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Review

Changing Agricultural Landscapes in Ethiopia: Examining Application of Adaptive Management Approach

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Received: 4 September 2020; Accepted: 8 October 2020; Published: 28 October 2020

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Abstract: Ethiopia has decades of experience in implementing land and water management interventions. The overarching objectives of this review were to synthesize evidences on the impact of implementation of land and water management practices on agricultural landscapes in Ethiopia and to evaluate the use of adaptive management (AM) approaches as a tool to manage uncertainties. We explored how elements of the structures and functions of landscapes have been transformed, and how the components of AM, such as structured decision-making and learning processes, have been applied. Despite numerous environmental and economic benefits of land and water management interventions in Ethiopia, this review revealed gaps in AM approaches. These include: (i) inadequate evidence-based contextualization of interventions, (ii) lack of monitoring of bio-physical and socioeconomic processes and changes post implementation, (iii) lack of trade-off analyses, and (iv) inadequacy of local community engagement and provision of feedback. Given the many uncertainties we must deal with, future investment in AM approaches tailored to the needs and context would help to achieve the goals of sustainable agricultural landscape transformation. The success depends, among other things, on the ability to learn from the knowledge generated and apply the learning as implementation evolves.

Keywords: landscape; land and water management; ecosystem services

1. Introduction

Geological weathering and erosion are constructive natural processes that maintain the functioning of agricultural landscapes and ecosystem services [1–3]. Anthropogenic drivers often accelerate some of these natural processes and can negatively affect the structure and functions of agricultural landscapes and ecosystem services [1,3,4].

A recent study by Nkonya et al. [5] demonstrated that about 30% of the global land area, home to about three billion people, suffers from land degradation. This is translated to an annual cost of about USD $300 billion. Land degradation is particularly severe in sub-Saharan Africa (SSA), which accounts for about 22% of the total global cost of land degradation. Like in other sub-Saharan African countries, land degradation is significant in Ethiopia and causing considerable negative environmental and economic impacts [6–10]. For example, the direct cost of the loss of soil and essential nutrients due to unsustainable land management was estimated in 1994 to be 3% of the country's agricultural GDP, or USD $106 million [11]. Gebreselassie et al. [12] estimated the net cost of land degradation in Ethiopia due to land use and land cover changes to be about USD $4.3 billion annually and this value is 44 times higher than the 1994 estimate.

The challenges of land degradation in Ethiopia entail the need to transform and restore the agricultural landscape by addressing the drivers of land degradation while maintaining or increasing ecosystem services. According to the World Bank [13], this would play an important role in reducing poverty. It was estimated that every 1% growth in Gross Domestic Product (GDP) would result in 0.15% reduction in poverty. Economic growth in the agricultural sector plays even a more important role: for every 1 % increase in agricultural output, poverty would decrease by 0.9%.

In relation to the management of agricultural landscapes in Ethiopia, Haregeweyn et al. [14] showed that indigenous soil and water conservation (SWC) measures have been applied for centuries but improved SWC measures only came into practice following the recurrent drought-triggered famines of the 1970s and 1980s. The implementation of indigenous and improved SWC measures can support addressing new challenges such as climate change impacts and can be considered as a socio-political opportunity for better livelihood outcomes [14]. In context of the current study, indigenous SWC measures refer to locally developed and practiced land and water management technologies (e.g., *Konso* stonewalled terrace), whilst improved SWC measures are newly introduced or when the design and implementation of indigenous SWC measures have been improved through science.

In this regard, Sayer et al. [15] demonstrated the need to adopt knowledge-intensive and site-specific sustainable agricultural landscape management options including the use of indigenous and improved SWC practices. Regardless of its type, SWC measures could add new structure to or change existing structures of landscape and thereby influence the landscape functions and the overall processes of landscape transformation. Birge et al. [16] argued that managing agricultural landscapes through land and water management practices (e.g., SWC measures) can take unpredictable trajectories and trigger unintended results (e.g., environmental pollution, land use conflicts); therefore, it must take into consideration temporal and spatial process variability and be aligned with the socio-political context. This entails mechanisms to operationalize adaptive management (AM) approaches. Adaptive management is an approach to natural resource management for people who must act despite uncertainty about what they are managing and the impacts of their actions [15–17]. The adaptive process is often represented as a cycle of plan, do, monitor, and learn.

The overarching objectives of this review were to synthesize evidences on the impact of implementation of land and water management practices on agricultural landscapes in Ethiopia and to evaluate the use of adaptive management (AM) approaches as a tool to manage uncertainties. The review employed generic AM cycles as proposed by Birge et al. [16].

2. Materials and Methods

2.1. Context of Transforming Agricultural Landscapes in Ethiopia and Analytical Framework Applied in This Review

A landscape is perceived as a system of natural, biophysical, and socio-cultural components that undergoes continuous transformation due to both natural and anthropogenic drivers [18,19], as presented in Figure 1. The natural processes (Figure 1C) involve, for example, the pedogenic process influenced by compounded effects of the lithosphere, hydrosphere, and biosphere as well as climate. The second, human-induced process (Figure 1A), is triggered by socioeconomic, cultural, and political interests [1]. Human social systems and landscape ecosystems are complex adaptive systems [20]: complex because ecosystems and human social systems have many elements and non-linear and dynamic connections between those elements (Figure 1); adaptive because they require feedback mechanisms with adaptive decisions/actions to a constantly changing environment [19].

In the context of this review, Ethiopia's agricultural landscapes are considered a mosaic of farmers' fields, infrastructures (e.g., terraces, micro dams) and occasional natural habitats, and they are the result of interactions between farming activities and the natural and socioeconomic settings in an area [19,21].

The ongoing implementation of land and water management practices and the resulting transformation of agricultural landscapes in Ethiopia is attributed to both natural and anthropogenic drivers [14,22]. People modify the landscape by changing its structures (e.g., by installing SWC measures, planting or cutting trees, building micro dams, extracting groundwater, changing land use, etc.) to attain improved landscape functions and support their livelihood [19]. In many cases, the focus of human-induced processes is on increasing provisioning ecosystem services (e.g., food production). Such a focus on a single ecosystem service can have negative feedback (Figure 1) on transforming landscapes and maintaining the diverse ecosystem services that multi-functional landscapes can provide. Following the objectives of this review, we focused on human-induced landscape transformations. We focused on transformation within agricultural landscapes and therefore, changes from agriculture to urban or vice versa were not considered. The analytical framework and key indicators used are illustrated in the next section.

According to Forman and Godron [20] landscapes have three user-defined components:

1. **Structure**–-a spatial pattern of landscape units, i.e., the spread of plants and animals, arrangement of landscape elements, land-use and land-cover (LULC), artificial structure etc.; (Figure 1B).
2. **Function—**the interactions between the landscape units, i.e., water, nutrient and energy fluxes, migration of organisms (Figure 1B), and usually used synonymously with ecosystem function and
3. **Changeability—**transformation of landscape structure and functioning over temporal scales.

Human-induced and natural processes act continually on the first two components while the third, changeability, is an integral part that is resultant of these actions and reactions (and thus not represented separately in Figure 1).

Helming et al. [23] indicate a three-layered hierarchy of landscape structures (Figure 1B) that are introduced here regarding human-induced transformations:

1. **Primary landscape structure** (Figure 1(B1)): This is the original and permanent basis for the other structures. Although it is least influenced by human activities, the primary landscape structure shapes the type and magnitude of interventions and their outcome under secondary and tertiary landscape structures. Hence, it is considered as intrinsic to interventions and not discussed in further detail in this review [18].
2. **Secondary landscape structure** (Figure 1(B2)): According to Skokanová and Eremiášová [24], this layer involves, for example, the current LULC or the geographical elements created to improve productivity, such as a dam or SWC measures. Given their multiple ecosystem functions and their pervasiveness in landscape transformation, LULC changes, SWC, and water harvesting-related indicators were key focus areas of this review [25]. We will use both quantitative and qualitative information to illustrate changes in ecosystem functions and services (e.g., biodiversity, soil erosion, agricultural productivity, carbon sequestration etc.) due to changes in secondary landscape structure.
3. **Tertiary landscape structure** (Figure 1(B3)): This layer comprises mainly of elements of the socioeconomic sphere such as (in) tangible interests, and expressions of and effects on society in the landscape [23]. Here, we focus on examples illustrating livelihood transformation in relation to secondary landscape structural changes such as income from agricultural activities (irrigation from micro dams, income from afforestation, rainfed farming intensification) and how different SWC measures have transformed positively or negatively livelihoods in the community.

