RUFORUM Working Document Series (ISSN 1607-9345) 2021, No. 19 (1):639-647.
Available from httpp://repository.ruforum.org

Research Application Summary

Tempo-spatial ecosystem service delivery variations of landscape restoration practices in Ethiopia

Biratu, A.A.,[1,2] Bedadi, B.,[1] Gebrehiwot, S.G.[3,4] Hordofa, T.,[2] Asmamaw, D.K.[5] & Melesse, A.[6]

[1]Haramaya University, College of Agriculture and Environmental Science, Haramaya Ethiopia,
[2]Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia
[3]Ethiopian Institute of Water Resource, Addis Ababa University, Addis Ababa, Ethiopia
[4]Water and Land Resource Center, Addis Ababa University, Addis Ababa, Ethiopia
[5]Ghent University, Soil Physics Research Group, Belgium and Bahir Dar University, Ethiopia
[6]Florida International University, USA
***Corresponding author:** aberaassefa@gmail.com

Abstract

Land degradation and impairment of ecosystem services (ES) have been a serious problem in Ethiopia, due to excessive pressure on and improper use of land and water resources. Thus, various land management (LM) practices have been implemented to enhance ecosystem service and environmental sustainability. However, very little is known about the influence of efficacious land management practices on multiple ecosystem service. This paper assesses the implication of land management practices on crop yield, soil carbon stock, soil fertility, soil moisture, runoff, soil loss, nutrient loss, and cultural/societal services. A systematic review and synthesis methods were employed. Accordingly, different search engines were used to search and access published articles. Then, predefined criteria were used to screen relevant articles, where 571 observations from 92 studies were extracted and synthesized. The results showed that agronomic practices were increased grain yields, soil carbon stock, soil fertility, and soil moisture on average by 27.6%, 29.47%, 43.36%, and 14.26%, respectively. Biological practices also regulated runoff, soil loss, and nutrient loss on average by 45.81%, 59.47%, and 93.55%, respectively. Overall, land management practices efficacious to enhance bundle ecosystem service delivery but soil bund and fanyaa juu reduced grain yields on average by 24.4% and 21.9%, respectively. This indicates that there are a trade-offs between provisioning and other services like regulating, supporting and cultural practices under physical structures. Furthermore, land management practices were used to deliver ecosystem service at different times, positions and spatial scales. The integration of properly designed physical structures with agronomic and biological practices is imperative to enhance ecosystem service and balance the trade-offs in the agricultural landscapes. Further, it is important to find out a combination of alternative agricultural land management practices and their impacts on bundle ecosystem services at different temporal and spatial scales.

Keywords: Agroecosystems, Ethiopia, grain yields, land management, trade-offs

Résumé

La dégradation des terres et la dégradation des services écosystémiques (SE) ont été un problème grave en Éthiopie, en raison d'une pression excessive et d'une mauvaise utilisation des terres et des ressources en eau. Ainsi, diverses pratiques de gestion des terres (LM) ont été mises en œuvre pour améliorer les services écosystémiques et la durabilité environnementale. Cependant, on sait très peu de choses sur l'influence des pratiques efficaces de gestion des terres sur les multiples services écosystémiques. Cet article évalue l'implication des pratiques de gestion des terres sur le rendement des cultures, le stock de carbone du sol, la fertilité du sol, l'humidité du sol, le ruissellement, la perte de sol, la perte de nutriments et les services culturels/sociétaux. Une revue systématique et des méthodes de synthèse ont été employées. En conséquence, différents moteurs de recherche ont été utilisés pour rechercher et accéder aux articles publiés. Ensuite, des critères prédéfinis ont été utilisés pour filtrer les articles pertinents, où 571 observations de 92 études ont été extraites et synthétisées. Les résultats ont montré que les pratiques agronomiques augmentaient les rendements en grains, le stock de carbone du sol, la fertilité du sol et l'humidité du sol en moyenne de 27,6 %, 29,47 %, 43,36 % et 14,26 %, respectivement. Les pratiques biologiques ont également régulé le ruissellement, la perte de sol et la perte de nutriments en moyenne de 45,81 %, 59,47 % et 93,55 %, respectivement. Dans l'ensemble, les pratiques de gestion des terres sont efficaces pour améliorer la fourniture de services écosystémiques groupés, mais la digue du sol et le fanyaa juu ont réduit les rendements céréaliers en moyenne de 24,4 % et 21,9 %, respectivement. Ceci indique qu'il existe un compromis entre l'approvisionnement et d'autres services tels que la régulation, le soutien et les pratiques culturelles dans les structures physiques. En outre, les pratiques de gestion des terres ont été utilisées pour fournir des services écosystémiques à différents moments, positions et échelles spatiales. L'intégration de structures physiques correctement conçues avec des pratiques agronomiques et biologiques est impérative pour améliorer les services écosystémiques et équilibrer les compromis dans les paysages agricoles. En outre, il est important de découvrir une combinaison de pratiques alternatives de gestion des terres agricoles et leurs impacts sur les services écosystémiques groupés à différentes échelles temporelles et spatiales.

