Cardinale *et al.*, 2012). Hence, the significance of biodiversity is not limited to the direct contribution to food security (as provisioning ESS); it also indirectly affects the regulating ESSs from adjacent land that acts to provide, for example, water, and pest control, among other services. Currently, land degradation, including biodiversity loss, has reduced productivity in 23% of the global terrestrial area, and an annual global crop output value of $235 to $577 billion is at risk as a result of pollinator loss (IPBES, 2019). Therefore, a balance has to be found among the various ESSs in multi-functional landscapes. Application of the principles of Climate-smart Agriculture (CSA), for example, can be considered as one of the options that can address the whole food production system (Cardinale *et al.*, 2012). The CSA can include specific options such as ecosystem-based agricultural management (conservation agriculture, agroforestry, crop residue management, water harvesting, and crop diversification). The maintained biodiversity in such improved systems can result in overall productivity enhancement across a variety of landscapes and ecosystems. In support of making rational decisions, Millennium Ecosystem Assessment (2005) indicated that some studies compared the total economic value of sustainable management of ecosystems with other management regimes involving conversion of the natural ecosystems into other land uses or unsustainable practices. These studies indicated that the benefit of managing the ecosystem more sustainably exceeded that of the converted ecosystem (Fig. 3), even though the private benefits, that is, the actual monetary benefits captured from the services entering the market would favor conversion or unsustainable management. These studies are consistent with the understanding that market failures associated with ecosystem services lead to greater conversion of ecosystems than is economically justified. Therefore, designing an effective marketing system has to be an integral part of the overall management strategies required for balancing conflicting interests in ecosystem services. The first options in the management practices (intact wetland, sustainable forestry, intact mangroves, and traditional forest use) with high net present values across all case countries considered in the graph (Fig. 3) represent sustainably managed ecosystems. On the other hand, the second options of the cases represent converted ecosystems.

Another comparative study of ecosystem services in biologically diversified versus conventional farming systems by (Kremen and Miles, 2012) indicated that the biologically diversified systems support substantially greater ecosystem services as compared with the conventional farming systems (driven mainly by economic interest). According to the study, the major ecosystem services supported by the diversified system include greater biodiversity, soil quality, carbon sequestration, water-holding capacity in surface soils, and resistance and resilience to climate change.

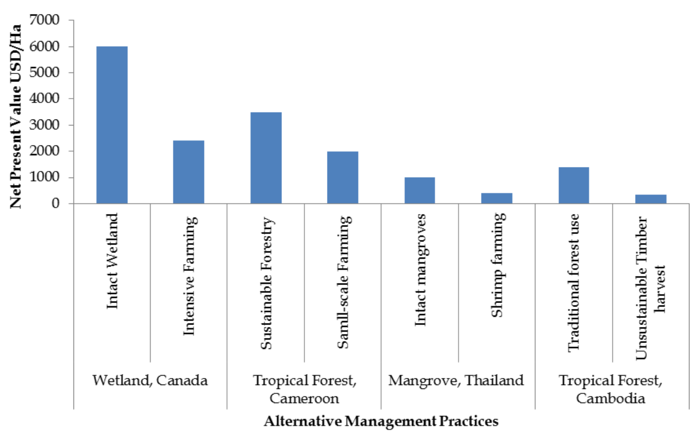

Figure 3. Economic benefits of conserved natural ecosystems and converted ecosystems
Source: Millennium Ecosystem Assessment (2005)

CONCLUSION

The extent of trade-offs between agricultural production and biodiversity conservation can generally vary depending on the various socio-economic and ecological settings, as well as the existing governance system within the scope of broader socio-ecological landscapes. Therefore, achieving desired levels of synergies and harmony among the various ecosystem services in general and between provisioning and regulating services, in particular, require due consideration of multi-criteria analysis in the specific context of a multi-functional socio-ecological landscape. Accordingly, ensuring the best balance between coffee production as a provisioning service and other ecosystem services in coffee-producing landscapes of south-western Ethiopia requires sound landscape governance that takes into account multiple dimensions, such as socioeconomic and demographic aspects; ecological aspects; as well as effective policy systems and institutional set-ups (including effective market systems).To that end, systematically designed research works exploring the trade-offs and governance systems of agricultural production and biodiversity conservation under contrasting biophysical and socio-economic settings are of paramount importance.

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