In this analytical framework, the landscape structure that relates to agricultural landscape transformation and land and water management practices belongs to the secondary layer (Figure 1(B2)). Some examples include expansion of cultivated land, exclosures for landscape restoration, physical SWC measures, and water harvesting structures. These are typical activities undertaken to manage agricultural landscapes in Ethiopia [14,23,26]. Tertiary landscape structures (Figure 1(B3)) are linked to landscape structure 2 (B2) and how it transforms livelihoods. Recent evidence related to how landscape structures B2 transform lives and livelihoods [27] is an important point of discussion, particularly in view of providing incentives to guide behavioral change and to support local communities in adopting certain land and water management interventions.

The functional component (Figure 1(B4)) of a landscape consists of the processes influenced by its structure and processes driven by the human and natural system. This component is synonymous with ecosystem function and controls the provision of ecosystem services (Figure 1D). In the introduced analytical framework, changes in the landscape function are driven by the changes in structure. For example, we consider how changes in the landscape structure such as LULC changes have influenced carbon sequestration, biodiversity, and erosion [28], or how SWC measures have influenced the restoration of degraded landscapes and agricultural production.

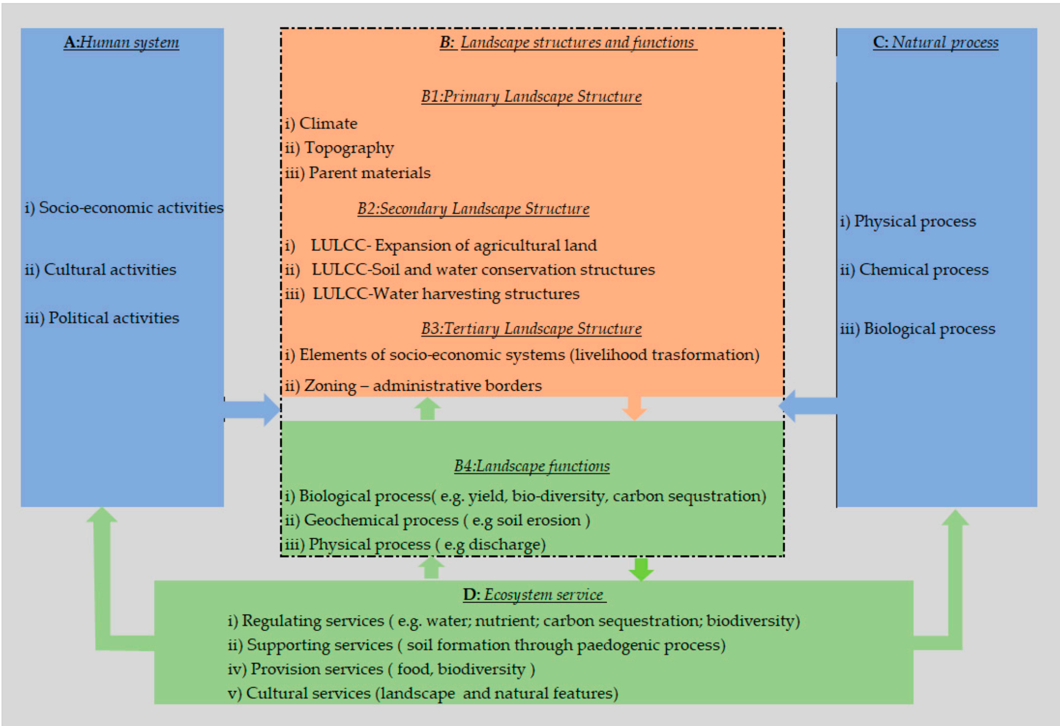

Figure 1. Framework of target indicators for a review of evidences of transformed landscapes and ecosystem services. (Authors synthesize based on Helming et al. [23] and Hermann et al. [19]). LULCC stands for land-use and land-cover changes.

Landscape structure and functions are highly interconnected. To gain an in-depth understanding of these, selection of the right scale is important considering that the spatial and temporal scales of the processes and observations need to be aligned. However, availability of quality data, both spatial and temporal, is often limiting. This work considers evidence generated at different scales (farm plots, watersheds, landscapes, and basins) and consolidates the implications at the national scale. Likewise, temporal scale information is fragmented too. However, assessment of interventions in terms of their long-term impact on the performance of a landscape in delivering a broad range of benefits including transformation of livelihoods and ecosystem services is very scarce in Ethiopia as in many developing countries. Therefore, establishing empirical evidences of temporal trends for the target indicators is beyond the scope of this review.

2.2. Data Sources

Data were collected from three major sources: peer-reviewed articles included in the Scopus and ISI Web of Science databases, grey literature, and expert knowledge following discussions in the agricultural water management platform in Ethiopia. The terms used to search for literature separately and in combination included 'landscape', 'landscape transformation', 'ecosystem services', 'sustainability', 'conservation and development', 'land use change', 'exclosure', 'soil erosion and sedimentation', and 'carbon sequestration'. Where relevant, we specified Ethiopia in these searches. From 71 articles identified, 26 were on the general scientific background of agricultural landscapes and their transformations and 45 were specific to Ethiopian agricultural landscapes.

Tables 1 and 2 indicate how often elements of AM were mentioned in the selected literature sources, either as recommendation or as gaps for sustainable landscape transformation and number of incidents where adaptive management (AM) elements were mentioned for each of the target indicators respectively. It also provides the number of cases where AM elements were mentioned (directly or implicitly) for each of the target indicators (as in Figure 1(B2, B3)). We observed that different elements of AM were mentioned 142 times, and more than 80% of these were for indicators under the structural landscape component.

Many articles note gaps in one or more elements of the AM approach for respective agricultural landscape transformation interventions. Some scholars connected structures and functions (Table 1) of landscapes in a cause and effect relationship. Therefore, many articles were assigned to multiple indicators.

2.3. Adaptive Management in Relation to Landscape Transformation

Adaptive management and the theory of change for landscape approaches [15,16] are comprehensive and complementary frameworks related to landscape interventions and restoration of ecosystem services. According to Sayer et al. [15], a theory of change traces the links between an intervention and an ultimate impact and makes the assumptions underpinning prediction of the result explicit. The theory of change demonstrates the causal pathway and feedback loops driving progress towards improved landscape performance. Furthermore, the studies noted that metrics are needed at multiple stages throughout the process to understand progress and to inform policy and decision-making.

The concept of AM has evolved in numerous directions, but all are centered around iterative learning about a system and making management decisions based on that learning [17,29]. The learning components focus on science (e.g., monitor, evaluate, and adjust) while the others focus more on structured decision-making by defining the problem, identifying objectives, formulating evaluation criteria, estimating outcome, evaluating trade off, and deciding [16]. The adaptive process is often represented as a cycle of plan, do, monitor, and learn and can guide informed decision-making while implementing activities related to landscape structural changes and also helps to address post-implementation trade-offs (Figure 1). We used elements representing both structured decision-making and the learning components to better understand the drivers and outcomes in the entire landscape (Table 1). In this line, Stirzaker et al. [29] argue that using real-life management of the system as a whole and turning it into an experiment by asking the right questions, implementing decisions, collecting the right data, and learning from the experience, is crucial to understanding landscape transformations.

The attributes of AM, which make it distinct from the traditional trial and error approach, is so that it involves exploring alternative ways to meet management objectives. It forecasts the outcomes of alternatives based on the current state of scientific knowledge and it implements one or more of these alternatives. Adaptive management monitors impacts of management actions, updates knowledge, and adjusts management decisions.

Table 1. Matrix matching the framework of target indicators of landscape structures B2 and B3 (Figure 1) and key elements of the adaptive management approach Birge et al. [16].

Indicators for Transformed Landscapes (as in B2 and B3)	Target Landscape Component (as in B2 and B3)	Key Elements of Adaptive Management								
		Structured Decision Making						Learning		
		Define/Contextualize the Problem	Identify the Objective	Formulate Evaluation Criteria	Estimate Outcome	Explicit Evidence for Trade-Off	Intervention and Resource Allocation	Monitor	Evaluate	Adjust/ Negotiation and Feedback
Land use and land cover change	Structural	X	X	X	X	X	X	X	X	X
Water harvesting		X	X	X	X	X	X	X	X	X
Soil and water conservation structures and practices		X	X	X	X	X	X	X	X	X
Discharge, sediment yield	Functional	*	*	X	X	*	*	X	X	X
Carbon sequestration, biodiversity		*	*	X	X	X	*	X	X	X
Livelihood transformation		*	*	X	X	*	*	X	X	X

X stands for cases where reviewed literature indicated application or lack of adaptive management (AM) triggered bad or good performances of the focus indicators. Indicators under functional elements do not follow the whole AM approach as they are the result of changes in the structure and of external drivers and therefore marked by *.