Mots-clés : Agroécosystèmes, Éthiopie, rendements céréaliers, gestion des terres, compromis

Introduction

Landscape restoration practices have been implemented by government and non-governmental organizations since the 1970s following the drought and starvation incident that threatened the northern parts of Ethiopia. After the incident of drought and starvation the Government of Ethiopia and international donors affirmed land degradation as the root cause of the rampant poverty and famine. As a result, several policies and legislations were developed to prioritize environmental protection for sustainable agriculture and economic growth in Ethiopia. For instance, forty years ago, soil conservation research program (SCRP), food for work program (FFW) and several other land restoration initiatives were launched and undertaken to tackle land degradation. Indeed, SCRP was an exemplary initiative and efforts were made to test, evaluate and adopt imported land management practices at plot/field level and in seven watersheds (Anjeni, Maybar, Andit-Tid, Dizi, and Hunde-Lafto) in the country.

Several efforts have been made through rehabilitation program and landscape restoration practices studies are still being done. Landscape restoration practices that have been widely implemented and studied in agricultural landscapes can be grouped as: physical structures, agronomic practices, and biological practices. Accordingly, conservation tillage (CT), mulch, ridge, and manure are categorized as the array of agronomic practices. Level/graded soil bunds, level/graded fanya juu and stone bunds are categorized as the array of physical structures, whereas grass strip, exclosure, and agroforestry are biological practices. However, additional efforts are still needed to study their efficiency and impacts considering different environment systems at different spatial scales in all agro-ecologies of Ethiopia.

Contemporary studies exhibited trade-offs between ecosystem services provision and production of food crops where agriculture is rainfed, smallholder and less intensive. As a result, the production of enough food crops to feed the ever-growing population without adversely affecting ecosystems health has taken as the priority agenda and important concern in

Ethiopia. In addition, WLE (2014); DeClerck *et al*. (2017) and Wood *et al*. (2018) indicated that targeting the trade-offs between crop production and regulating as well as supporting services in the agricultural landscape is mandatory to achieve sustainable development goals (SDG) (2, 6, 13, 14 and 15).

Approaches followed to assess bundle Ecosystem Service delivery

In order to know the implication of landscape restoration practices on the delivery of bundle ES systematic experiment-based review and synthesis method was employed. MEA classification of ES was followed to classify and identify response variables (MEA, 2005). Hence crop yields, soil loss, runoff, nutrient loss (TN, Ava P and OM), soil nutrients retention (TN, Ava P and OM), soil moisture, and SOC stock were taken as response variables. Key search words or search-strings were used to find published articles for review and synthesis. List of landscape restoration practices such as 'level soil bund', 'level fanya juu', 'graded soil bund', 'graded fanya juu', 'stone bund', 'grass strip', 'agroforestry', 'exclosure', 'CT', 'mulch', 'tied-ridge' and 'manure' that related with Ethiopia were used as search-strings. Predefined criteria were used to screen relevant articles, and 561 observations from 82 studies were extracted and synthesized. The relative mean difference in (%) for response variables at field scale were calculated based on the following formula:

$$\text{Relative mean difference} \quad (\%) = [(\text{treatment mean} - \text{control mean})/\text{control mean}] \times 100$$