Table 2. Total number of incidents where adaptive management (AM) elements were mentioned for each of the target indicators in identified literature suggesting gaps in key ingredients of AM in landscape transformation interventions.

Example of Indicators for Transformed Landscape	Target Landscape Component	Number of Incidents AM Elements were Mentioned *									Total Number of Incidents AM Elements Mentioned for Each of the Target Indicators
		Structured decision						Learning			
		Define/Contextualize the Problem	Identify the objective	Formulate Evaluation Criteria	Estimate Outcome	Explicit Evidence for Trade-Off	Intervention and Resource Allocation	Monitor	Evaluate	Adjust/ Negotiation and Feedback	
LULC change and related agricultural practices	Structural	8	4	2	4	8	3	3	5	4	41
Water harvesting		8		17	1	4	4	2	2	4	42
SWC structures		10	3		2	6	3	2	3	5	34
Discharge, sediment yield,	Functional	1				3			1	1	6
Carbon sequestration, biodiversity		1				3		2	2	2	10
Livelihood transformation		1	1		1		1	1	1	3	9
Total number of incidents each element of AM was mentioned		29	8	19	8	24	11	10	14	19	142

* The numbers refer only to literature published on Ethiopian agricultural landscapes in context of the targeted indicators (Table 1 and Figure 1), SWC refers to soil and water conservation.

In this review, we argue that the principles of AM can be applied to the concept of landscape transformation because of agricultural landscape intensification. We argue that the identification and monitoring of relevant indicators representing key landscape structures and functions support adaptive learning and decision-making in sustainable agricultural intensification. We apply the developed framework in the context of degraded landscapes and the implementation of physical and biological SWC measures. Table 1 matches the framework of target indicators (B2 and B3 in Figure 1) with key elements of the AM approach [16]. For each of the selected indicators, we explored if the literature reviewed attributed the failure or success of the interventions to one or more elements of the AM approach in Ethiopia [16].

The contributions of this review include: (i) the proposed analytical framework and demonstrating its applicability to target indicators and understanding landscape transformation for specific areas and this can be applied elsewhere, for example in SSA. (ii) Presentation of structure and function of landscape transformation interactively and relating each of them with the learning and decision-making elements of adaptive management in the Ethiopia context.

3. Results and Discussion

3.1. Managing Agricultural Landscapes in Ethiopia: Structural Indicators of Transforming Landscapes

3.1.1. Land-Use and Land-Cover Changes: Expansion of Cultivated Land

Changes in LULC globally are driven by multiple factors including population increase, poverty, economic activities, and other socioeconomic factors [30]. Land-use and land-cover changes are so pervasive that when aggregated globally, they significantly affect key aspects of the landscape structure [28].

Several studies by Kindu et al. [31], Gashaw et al. [32], and Deribew and Dalacho [33] documented changes in LULC and ecosystem services across time in Ethiopia. Many of them, however, did not enumerate comprehensive nationwide evidence. Available information at the micro scale (e.g., farm fields, watersheds) and meso scale (river basins, regions) show, however, that the magnitude of change is enormous, and that the direction of change varies across regions and scale of studies. For example, from a 145-year analysis of the situation in the northern highlands of Ethiopia, Nyssen et al. [22] concluded that the landscape is greener now. The findings of Gebremichael et al. [34] from their work in the Blue Nile basin concluded that erosion and sedimentation increased by 81% due to increased land conversion to crop land. The only recent national-scale land-use change study involving agricultural land expansion (2000–2010) was done by the United Nation Convention to Combat Desertification (UNCCD) [35]; it showed only a 0.38% decline in forest cover with a proportionate increase in crop land and shrub, grasslands, and sparsely vegetated areas.

Despite the small change from natural land cover to cultivated land as illustrated by the national-scale work [35], contrasting values available from meso and micro scale studies imply that there are hotspot areas of LULC change where ecosystem functions and services are degrading rapidly [36]. As summarized in Table 2, the total number of incidents that AM elements mentioned as recommendation or gaps in current LULC practice was 42. Of this, more than 70% related to the element of structured decision while the rest related to learning components of adaptive management.

Overall, from an agricultural land perspective, three major causes of LULC changes can be recognized: (i) expansion of agricultural land due to individual farms encroaching into other land-use types; (ii) foreign direct investment (FDI) in agriculture; and (iii) restoration of degraded lands through physical soil conservation measures integrated with tree planting and biological soil conservation measures through, for example, exclosures.

(i) Expansion of agricultural land due to activities by local farm investments

Studies indicated that agricultural lands have been increasing in different parts of the country at the expense of forested land, grassland, and shrublands. For example, a study conducted in the central highlands of Ethiopia [37] demonstrated a 62% increase in cropland between 1975 and 2014, which has mainly occurred at the expense of grasslands. Similarly, Derebew and Dalacho [33] showed that over the course of 60 years (1957–2017), agricultural land and forest land showed a comparably equal extent of net change (+36.7% and −37.8%, respectively), but in opposite directions. Such changes in agricultural lands had resulted in an increase in total crop production over the past decade [38].

However, studies by the World Bank [13] and Bachewe et al. [39] showed that the relative contribution of agricultural land expansion to increases in agricultural production was decreasing in the period 2005–2015, which can be explained by the gain in yield due to increased use of fertilizers, herbicides, improved seeds, and irrigation. This finding was supported by Franks et al. [38] who found that there had been a tendency of production gains accruing from higher land productivity rather than an expansion of cultivated land. Similarly, the World Bank [13] reported that the agricultural sector of Ethiopia recorded a remarkably rapid growth in the past decade, and that this was the result of strong yield growth as well as an increase in cultivated area, which rose by 7% and 2.7% per year, respectively, during the period 2004–2014. Kibret et al. [40], from their LULC change study in south and central Ethiopia, concluded that land conversion to agriculture in that part of the country may have reached a cut-off point beyond which it would have ecological consequences. Headey et al. [41] also argued that with little suitable land still available for expansion of crop cultivation, especially in the highlands, future cereal production growth would have to come from yield improvement.

Despite the presence of some areas where production still depends on expansion of cultivated land, many of the evidences above [13,39–41] suggested that future direction of agricultural productivity increase in Ethiopia could be intensification. In order for intensification and extensification to be sustainable, tools such as AM can be useful. It guides the process to assess the underlying trade-offs and seek options for optimal management choices under conditions of uncertainty.

(ii) Foreign direct investment in agriculture

Despite the few studies that explore the nature and benefits of FDI in Ethiopia, Mulue et al. [42] reported that between 1992 and 2017 an investment in 122 projects (8.8 ETB (about 2.6 billion USD)) was recorded: the third largest areas of FDI following manufacturing and contracting. Bossio et al. [43] indicated FDI in agriculture with close to 2 million ha of disclosed contracts for lease of land. Many of these land areas were in Gambela, Beni-Shangul Gumz, and in Oromia regional states.

The aim of such investments was to increase provisioning ecosystem services (food production), technology transfer, job creation, and flow of capital into the country [42]. Although only a smaller portion of the 2 million ha of land has been put in practice, scholars argue that the environmental sustainability in agricultural production is a major issue in the context of large-scale FDI in agricultural land [42]. Intensive agricultural production has negative impacts on biodiversity, forest, land, soil, and water resources. In this regard, Teklu et al. [44] reported the emerging threat of pesticide pollution of water resources in the Rift Valley: areas where flower farms and intensive irrigated agriculture are practiced partly through FDI. Overall, limited empirical evidences have been gathered on the opportunity costs (e.g., environmental impacts, human health) of such land-use change.

Bossio et al. [43], who examined the impacts of FDI on water resources, indicated a potential increase in the consumptive use of freshwater resources, thus straining the already scarce freshwater resources although the investment may indeed enhance land and water productivity. Here, there can be multiple suggestions in relation to AM to mitigate the negative impacts of such landscape transformation measures: (i) identify areas with the least opportunity cost; and (ii) systematically monitor the emerging changes in landscape structure and functions in order to contribute to evidences supporting the AM cycle and application of the knowledge in future development endeavors [42].

(iii) Restoration of degraded landscapes through physical and biological soil conservation measures

Since the 1970s and 1980s, several national programs, including the Sustainable Land Management (SLM) program (phases I and II) and the Productive Safety Net Program (PSNP), supported the implementation of SWC measures in the country. For example, during the period 2010–2015, more than 15 million people contributed unpaid labor (equivalent to USD 750 million each year) to the SLM program [45]. During this same period, SWC measures have been introduced in more than 3,000 watersheds and more than 12 million hectares of land have been rehabilitated by implementing physical different soil and water conservation measures [45,46].

There are a number of biological and physical SWC measures currently applied across Ethiopia. The practices are mostly single technology focused or occasionally integrate physical and biological measures. The most common physical SWC measures are gully rehabilitation, furrow, check dams, waterway, fanya juu, drainage ditches, cut off drains, bunds of different type (stone, soil, or combined), terraces, counture ploughing, and water harvesting. The biological SWC measures involve practices such as alley cropping, grass strips, afforestation, and exclosure. Exclosures are usually community-initiated practices on degraded grassland with shallow soil and increasingly have become a space for integration of physical and biological conservation measures.

Studies demonstrated that the implemented physical SWC measures played an important role in rehabilitating degraded landscapes and improving ecosystem services [27,47–49]. For example, the transformation of these landscapes through SWC measures the resulting increases in water retention and ground water recharge. This provides opportunities to support supplementary or full irrigation in rainfed or dry season agriculture, respectively [50]. Shallow ground water with less than 20 m depth incurs less cost and is easier to extract, thus it can be an incentive to invest in SWC. Estimates show that shallow ground water can irrigate as much as 8% of total irrigable land in Ethiopia [51]. Gowing et al. [50] argue that increased groundwater recharge and availability of shallow groundwater is an opportunity for intensification of agriculture and ecosystem services. Sustainable exploitation of this opportunity, however, needs careful monitoring of impacts of water abstraction, use, and impacts on water quality, which are implicitly linked to application of AM approach.

Of the biological soil conservation measures, establishment of exclosures on degraded landscapes has been given more emphasis due to its multiple benefits [52–55]. Exclosures are areas protected from the interference of humans and livestock to promote natural regeneration of secondary vegetation. Recent estimates indicated that more that 4.2 million hectares of land in the country are covered by exclosures [27]. Ethiopia recently pledged to rehabilitate 15 million ha of degraded land by 2030 [45] and, according to the government's plan, about 50% of the land—over 7 million ha—will be rehabilitated by establishing exclosures [45].

However, local communities raise concerns about the long-term soil conservation approaches and technologies discussed above, as the measures are not effective in generating short-term economic benefits [27]. The critical questions, therefore, are: (i) how would this land and water management, specifically SWC measures, work for poor rural communities? (ii) How well are farmers organized and enabled for taking collective action? (iii) What are the incentives and requirements to support local communities to adopt long-term conservation approaches? A recent work by Mekuria et al. [27] proposed a business model scenario to explore the feasibility of exclosures and address the complex challenges related to implementation. These business models identified short-term revenue streams such as beekeeping, harvesting fodder for livestock fattening, and cultivating high-value plant species, including fruit trees and herbs. These are feasible, sustainable economic activities that could allow for the restoration of ecosystem services over the long term if anchored to the principles of AM.

The other challenge is that the implementation of SWC measures in agricultural landscapes lacks monitoring, stakeholder's engagement, and longer-term impact assessment and that the approach in general lacks the learning ingredients of the AM cycle [16,17,56]. The fact that impacts of SWC measures are a function of time requiring context-specific intervention, development of a matrix of evaluation criteria and involvement of the local community, as illustrated in the AM cycle and theory of change, is crucial [16,17]. As summarized in Table 2, the total number of incidents that AM elements were mentioned as recommendation or gaps in current SWC practice were 34. Of this, 71% of the count was under the element of structured decision while the rest related to learning components of AM.

Recent initiatives by the World Bank to include hydro-meteorological monitoring systems as part of the SLM (phase III) in Ethiopia, might in part be a response to such criticism. Some of the key gaps such as the lack of evaluation, contextualization of interventions, and assessment of outcomes of SWC measures in relation to livelihood improvement are summarized in Table 3.

3.1.2. Small Water Harvesting Structures

Expanding water harvesting structures is one of the adaptation mechanisms necessary for transforming landscape structures for better ecosystem service provision in the face of climate change. As concomitant benefits, water harvesting can reduce surface runoff and erosion and recharges ground water. Accordingly, many regional and national governments introduced the implementation of water harvesting structures to improve livelihoods and adapt to climate change since the 2000s [58,59]. However, the impacts of implemented water harvesting structures (such as farm ponds and micro dams) on livelihoods are constrained by siltation, seepage losses, insufficient flows, structural damage, and spillway erosion [60].

In this regard, Gebremedhin et al. [60] showed that 61% of the water harvesting structures constructed in northern Ethiopia had siltation problems, 53% suffered from leakages, 22% had insufficient inflows, 25% were handicapped by structural damage, and 21% faced spillway erosion problems. Furthermore, lack of benefit sharing mechanisms hampered improving equity, as in most cases better-off farmers benefited more than poor farmers [61–63]. This suggests that the location, design to improve seepage losses, construction, and maintenance to combat siltation as well as governance of these structures need to be improved. These substantiate evidences summarized in Table 2 illustrate the highest total number of AM elements mentioned as recommendation or gaps in current water harvesting structure and practices (43). Of the total counts of the incident, 81% of the count was related to the element of structured decision-making (Table 2).

Despite the huge potential, both in terms of available runoff and land resources, what has been achieved and recorded in this respect until now is limited and many interventions related to small water harvesting structure and practices did not meet the expectation of the farmers and there are several cases of dis-adoption. We argue that enabling AM and incorporating elements of the impact pathway, as suggested by Sayer et al. [17] and AM as suggested by Birge et al. [16], would be a good starting point to overcome some of the bottlenecks. Adaptive management demands early community engagement, understanding trade-offs, and monitoring of changes and impacts and learning therefrom [64]. Therefore, if tailored to context and adopted, it could mitigate the negative environmental, economic, and social consequences of small water harvesting interventions currently observed.

3.2. Livelihood Transformation through Natural Resources Management and Agricultural Activities

As indicated in Figure 1, the tertiary layer of agricultural landscape structure focuses on how agricultural and natural resource management-related activities are transforming livelihoods. We use the Productive Safety Net Program (PSNP), where millions of farmers participate each year, as an example, to illustrate the key role the AM approach could play in sustaining the impacts of natural resource management interventions on livelihood transformation. One of the major components in PSNP is a public works program. Under this program, eligible households with able-bodied adults are enrolled into the public works program, which involves enhancing agricultural landscape structure (soil conservation structure). These public works activities occur for 6 months of each year, during which clients receive a salary based upon their household size. Public works clients are expected to graduate from the program when they gain sufficient assets.

Relating this to AM would require us to answer the following questions: (i) whether sufficient evidence is available on how the implementation of different land and water management interventions under PSNP transform the three livelihood clusters, (ii) what learning has been generated from the evidence and (iii) what learnings have been used to plan and design next phases of the program. In the case of PSNP, many studies have focused on the impact of payments made to program participants on wealth accumulation and local infrastructure development (e.g., roads, schools, etc.) rather than on the actual longer-term environmental and livelihood impacts of these interventions [65]. This clearly illustrates inadequate knowledge management efforts on how investments in agricultural landscapes are transforming livelihoods and the local economy. Several other land and water management programs also lack short-term and long-term evidences of impacts on smallholder livelihoods. This is supported by the proportion of learning elements of AM (from the total number of counts of incidents mentioning AM elements) mentioned as a recommendation or gaps in the current livelihood transformation-related indicators (56%; figure not indicated in Table 2).

Table 3. Examples of recent agricultural LULC studies in Ethiopia and the key gaps they discussed in relation to the adaptive management cycle.