Result and Discussion

Landscape scale restoration for bundle delivery. Studies conducted so far to assess the collective impact of land management practices on ecosystem service at landscape scale level are presented in Table 1. Results are from studies conducted based on before and after land management practices as well as comparing two nested landscapes (treated and non-treated) analysis approaches.Various types of land management practices were implemented at different positions and conditions of the landscapes. As a result, different types and magnitudes of ecosystem service were observed across studied landscapes (Table 1). Similarly, several studies indicated the factors that determine the variability of ecosystem service in the landscapes after land management practices implementation of land management practices. These factors include density of physical structures, rainfall variability, size of the landscapes, landscape positions where land management practices were operated, the type of land management practices, and quality of implemented land management practices. The land management practices, population density, and land use changes alter ecosystem services at the landscape scale. Commonly, landscape-scale studies have only documented the collective impact of all land management practices implemented at landscape levels. This makes its difficult to identify the contribution of each practice explicitly at the landscape scale.

Field scale impact of land restoration practices on Ecosystem Services delivery. Here the combined average results of pilot-scale studies were used and presented using a radar graph (Figure 1). The combined results of reviewed studies on different land management practices were based on their category under the array of agronomic and/or physical structures on the ecosystem service trade-offs and side benefits. Thus, the combined average results presented were based on 323 (56%) and 215 (37.3%) observations of the array of agronomic and physical structures of land management, respectively.

Table 1. The impacts on Ecosystem Service after Land Management practices implementation at the landscape scale

Study area	ES delivery after LM practices
Abreha-Weatsbeha	• About 80-100 % of soil erosion reduced • Soil moisture and biodiversity increased • Groundwater level increased by 1.5 m • Staple crop yield increased by 1.21 t h^{-1} • Fodder availability improved by 100 %
Sero	• Groundwater recharge and streamflow increased • Crop yield increased on average by 1.55 t h^{-1} • Biodiversity increased
Dibdibo,	• Both surface and groundwater increased
Mariam Shewito	• Groundwater level increased by 1m • Sedimentation in the dam decreased by 60 %
May Demu	• Both surface and groundwater increased
Gerebshelela	• Availability of fodder increased by 80 % • Staple crop increased by 5-20 % • Soil erosion reduced by 50 %
Bechyti	• Availability of fodder increased by 50 % • Staple crop yields increased by 250 % • Soil erosion reduced by 60 %
Goho-Cheri	• Availability of fodder increased by 60 % • Staple crop yields increased by 20-50 % • Soil erosion reduced by 75 %
Kereba	• Availability of fodder increased by 95 % • Staple crop yields increased by 200 % • Soil erosion reduced by 90 %
Bedesa Kela	• Availability of fodder increased by 50 % • Staple crop yields increased by 5-20 % • Soil erosion reduced by 35 %
Debre Mawi	• Runoff and sediment loss reduced by 50 %
May Zeg-zeg	• Runoff coefficients reduced by 11.6 % • Soil loss decreased by 21 % • Reduction of direct runoff volume by 81 % • Water balance of the catchment positively influenced • Ground water table and base flow increased
Mendae	• Runoff reduced by 9.69 % • Groundwater recharge is increased by 17.6 %
Gumara-Maksegnit	• Sediment yield reduced by 28-38% • Direct runoff reduced by 19%
Agula	• Direct runoff reduced by 84% • Base flow improved by 55% • The soil storage increased by two-fold
Alekit	• Direct runoff decreased by 43.87% • Base flow increased by 48% • Sediment yield decreased by 69% • Losses of P reduced by 99 % • Losses of N reduced by 67.7 %
WS1-Shewa	• Discharge reduced by 44.39 % • Soil loss reduced by 74.36 %

Among regulating services, water purification refers to the regulation of nutrient losses (OM, TN, and Ava. P), runoff and soil erosion regulation and SOC stock. Based on Haile *et al.* (2006) and UNESCO (2011) the contribution of physical structure for cultural heritage services was estimated as 75% but agronomic and biological practices contributed up to 25%. Yield improvement and soil fertility, as well as soil moisture storage, represent for provisioning and supporting services, respectively. The negative results were taken as zero to simplify display on the graph.