Authors	Focus Issues	Spatial and Temporal Scale	Key Conclusion	Examples of Reflection on AM
Nyssen et al. [22]	Land-cover change	145 years; northern Ethiopian mountains by re-photographed 361 landscapes that appear on historical photographs (1868–1994)	The northern Ethiopian highlands are currently greener than at any time in the last 145 years.	Lack of explicit evidence on trade-off outcomes and contextualization of the problem—example eucalyptus dominated LULC.
Tadesse et al. [28]	Land-use land-cover change and erosion	2001–2015; watershed	Vegetative cover in the study watershed reduced by 91% during 2001–2010 and increased by 88% during 2010–2015.	Need for sustainable land management practices for sustainable livelihoods of local people.
Gebremichael et al. [34]	Erosion as influenced by land-use change	1973–2000; Upper Blue Nile Basin	Conversion of natural land use to agriculture and barren land has contributed to increasing sediment movement and runoff	Need for upstream-downstream consideration (trade-off).
Bossio et al. [43]	Foreign direct investment, land-use change, ecosystem services	2000–2012; national but not spatially explicit	Local food security without compromising local and downstream water availability.	Lack of trade-off analysis in enhancing foreign direct investment.
Tefera et al. [57]	Exclosed area management, land-use change, ecosystem services	Small catchment in Tekeze and Awash river basins; temporal scale not indicated	Lack of clear management guidelines for exclosure.	Need for monitoring and evaluation, contextualization of intervention, lack of outcomes in relation to livelihood improvement.
Kibret et al. [39]	Agricultural land expansion	1972–2013; south central Ethiopia	Agriculture has reached its maximum extension on suitable lands and is now expanding into marginal lands. Sustainable intensification trajectory is needed.	Current land-use change interventions need to consider elements of AM.
UNCCD [35]	Land-use change, land degradation neutrality	2015 and projected; nationwide		Lack of monitoring, negotiation, evaluation, capacity of implementers.

The only available comprehensive information, on how agricultural activities improve livelihood and level of poverty, is reported by the World Bank [13]. Using the international poverty line (USD $1.90 per day at 2011 purchasing power parity (PPP)) as a yardstick, poverty is reported to have fallen from

55.3% in 2000 to 33.5% in 2011. A decomposition of yield increase reveals the importance of increased input use (e.g., improved seeds and agrochemicals) as well as total factor productivity growth (ratio of aggregate output (e.g., GDP) to aggregate inputs (2.3% per year)). A doubling of the adoption of improved seeds and fertilizer played a major role in sustaining higher yields. Ethiopia's real GDP has tripled since 2004, although it remains well below regional and low-income country levels. Recent work by Sheahan and Barrett [63] revealed that less than 4% of farm households in Ethiopia use integrated inputs consisting of inorganic fertilizer, irrigation, and improved seed varieties, which implies that there are untapped productivity gains to be made from coordinated modern input use by deploying governance mechanisms (and improved knowledge and skills, supply chains, business models etc.) to promote its uptake. This supports the claim discussed earlier that future Ethiopian food production largely depends on intensification; it also implies the need for an integrated and evidence-based approach, supporting AM, to ensure a sustainable intensification pathway [16].

3.3. Examples of Transformed Landscape Functional Indicators

As stated earlier, the structural and functional components of a landscape are very interactive with strong feedback loops. What we presented here are examples of how changes in the landscape structures influence the ecosystem services embedded in the landscape functions. We present below selected indicators such as impacts on yield, sediment, and discharge, as well as on carbon sequestration and biodiversity. Keeping in mind the interactions of structural and functional elements of a landscape, the selection of examples is based on two key factors: (i) examples that reflect what we demonstrated earlier under structural landscape components; and (ii) examples that can have long- and short-term impacts and include multiple ecosystem services.

3.3.1. Impacts of SWC Measures on Crop Yield, Discharge, and Sediment Yield

Adimassu et al. [10] summarized the impacts of SWC practices on the grain yield of crops. These same authors indicated that the impacts of SWC measures on grain yield are divergent and influenced by the type of SWC measure. The authors concluded that most of the physical SWC measures were less effective in enhancing grain yield of crops and attributed the reduced yield to the trade-off of increased area the SWC structures occupied [10]. In high rainfall areas there was higher likelihood of waterlogging, which contributed to the reduced yield implying lack of contextualizing interventions as suggested in AM [16].

Several other studies have demonstrated that the implemented SWC measures had positive impacts on reducing surface runoff and sediment load. For example, a study conducted in north western Ethiopia by Dagnew et al. [66] showed that SWC practices significantly reduced the daily, monthly, and annual runoff and sediment load compared to untreated lands. Zegeye et al. [67] reported that gully head treatment reduced surface runoff by up to 42% compared to the runoff generated from untreated gullies. Gebremichael et al. [34], who illustrated trends of the Blue Nile flow (1970–2009) and sediment load (1980–2009) at the outlet of the Upper Blue Nile basin at El Diem station, reported statistically significant increasing trends of annual stream flow, wet-season stream flow, and sediment load at 5% confidence level. The dry-season flow showed a significant decrease. However, during the same period, annual rainfall over the basin showed no significant increase. The counter-intuitive finding is why larger basin wide impact assessment (e.g., Gebremichael et al. [34]) showed an increase in trends of sediment yield and runoff, while SWC measures are proven to be effective at smaller scales as suggested for example by Dagnew et al. [66]. This could be explained by the fact that the overall area where SWC measures were applied is still small and that the total basin runoff is controlled by the over-proportional increase of runoff, which comes from non- SWC areas.

One of the lessons in terms of application of the AM cycle is that most of the SWC measures lack proper geographic, plot-level, and social targeting [10], thus, the positive impact on the landscape ecosystem functions (runoff, sediment yield) is low. This is counter-intuitive given decades of experiences of SWC research and generation of many context-specific technologies and guidelines in

Ethiopia. We argue that while generating contextualized SWC technologies is a key step, presence of the right institutions is what enables the use of these technologies and adoption of AM practices. In Ethiopia, several gaps related to institution and policy that explain lack of contextualization of SWC measures can be enumerated. These involve, for example, organizational instability; inefficient organizational structure (due to understaffing, under equipping), lack of linkages and alliances between institutions; shortage of skilled manpower, inadequate office and workshop facilities, and lack of integrated information management systems.

Sayer et al. [17] and Birge et al. [16], in relation to the AM cycle for landscape interventions, suggested a defined objective, site-specific intervention, and trade-off analysis and community participation as important ingredients for sustainable landscape management. These gaps in real-world case studies are reflected on a number of incidences (Table 2) where these AM elements were mentioned in the reviewed literature as recommendations or gaps, though these are smaller compared to other indicators considered.

Haileslassie et al. [68] argued that farm systems are heterogeneous; each farm system is unique in terms of its livelihood assets (including both biophysical and socioeconomic resources) and agricultural practices, and therefore unique in terms of sustainability. Considering this use of a single indicator such as crop yield or runoff to evaluate the transformation of landscape functions is inappropriate. Conceptually, heterogeneity applies also to scales of analysis. For example, a sediment yield assessment or runoff measurement at plot level will have different values and implications compared to watershed level-derived estimates because of sediment redistribution pathways. Therefore, a conclusion about impacts of change of agricultural landscape structure on landscape functions using single scale and incomplete indicators is misleading. When it comes to landscape functional indicators, the challenge is to develop spatially explicit monitoring and learning techniques involving suggestions by Sayer et al. [17] and Birge et al. [16] to support management (Table 2).

In sum, the implementation of SWC measures in the country (i) failed to match hotspot areas with technologies and farms [61–63,69]; (ii) erosion processes intensified after the LULC changes in the central, western and southern part of Ethiopia, which were covered with non-cultivated land during the initial "wake up" stage of the need for SWC measures [34,57]; (iii) lack of standard evaluation criteria and a comprehensive matrix addressing temporal, spatial, and social dimensions of SWC [69]; (iv) failure to counterbalance the impacts of historical LULC changes; and (v) often failure to engage farmers and thus, did not manage to increase adoption at larger scale [27]. The major challenges in relation to indicators of landscape functions (persisting erosion, increasing runoff and siltation of water harvesting structures, and downstream water bodies and infrastructure) are related to these failures. The above summaries are also related to lack of structured decision-making and learning processes in development interventions. The traditional trial-and-error approach, which is often a dominant practice in the current land and water management in Ethiopia, can accomplish learning from what went wrong in the past, considering a feedback loop, and adapting when necessary to avoid similar mistakes. Such an approach is not suitable for ecological systems for two reasons. First, slow feedback may mask long-term undesirable management outcomes. Second, ecosystems do not recalibrate to some predictable, stable state following failure. Instead, management mistakes can be persistent and costly [16], thus AM that (unlike the traditional trial and error) emphasizes learning while doing could be appropriate [64].