Each land management practice has a different contribution to ecosystem service delivery. The radar graph showed that physical structures have reduced crop production but have a positive impact on regulating and supporting social services. On the other hand, agronomic practices have a positive impact on provisioning, regulating, supporting but not on social services. However, physical and agronomic practices generally increase SOC stock. Biological and agronomic practices were by far better than physical structures to regulate climate change impact via carbon sequestration.

In addition, soil fertility improvement appears much higher under agronomic practices than physical structures. The capacity of biological practices to improve water quality and reduce nutrients that pollute water bodies also appears much higher than physical structures and agronomic practices.

Therefore, the integration of physical and agronomic practices is not a choice but a must to balance the observed ecosystem service trade-offs and achieve SDG. These observations suggest that ecosystem service trade-offs analysis is important for increasing agricultural production and environmental protection.

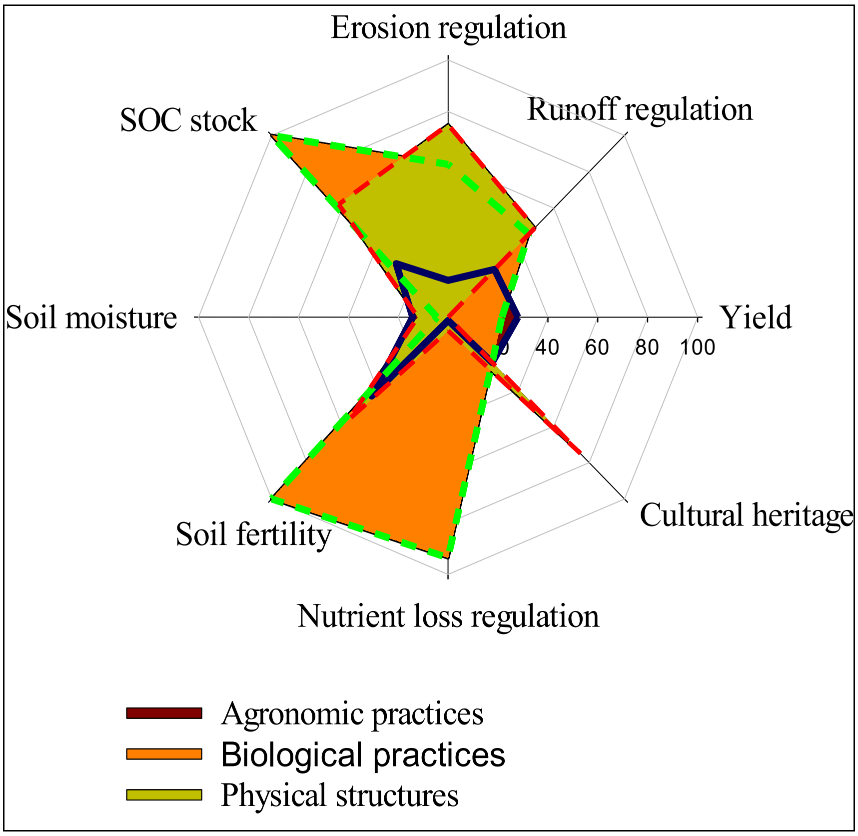

Figure 1. Radar graph reflecting the percentage of Ecosystem Service delivery based on the combined mean results of Land Management practices

Spatio-temporal variations of Ecosyetm Services delivery on landscape restoration practices

In principle, all land management practices are needed to have sustainable benefits over the whole landscapes. However, the mode of ecosystem service delivery due to different land management practices varies at different locations, times as well as spatial scales. The time differences were commonly expressed in the first three, five and ten years after the land management practices were implemented. For instance, the impacts of physical structures except stone bunds were reported to reduce grain yields in the first five years (Adego *et al*., 2012). A study that was done in Tigray revealed increased grain yields of 53% after 3 to 18 years since stone bunds were implemented (Nyssen *et al*., 2007b). Kosmowski (2018) also showed that physical structures mitigated the 2015 drought incidence in semi-arid areas of Ethiopia, after bunds were developed to bench terrace.

Within a decade, stone bunds could reduce the slope by 3% and in the first three years, the slope is reduced by 1% (Nyssen *et al*., 2019). This is due to the soils that are deposited in the stone bund treated land within a short period of time (Nyssen *et al*., 2019). Gebrernichael *et al*. (2005) also indicated that significant amount of eroded soils get trapped in the newly stone bund treated lands. Furthermore, a study conducted in Gojam showed that the capacity of physical structures to prevent soil losses had increased by 28.5% after 15 years and the average grain yields decreased by 10% compared to non-conserved farm (Shiferaw and Holden, 1999). In general, it is possible to conclude that physical structures require some years to influence the whole ecosystem service positively. However, integrated implementation of soil bund and crop rotation has resulted in significant grain yield gains in a short time (2 years); soil fertility may require a longer time (Erkossa *et al*., 2018).

Variations in ecosystem service delivery through time have been observed under conservation tilage practices. A study conducted in Tigray on a conservation tilage system showed that DER+ increased wheat yield after eight years from 2.03 t ha^{-1} to 4.2 t ha^{-1} but after two years it was increased 2.03 t ha^{-1} to 2.76 t ha^{-1} (Araya *et al*., 2015). Soil loss was reduced on average by 50% yr^{-1} after two years and 41.7% yr^{-1} after eight years (Araya *et al*., 2015). The wheat yield increased consistently in the years where DER+ was applied. The long term impact of DER+ is more significant on grain yield increment than runoff and soil loss reduction. Therefore, it is possible to conclude that the conservation tilage systems require some years to provide full benefit (Nyssen *et al*., 2011). Similarly, studies conducted in central rift-valley of Ethiopia indicated that zero tillage reduced grain yields in the first year (Liben *et al*., 2017). However, among the conservation tilage practices, deep tillage using improved tillage implements improved infiltrations and bulk density of the soils and increased grain yields in the first years compared to zero tillage (Hussien *et al*., 2019). Overall, zero tillage was not effective in improving grain yields and Ecosystem Service but the other conservation tilage practices improved all ecosystem service in the first year (Liben *et al*., 2017).

The spatial differences of the impacts of land management practices were observed at onsite, offsite, landscape positions, plot and landscape level. Numerous studies reported the onsite and offsite impacts of land management practices in diverse manners. For instance, Vancampenhout *et al*. (2006) and Adego *et al*. (2012) reported the increment of crop yields at the vicinity of stone bunds. The same studies indicated that the impact of stone bunds on crop yields varied at accumulation, central and erosion zone of plots. In addition, Ava P and

TN were reported to be higher nearby the lower positions of stone bunds. Similarly, Nyssen *et al*. (2008c) indicated that the average grain yields at the lower part of the stone bunds were higher than in the middle and upper parts by 53%. In addition, improvement in hydrological conditions and reduction of siltation risks on the water body were also exhibited as offsite benefits of Stone bunds (Nyssen *et al*., 2019). According to Damene *et al*. (2012), middle, upper and lower positions of the terrace had bulk density values of 1.60 g/cm^3, 1.24 g/cm^3, and 1.21 g/cm^3, respectively. On the other hand, a study conducted in northwestern Ethiopia showed the capacity of physical structures to enable horizontal water flow in the farmland and support crop production under variable rainfall or limited moisture conditions (Adego *et al*., 2012). Similarly, studies conducted in the southern highlands of Ethiopia have reported soil moisture variation at nearby and at a distance of stone bunds (Vancampenhout *et al*., 2006). However, improved tillage implements have enabled uniform distribution of soil moisture in the farms (Kidane *et al*., 2012). The impact of land management practices on soil moisture is not only about the amount of moisture stored in the soil but also the distribution of soil moisture all over the farmland. Indeed, Nyssen *et al*. (2011) revealed that conservation tilage system of DER+ prevent the downstream position from flood risk by reducing runoff on average by 50%. However, a study done to extrapolate and appraise the impact of land management practices on soil loss and runoff at field and landscape level showed different results (Yaekob *et al*., 2020). Offsite damages like river banks erosion and gully erosion might be the possible reasons for the observed soil loss difference between field and landscape scale. Nevertheless there is limited information on field and landscape scale relationships on the type as well as extent of ecosystem service after conservation. However, landscape wide studies are needed to understand the world wide implication of ecosystem service and land management practices implementation (Nyssen *et al*., 2009). This study revealed that the trade-offs exhibited between ecosystem service in field scale studies were not observed in landscape scale studies. This is probably due to the collective impact of land management practices at landscape scale being much higher than at field scale. Therefore, in order to recognize and understand the benefits of land management practices, landscape wide assessment are needed. Effectiveness of land management practices due to biophysical factors might be determined through the integration of various practices. This indicates the importance of combinations between different land management practices for provision of multiple services. The combinations should be economically feasible, technically relevant, socially acceptable, and locally applicable.