3.3.2. Impacts on Carbon Sequestration and Biodiversity

Studies demonstrated that the various land and water management measures implemented in the country (change in landscape structure) contributed to the restoration of both below- and above-ground carbon storage. For example, Woolf et al. [70] estimated the mean carbon benefit (both above- and below-ground carbon) across the Productive Safety Net Program (PSNP) sites to about 5.7 tons of CO_2^e per ha per year. Extrapolating these results to the whole intervention area of the PSNP (600,000 ha) would imply that a total carbon benefit in the order of 3.4 million t CO_2^e per year has already been achieved by PSNP.

Similarly, studies by Mekuria et al. [53,54] and Anwar et al. [71] demonstrated that land and water management practices (mainly exclosure) are effective at increasing ecosystem carbon stocks (ECS). For example, a study conducted by Mekuria et al. [53,54] in Tigray, the most northern part of Ethiopia, showed that differences in ECS between exclosures and grazing lands varied between 29 (±4.9) and 61 (±6.7) C t ha^{-1} and increased with exclosure duration. A study in northwestern Ethiopia [56] showed considerable increases in above-ground carbon (ranged from 0.6 to 4.2 t C ha^{-1}) following the establishment of exclosures. Anwar et al. [71] showed that over a period of six years, above-ground biomass increased by 56 t ha^{-1} (or 81%) at the watershed scale because of the conversion of communal grazing land to exclosure.

SWC measures were also effective in improving biodiversity. For example, studies [53,70] detected higher plant species richness and diversity in exclosures compared to communal grazing lands. Furthermore, differences in plant species richness and diversity compared to adjacent communal grazing lands increased with age of the exclosure.

In the AM approach, spatially explicit analyses and continuous monitoring are important to inform local authorities about the gains and losses of investments and continuously adapt the management approach as necessary. For farm households contributing free labor, the establishment of exclosures for carbon sequestration may not make sense. Smallholder farmers are often risk-averse and focused on short-term gains. The bottom line, however, is how such community segments can be incentivized better in light of superior objectives, and how to understand and minimize all trade-offs arising from such interventions to enable wider adoption of the practice to support sustainable landscape transformation. For example, exclosures require land, labor, and water—but all these resources have opportunity costs. The point then is whether the benefits from carbon sequestration and restoration of biodiversity can exceed the opportunity costs of these inputs today and tomorrow, and how can farmers who bear the costs (labor, land loss, etc.) be compensated—in real money—paid by polluters who pay for carbon emissions?

These are important issues that research and AM need to explore and make interventions that are context-specific and sustainable. This is demonstrated by the proportion of highest learning elements of AM from the total number of incidents AM elements mentioned as recommendations or gaps in the carbon sequestration related indicators (60%, figure not indicated in Table 2).

4. Conclusions

This review synthesized evidences of transformed structural (e.g., LULC, small water harvesting structures, exclosure, and livelihood transformation) and functional (e.g., production, runoff, sediment, biodiversity, and carbon sequestration) elements of the Ethiopian agricultural landscape, and identified gaps in the application of an AM cycle in planning and implementation of SWC measures.

Despite numerous environmental and socioeconomic benefits of land and water management interventions, application of elements of AM cycles have emerged as important gaps in Ethiopia, but with a different magnitude (Table 2). The most frequently mentioned elements of AM in the reviewed literature were lack of contextualizing interventions (20%) followed by explicit trade-offs (17%) and negotiation and feedback (13%). Although elements of AM are not mutually exclusive, the above trends show where the future focus of investment of land and water management should be. Overall, these gaps can be summarized as follows: (i) insufficient knowledge management efforts, particularly in relation to evidence-based contextualization of interventions, and continuous post-intervention monitoring of bio-physical and socioeconomic changes, (ii) lack of evidence of trade-off analysis and implementation of management options, (iii) inadequacy of local community engagement at the onset of interventions and provision of feedback mechanisms as implementation evolves, and (iv) information gaps on the outcome and impact estimation and how land and water management intervention transform local community livelihoods across space and time.

Against this background, we conclude that planning and implementation of interventions to transform agricultural landscapes for improved ecosystem services needs structured decision support and continuous learning tools, which are currently limited in Ethiopia and many SSA. Given the many uncertainties we must deal with (e.g., impacts of climate change), land and water management intensification should not follow a business-as-usual approach. Addressing the identified gaps will help to attain sustainability of land and water management interventions and to ensure that the people's needs are met now and in the future. For this to happen, SSA and specifically Ethiopia, the focus of this review, need to follow an AM approach in landscape transformation. While application of AM is a useful tool to guide natural resources decision-making, it is not an end by itself. It is rather a means for informed decisions. The success in SSA depends, among other things, on how AM is tailored to context (social, environmental, and economic) and the ability to learn from the knowledge generated and apply the learning as implementation evolves and the measure of its success should be how well it helps meet sustainable landscape transformation goals across the scale.

Author Contributions: This paper is an output from concerted efforts of all co-authors. Conceptualization—A.H.; methodology—A.H., W.M., P.S.; writing original draft—A.H., W.B.; review and editing and visualization (S.U., E.L., P.S.). All authors have read and agreed to the published version of the manuscript.

Funding: The authors are grateful for financial support from the Coordinated Research Program Water, Land and Ecosystem (WLE) of the CGIAR and Growth for future program II: Natural resources management for resilience and economic development in rural Ethiopia project financed by Swedish International Development Cooperation Agency (SIDA).

Acknowledgments: We would like to thank Jennie Barron who reviewed the draft manuscript, and we recognize members of the agricultural water management platform in Ethiopia for their constructive comments during the conceptualization of this review.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Lal, R. Soil conservation and ecosystem services. *Int. Soil Water Conserv. Res.* **2014**, *3*, 36–47. [CrossRef]
2. Dumanski, J. Evolving concepts and opportunities in soil conservation. *Int. Soil Water Conserv. Res.* **2015**, *3*, 1–14. [CrossRef]
3. Vanwalleghem, T.; Gómez, J.A.; Amate, J.I.; González de Molina, M.; Vanderlinden, K.; Guzmán, G.; Giráldez, J.V. Impact of historical land use and soil management change on soil erosion and agricultural sustainability during the Anthropocene. *Anthropocene* **2017**, *17*, 13–29. [CrossRef]
4. Hurni, H.; Tato, K.; Zeleke, G. The implications of changes in population, land use, and land management for surface runoff in the Upper Nile Basin area of Ethiopia. *Mt. Res. Dev.* **2005**, *25*, 147–154. [CrossRef]
5. Nkonya, E.; Mirzabaev, A.; Von Braun, J.; Mirzabaev, A.; Von Braun, Á.J.; Von Braun, J. *Economics of Land Degradation and Improvement: An Introduction and Overview*; Springer Open: Berlin/Heidelberg, Germany, 2016; ISBN 978-3-319-19168-3.
6. Food and Agriculture Organization of the United Nations (FAO). *Highlands Reclamation Study Ethiopia Final Report*; FAO: Rome, Italy, 1986; Volume I, pp. 135–231.
7. Sutcliffe, J.P. *Economic Assessment of Land Degradation in the Ethiopian Highlands*; National Conservation Strategy Secretariat, Ministry of Planning and Economic Development: Addis Ababa, Ethiopia, 1993.
8. Haileslassie, A.; Priess, J.; Veldkamp, E.; Lesschen, J.P. Smallholders' soil fertility management in the Central Highlands of Ethiopia: Implications for nutrient stocks, balances and sustainability of agroecosystems. *Nutr. Cycl. Agroecosys* **2006**, *75*, 135–146. [CrossRef]
9. Yirga, C.; Hassan, R.M. Social costs and incentives for optimal control of soil nutrient depletion in the central highlands of Ethiopia. *Agric. Syst.* **2010**, *103*, 153–160. [CrossRef]
10. Adimassu, Z.; Langan, S.; Johnston, R.; Mekuria, W.; Amede, T. Impacts of soil and water conservation practices on crop yield, run-off, soil loss and nutrient loss in Ethiopia: Review and synthesis. *Environ. Manag.* **2017**, *59*, 87–101. [CrossRef]
11. Bojo, J.; Cassells, D. *Land Degradation and Rehabilitation in Ethiopia: A Reassessment*; AFTES Working Paper No. 17; The World Bank: Washington, DC, USA, 1995; pp. 1–41.