Conclusion

The benefits of landscape restoration practices for preserving and enhancing ecosystem service is paramount at field and landscape scale. The reviewed published articles indicated that the potential of agricultural landscapes to deliver bundle ecosystem service is strongly influenced by implemented landscape restoration practices. Landscape scale restoration would enhance ecosystem service synergy and make ‘climate smart’ agricultural landscapes. Besides, the delivery of bundle ecosystem service would vary depending on biophysical factors, density or extent of land management, and technical quality of land management practices implemented in agricultural landscapes. Therefore, proper design and integrated implementation of physical, biological and agronomic practices would be crucial to balance ecosystem service tradeoffs and rehabilitation of degraded lands. By doing so, it is also possible to enhance the provision of multiple ecosystem service to and from agricultural landscapes. In the future, it will be necessary to find out the best combination of different land management practices at different spatio-temporal scales in order to boost the multiple ecosystem service and reduce ecosystem disservices.

Acknowledgement

Funding for this research was provided by the Social and Environmental Trade-offs in African Agriculture (SENTINEL) of the Global Challenges Research Fund (GCRF)-UK through the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), Haramaya University and EIAR. Grant # RU/2019/GTA/DRG/042. This paper is a contribution to the Seventh Africa Higher Education Week and the RUFORUM Triennial Conference held 6-10 December, 2021 in Cotonou, Benin.

Reference

Adego, E., Akalu, T. and Mati, B. 2012. Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjenie watershed, Ethiopia. *Agricultural Water Management* 117: 55-61.

Araya, T., Nyssen, J., Govaerts, B., Baudron, F., Carpentier, L., Bauer, H., Lanckriet, S., Deckers, J. and Cornelis, W. M. 2015. Restoring cropland productivity and profitability in Northern Ethiopian drylands after nine years of resource conserving agriculture. *Experimental Agriculture* 52 (2): 165–187

Damene, S., Tamene, L. and Vlek, L.P. 2012. Performance of farmland terraces in maintaining soil fertility: A case of Lake Maybar watershed in Wello, northern highlands of Ethiopia. J*ournal of Life Sciences* 6 (11): 1251-1261.

DeClerck, F.A., Jones, S.K., Attwood, S., Bossio, D., Girvetz, E., Chaplin-Kramer, B., Enfors, E., Fremier, A.K., Gordon, L.J., Kizito, F. and Noriega, I.L. 2016. Agricultural ecosystems and their services: the vanguard of sustainability?. *Current Opinion in Environmental Sustainability* 23 (1): 92-99.

Erkossa, T., Williams, T. and Laekemariam, F. 2018. Integrated soil, water and agronomic management effects on crop productivity and selected soil properties in Western Ethiopia. I*nternational Soil and Water Conservation Research* 6 (4): 305 - 316.

Gebremichael, D., Nyssen, J., Poesen, J., Deckers, J., Haile, M. Govers, G. and Moeyersons, J. 2005. Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray Highlands, northern Ethiopia. *Soil Use and Management* 21 (3): 287-297.