12. Gebreselassie, S.; Kirui, O.K.; Mirzabaev, A. Economics of land degradation and improvement in Ethiopia. In *Economics of Land Degradation and Improvement—A Global Assessment for Sustainable Development*; Nkonya, E., Mirzabaev, A., von Braun, J., Eds.; Springer: Berlin/Heidelberg, Germany, 2016; p. 683.
13. World Bank. *Federal Democratic Republic of Ethiopia—Priorities for Ending Extreme Poverty and Promoting Shared Prosperity: Systematic Country Diagnostic*; World Bank: Addis Ababa, Ethiopia, 2016; pp. 2–29.
14. Haregeweyn, N.; Tsunekawa, A.; Nyssen, J.; Poesen, J.; Tsubo, M.; Tsegaye, M.D.; Tegegne, F. Soil erosion and conservation in Ethiopia: A review. *Prog. Phys. Geog.* **2015**, *39*, 750–774. [CrossRef]
15. Sayer, J.A.; Margules, C.; Boedhihartono, A.K.; Sunderland, T.; Langston, J.D.; Reed, J.; Purnomo, A. Measuring the effectiveness of landscape approaches to conservation and development. *Sustain. Sci.* **2017**, *12*, 465–476. [CrossRef]
16. Birgé, H.E.; Allen, C.R.; Garmestani, A.S.; Pope, K.L. AM for ecosystem services. *Jenvman* **2016**, *183*, 343–352. [CrossRef]
17. Webb, J.A.; Watts, R.J.; Allan, C.; Warner, A.T. Principles for Monitoring, Evaluation, and AM of Environmental Water Regimes. In *Water for the Environment*; Avril, C., Horne, J., Angus, W., Michael, J., Stewardson, B.R., Mike, A., Eds.; Elsevier: Amsterdam, The Netherlands; Academic Press: Cambridge, MA, USA, 2017; pp. 599–623.
18. Zonneveld, I.S.; Forman, R.T.T. *Changing Landscape: An Ecological Perspective*; Springer: New York, NY, USA, 1990; p. 73.
19. Hermann, A.; Schleifer, S.; Wrbka, T. The Concept of Ecosystem Services Regarding Landscape Research: A Review. *Living Rev. Landsc. Res.* **2011**, *5*, 1–37. [CrossRef]
20. Forman, R.T.T.; Godron, M. *Landscape Ecology*; John Wiley & Sons: New York, NY, USA, 1986; p. 620.
21. Marshall, E.J.P. Agricultural landscapes field margin habitats and their interaction with crop production. *J. Crop. Improv.* **2008**, *12*, 365–404. [CrossRef]
22. Nyssen, J.; Frankl, A.; Haile, M.; Hurni, H.; Descheemaeker, K.; Crummey, D.; Poesen, J. Environmental conditions and human drivers for changes to north Ethiopian mountain landscapes over 145 years. *Sci. Total. Environ.* **2014**, *1*, 64–179. [CrossRef]
23. Helming, K.; Perez-soba, P.; Tabbush, P. *Sustainability Impact Assessment of Land Use Change*; Springer: Berlin/Heidelberg, Germany, 2008; p. 262.
24. Skokanová, H.; Eremiášová, R. Changes in the secondary landscape structure and their connection with ecological stability: The cases of two model areas in the Czech Republic. *Ekológia (Bratislava)* **2012**, *31*, 33–45. [CrossRef]
25. Gális, M.; Galková, J.; Straňák, J. Impact of secondary landscape structures on the presence of non-native plant species in the cadastral area of the Topol'čany town. *Ekologia (Bratislava)* **2016**, *35*, 136–147. [CrossRef]
26. Gadisa, C. Historical perspectives and present scenarios of watershed management in Ethiopia. *Ijnrem* **2016**, *3*, 115–127.
27. Mekuria, W.; Gebregziabher, G.; Lefore, N. *Exclosures for Landscape Restoration in Ethiopia: Business Model Scenarios and Suitability*; IWMI research report 175; International Water Management Institute (IWMI): Colombo, Sri Lanka, 2020; pp. 7–27.
28. Tadesse, L.; Suryabhagavan, K.V.; Sridhar, G.; Legesse, G. Land use and land cover changes and soil erosion in Yezat watershed, North Western Ethiopia. *Int. Soil Water Conserv. Res.* **2017**, *5*, 85–94. [CrossRef]
29. Stirzaker, R.J.; Roux, D.J.; Biggs, H.C. Learning to bridge the gap between AM and organisational culture. *Koedoe* **2011**, *53*, 1–6. [CrossRef]
30. Lambin, E.F.; Turner, B.L.; Geist, H.J.; Agbola, S.B.; Angelsen, A.; Bruce, J.W.; Xu, J. The causes of land-use and land-cover change: Moving beyond the myths. *Global Environ. Chang.* **2001**, *11*, 261–269. [CrossRef]
31. Kindu, M.; Schneider, T.; Teketay, D.; Knoke, T. Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands. *Sci. Total. Environ.* **2016**, *547*, 137–147. [CrossRef]
32. Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W.; Tolessa, T.; Kindu, M. Estimating the impacts of land use/land cover changes on Ecosystem Service Values: The case of the Andassa watershed in the Upper Blue Nile basin of Ethiopia. *Ecosyst. Serv.* **2018**, *31*, 219–228. [CrossRef]
33. Deribew, K.T.; Dalecho, D.W. Land use and forest cover dynamics in the North-eastern Addis Ababa, central highlands of Ethiopia. *Environ. Syst. Res.* **2019**, *8*, 8. [CrossRef]

34. Gebremichael, T.G.; Mohamed, Y.A.; Betrie, G.D.; van der Zaag, P.; Teferi, E. Trend analysis of runoff and sediment fluxes in the Upper Blue Nile basin: A combined analysis of statistical tests, physically based models and land-use maps. *J. Hydrol.* **2013**, *482*, 57–68. [CrossRef]
35. United Nations Convention to Combat Desertification (UNCCD). *Land and Soil in the Context of a Green Economy for Sustainable Development, Food Security and Poverty Eradication*; UNCCD: Bonn, Germany, 2011.
36. Teferi, E.; Bewket, W.; Uhlenbrook, S.; Wenninger, J. Understanding recent land use and land cover dynamics in the source region of the Upper Blue Nile, Ethiopia: Spatially explicit statistical modeling of systematic transitions. *Agric. Ecosyst. Environ.* **2013**, *165*, 98–117. [CrossRef]
37. Desalegn, T.; Cruz, F.; Kindu, M.; Turrión, M.B.; Gonzalo, J. Land-use/land-cover (LULC) change and socioeconomic conditions of local community in the central highlands of Ethiopia. *Int. J. Sust Dev. World.* **2014**, *21*, 406–413. [CrossRef]
38. Franks, P.; Hou-Jones, X.; Fikreyesus, D.; Sintayehu, M.; Mamuye, S.; Danso, E.Y.; Meshack, C.K.; McNicol, I.; Soesbergen, A.V. *Reconciling Forest Conservation with Food Production in Sub-Saharan Africa: Case Studies from Ethiopia, Ghana and Tanzania*; Research Report; International Institute for Environment and Development (IIED): London, UK, 2017; pp. 17–39.
39. Bachewe, F.; Berhane, G.; Minten, B.; Taffesse, A.S. Agricultural Transformation in Africa? Assessing the Evidence in Ethiopia. *World Dev.* **2018**, *105*, 286–298. [CrossRef]
40. Kibret, K.S.; Marohn, C.; Cadisch, G. Assessment of land use and land cover change in South Central Ethiopia during four decades based on integrated analysis of multi-temporal images and geospatial vector data. *Rsase* **2016**, *3*, 1–19. [CrossRef]
41. Headey, D.; Dereje, M.; Taffesse, A.S. Land constraints and agricultural intensification in Ethiopia: A village-level analysis of high-potential areas. *Food Policy* **2014**, *48*, 129–141. [CrossRef]
42. Mulu, G.; Birhanu, B.; Girum, A. *Foreign Direct Investment in Ethiopia: Challenges, Opportunities and Policy Options for Effective Use to Stimulate Industrialization*; Policy Study and Research Center: Addis Ababa, Ethiopia, 2017; pp. 30–70.
43. Bossio, D.; McCartney, M.; Erkossa, T.; Dile, Y.; Killiches, F.; Hoff, H. Water implications of foreign direct investment in Ethiopia's agricultural sector. *Water Altern.* **2012**, *5*, 223–242.
44. Teklu, B.M.; Adriaanse, P.I.; Ter Horst, M.M.S.; Deneer, J.W.; Van den Brink, P.J. Surface water risk assessment of pesticides in Ethiopia. *Sci. Total. Environ.* **2015**, *508*, 566–574. [CrossRef]
45. Seyoum, Y. Forest landscape restoration experiences in Ethiopia. In Proceedings of the First Regional Conference of the African Forest Landscape Restoration Initiative, Addis Ababa, Ethiopia, 11–12 October 2016; pp. 18–34.
46. Lemenih, M.; Kassa, H. Re-greening Ethiopia: History, challenges, and lessons. *Forests* **2014**, *5*, 1896–1909. [CrossRef]
47. Dagnew, D.C.; Guzman, C.D.; Akale, A.T.; Tebebu, T.Y.; Steenhuis, T. Effects of land use on catchment runoff and soil loss in the sub-humid Ethiopian highlands. *Ecohydrol. Hydrobiol.* **2017**, *17*, 274–282. [CrossRef]
48. Zegeye, A.; Eddy, J.L.; Tammo, S.; Steenhuis, M.W.; Tilahun, A. Bank stability and toe erosion model as a decision tool for gully bank stabilization in sub humid Ethiopian highlands. *Ecohydrol. Hydrobiol.* **2020**, *20*, 301–311. [CrossRef]
49. Addisie, M.; Eddy, J.L.; Dessalew, W.A.; Getaneh, K.A.; Seifu, A.T.; Petra, S.; Mekuria, W.; Mikael, M.M.; Tammo, S.S. Assessment of practices for controlling shallow valley-bottom gullies in the sub-Humid Ethiopian Highlands. *Water* **2018**, *10*, 389. [CrossRef]
50. Gowing, J.; Parkin, G.; Forsythe, N.; Walker, D.; Haile, A.T.; Alamirew, D. Shallow groundwater in sub-Saharan Africa: Neglected opportunity for sustainable intensification of small-scale agriculture. *Hydrol. Earth Syst. Sci. Discuss.* **2016**, *2015*, 2549. [CrossRef]
51. Worqlul Abeyou, W.; Jaehak, J.; Yihun, T.; Dile, J.O.; Petra, S.; Thomas, G.; Srinivasan, R.; Neville, C. Assessing Potential Land Suitable for Surface Irrigation Using Groundwater in Ethiopia. *Appl. Geogr.* **2017**, *85*, 1–13. [CrossRef]
52. Girmay, G.; Singh, B.R.; Nyssen, J.; Borrosen, T. Runoff and sediment associated nutrient losses under different land uses in Tigray, northern Ethiopia. *J. Hydrol.* **2009**, *376*, 70–80. [CrossRef]
53. Mekuria, W.; Langan, S.; Johnston, R.; Belay, B.; Amare, D.; Gashaw, T.; Desta, G.; Noble, N.; Wale, A. Restoring above-ground carbon and biodiversity: A case study from the Nile basin, Ethiopia. *Forest Sci. Technol.* **2015**, *11*, 86–96. [CrossRef]

54. Mekuria, W.; Langan, S.; Noble, A.; Johnston, R. Soil restoration after seven years of exclosure management in north-western Ethiopia. *LDD* **2017**, *28*, 1287–1297.
55. Aynekulu, E.; Mekuria, W.; Tsegaye, D.; Feyissa, K.; Angassa, A.; Leeuwa, J.; Shepherd, K. Long-term livestock exclosure did not affect soil carbon in southern Ethiopian rangelands. *Geoderma* **2017**, *307*, 1–7. [CrossRef]
56. Haregeweyn, N.; Tsunekawa, A.; Poesen, J.; Tsubo, M.; Meshesha, D.T.; Fenta, A.A.; Adgo, E. Comprehensive assessment of soil erosion risk for better land use planning in river basins: Case study of the Upper Blue Nile River. *Sci. Total. Environ.* **2017**, *574*, 95–108. [CrossRef] [PubMed]
57. Tefera, M.; Demel, T.; Hultén, H.; Yemshaw, Y. The role of communities in closed area management in Ethiopia. *Mt. Res. Dev.* **2005**, *25*, 44–50. [CrossRef]
58. Rämi, H. *Ponds Filled with Challenges*; UN OCHA: Addis Ababa, Ethiopia, 2003; pp. 1–25.
59. Mume, J. Impacts of rain-water-harvesting and socioeconomic factors on household food security and income in moisture stress areas of Eastern Hararghe, Ethiopia. *Int. J. Novel Res. Marketing Manag. Econ.* **2014**, *1*, 10–23.
60. Gebremedhin, B.; Tesfamichael, G.; Kristine, M.; Walraevens, K. Overview of micro-dam reservoirs (MDR) in Tigray (northern Ethiopia): Challenges and benefits. *J. Afr. Earth Sci.* **2016**, *123*, 210–222.
61. Hagos, F.; Group, C.; Erkossa, T.; Water, I. Economics of selected water control technologies and their successful use: The case of Ethiopia. *Ethiop. J. Agric. Sci.* **2013**, *23*, 41–59.
62. Zingiro, A.; Okello, J.J.; Guthiga, P.M. Assessment of adoption and impact of rainwater harvesting technologies on rural farm household income: The case of rainwater harvesting ponds in Rwanda. *Environ. Dev. Sustain.* **2014**, *16*, 1281–1298. [CrossRef]
63. Sheahan, M.; Barrett, C.B. Ten striking facts about agricultural input use in Sub-Saharan Africa. *Food Policy* **2017**, *67*, 12–25. [CrossRef]
64. Parry, K.; van Rooyen, F.A.; Bjornlund, H.; Kissoly, L.; Moyo, M.; Sousa, W. The Importance of Learning Processes in Transitioning Small-Scale Irrigation Schemes. *Int. J. Water Resour. Dev.* **2020**. [CrossRef]
65. Berhane, G.; Hoddinott, J.; Kumar, N.; Margolies, A. *The Impact of the Productive Safety Net Programme on Schooling, Child Labour, and the Nutritional Status of Children in Ethiopia*; The International Initiative for Impact Evaluation: New Delhi, India, 2017; pp. 9–61.
66. Dagnew, D.C.; Guzman, C.; Zegeye, A.; Akal, A.T.; Moges, M.A.; Tebebu, A.T.; Mekuria, W.; Ayana, E.K.; Tilahun, S.A.; Steenhuis, T.S. Sediment loss patterns in the sub-humid Ethiopian Highlands. *LDD* **2017**, *28*, 1795–1805. [CrossRef]
67. Zegeye, A.; Tammo, S.S.; Mekuria, W.; Dagnaw, D.; Addisse, M.; Tilahun, S.; Kasse, T. Effect of Gully Headcut Treatment on Sediment Load and Gully Expansion in the Sub Humid Ethiopian Highlands. *Environ. Ecol. Res.* **2017**, *5*, 138–144. [CrossRef]
68. Haileslassie, A.; Craufurd, P.; Thiagarajah, R.; Kumar, S.; Whitbread, A.; Rathor, A.; Blummel, M.; Ericsson, P.; Kakumanu, K. Empirical evaluation of sustainability of divergent farms in the dryland farming systems of India. *Ecol. Indic.* **2016**, *60*, 710–723. [CrossRef]
69. Kibret, K.S.; Haileslassie, A.; Mekuria, B.W.; Schmitter, P. Multicriteria Decision-Support System to Assess the Potential of Exclosure-Based Conservation in Ethiopia. *Renew Agric. Food Syst.* **2020**, 1–15. [CrossRef]
70. Woolf, D.; Jirka, S.; Milne, E.; Easter, M.; De Gloria, S.; Solomon, D.; Lehmann, J. Climate change mitigation Potential of Ethiopia's Productive Safety-Net Program (PSNP). In *A World Bank Climate Smart Initiative (CSI) Report*; Cornell Universit: Ithaca, NY, USA, 2015; pp. 50–72.
71. Anwar, A.; Mekuria, W.; Belay, Y.; Tilahun, S.; Tammo, S. Exclosures improve degraded landscapes in the sub-humid Ethiopian Highlands: The Ferenj Wuha watershed. *Jenvman* **2020**, *270*, 110802.