Haile, M., Herweg, K. and Stillhardt, B. 2006. Sustainable land management. A new approach to soil and water conservation in Ethiopia. Centre for Development and Environment (CDE) and NCCR North-South. 305pp.

Hussein, M.A., Muche, H., Schmitter, P., Nakawuka, P., Tilahun S.A., Langan, S., Barron, J. and Steenhuis, T.S. 2019. Deep tillage improves degraded soils in the (sub) humid Ethiopian Highlands. *Land* 8 (11): 159.

Kidane, D., Temesgen, M. and Abdelkadir, A. 2012. Effect of winged subsoiler and traditional tillage integrated with Fanya Juu on selected soil physico-chemical and soil water properties in the northwestern highlands of Ethiopia. *East African Journal of Sciences* 6 (2): 105-116.

Kosmowski, F. 2018. Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia. *Agricultural Water Management* 204: 11–16

Liben, F.M., Hassen, S.J., Weyesa, B.T., Wortmann, C.S., Kim, H.K., Kidane, M.S., Yeda, G.G. and Beshir, B. 2017. Conservation agriculture for maize and bean production in the Central Rift Valley of Ethiopia. *Agronomy Journal* 109 (6): 2988-2997.

Millennium Ecosystem Assessment (MEA). 2005. Ecosystems and human wellbeing: a synthesis. Washington, DC, USA.

Nyssen, J., Poesen, J. and Deckers, J. 2009. Land degradation and soil and water conservation in tropical highlands. *Soil and Tillage Research* 103 (2): 197-202.

Nyssen, J., Govaerts, B., Araya, T., Cornelis, W.M., Bauer, H., Haile, M., Sayre, K. and Deckers, J. 2011. The use of the Maresha ard plows for conservation agriculture in Northern Ethiopia. *Agronomy for Sustainable Development* 31 (2): 287-297.

Nyssen, J., Poesen, J., Gebremichael D, Vancampenhout, K., Daes, M., Yihdego G, Govers. G., Leirs, H., Moeyersons, J., Naudts, J., Haregeweyn, N, Haile, M. and Deckers, J. 2007b. Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia. *Soil and Tillage Research* 94: 151-163.

Nyssen, J., Gebregziabher, S., Gebremichael, D., Guyassa, E., Deckers, J. and Poesen, J. 2019. Farmland management, tillage and resulting cultivation terraces. pp. 387-402. sIn: Geo-trekking in Ethiopia's Tropical Mountains. Springer, Cham.

Shiferaw, B. and Holden, S. 1999. Soil erosion and smallholder conservation decisions in the Highlands of Ethiopia. *World Development* 27 (4): 739 -752.

United Nations Educational, Scientific and Cultural Organization (UNESCO). 2011. Decisions adopted by the World Heritage Committee at its 35th session. World Heritage Committee, thirty-fifth session. UNESCO Headquarters, Paris, France.

Vancampenhout, K., Nyssen, J., Gebremichael, D., Deckers, J., Poesen, J., Haile, M. and Moeyersons, J. 2006. Stone bunds for soil conservation in the northern Ethiopian highlands: Impacts on soil fertility and crop yield. *Soil and Tillage Research* 90 (1-2): 1-15.

Water, Land, and Ecosystems (WLE). 2014. Ecosystem services and resilience framework. CGIAR Research Program on Water, Land, and Ecosystems. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Wood, S.L., Jones, S.K., Johnson, J.A., Brauman, K.A., Chaplin-Kramer, R., Fremier, A., Girvetz, E., Gordon, L.J., Kappel, C.V., Mandle, L. and Mulligan, M. 2018. Distilling the role of ecosystem services in the Sustainable Development Goals. *Ecosystem Services* 29: 70-82.

Yaekob, T., Tamene, L., Gebrehiwot S.G., Demissie S.S., Adimassu Z., Woldearegay, K., Mekonnen, K., Amede, T., Abera, W., Recha, J.W., Solomon, D. and Thorne, P. 2020. Assessing the impacts of different land uses and soil and water conservation interventions on runoff and sediment yield at different scales in the central highlands of Ethiopia. *Renewable Agriculture and Food Systems* 1–15pp.