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# Restoration Potential of Degraded Agricultural Land in Sub-Saharan Africa: A Review

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**ABSTRACT**

Land degradation is a major challenge affecting the sustainability of agriculture and livestock production systems worldwide. Poor soil and water management practices coupled with unsustainable agricultural practices are known to accelerate land degradation. Globally, approximately 18.1 million km2 of land is degraded, of which 62% is due to unsustainable use of the land and 38% is due to overgrazing. Generally, 20% of the arable land, 30% of forest land, and 10% of grazing land are affected by land degradation. In Sub-Saharan Africa which is 46% grassland, 12% crop land, and 26% forest land. Also, land degradation affects approximately 1.5 billion people. Different restoration strategies have been employed, including restoring natural vegetation cover, agroforestry, sustainable rangeland management, and soil and water conservation practices. However, the adoption and effectiveness of these strategies are low and the problem of land degradation is still increasing. The main objective of this work was to explore potentials for restoring and managing degraded land in Sub-Saharan Africa, focusing on enhancing plant nutrient availability, soil ecological services, and improving soil physical properties such as texture and reducing vulnerability to soil erosion. This review found that there is much potential for the restoration of degraded land in Sub-Saharan Africa (SSA) by assessing, monitoring, and improvement of soil quality. However, these strategies are mostly used for improving crop yield only in most Sab Saharan regions. This paper suggests the use of these technologies for restoring or improving the quality of degraded land in the SSA.

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## Introduction

Land degradation is a major challenge affecting sustainability in agriculture and livestock production systems worldwide. Poor soil and water management practices coupled with unsustainable agricultural practices are known to influence land degradation. Land degradation is associated with the decline in soil biological, chemical, and physical quality and reduces the ability of the soil to provide ecological services. About 65% of the total land is degraded in Sub-Saharan Africa (SSA) affecting social-environmental systems hydrological cycle, and biochemical processes. Land degradation remains an important issue worldwide due to its negative effect on agriculture, environment, and food security [1-8].

Globally, approximately 18.1 million km2 of land is degraded of which 62% is due to unsustainable use of the land and 38% is due to overgrazing. Generally, 20% of the arable land, 30% forests, and 10% grazing land are affected by land degradation, which affects approximately 1.5 billion people. A study done by in Africa reported about 25% of the land was disposed of to water erosion and about 22% to wind erosion. In Sub-Saharan Africa which is 46% grassland, 12% crop land, and 26% forest land. According to 39% of the land in the African continent and as much as 65% of the agricultural land are affected by desertification. Reported that 30% of the land in SSA is degraded by soil erosion, nutrient mining, deforestation, and overgrazing [9-16].

Land degradation has been caused by anthropogenic factors, natural factors, or a combination of both. The high prevalence of land degradation noted here has multiple impacts on rural livelihoods and adaptation capacity for growing crops on degraded land. These natural processes include nutrient cycling, soil erosion control, carbon sequestration, and water regulation. On the other hand, land degradation is progressively derived by deforestation and vegetation cover loss unfavorable government policies on land use and management, insecurity of tenure, overstocking, slash and bush firing, and lack of adequate soil and water conservation interventions. Severe effects of land degradation occurred in Sub-Saharan Africa where most of the people depend on land for their economies. The value of land resources greatly supports various socioeconomic activities such as agriculture, livestock keeping, food production, industrial production, and rural development in most developing countries and also developed countries. Hence any interruptions which affect the ecological services provided by the land will affect the livelihood of the people [10,17-22].

United Nations reported that about one-quarter of the world's land surface is degraded and other 12 million hectares become degraded annually. The annual global cost of land degradation due to land use/cover change (LUCC) and using land degrading management practices on static cropland and grazing land is about 300 billion USD. Sub-Saharan Africa (SSA) accounts for the largest share (22 %) of the total global cost of land degradation. About 46 % of the cost of land degradation due to LUCC which accounts for 78 % of the US$300 billion loss is borne by land users and the remaining share (54 %) is borne by consumers of ecosystem services off the farm such as the high price of food crops. This further illustrates that land degradation is a global problem even though its impact is much greater on poor land users. The cost of taking action against land degradation is much lower than the cost of inaction and the returns to taking action are high. According to an average of one US dollar invested into the restoration of degraded land gives five US dollars in returns. This provides a strong incentive for taking action against land degradation [23].

Different management strategies have been used to reverse land degradation, including restoring natural vegetation cover, soil, and water conservation, and planting drought-resistant shrubs and grasses to help bind the soil and prevent further soil erosion. Others include planting more trees, controlling grazing, building dams, and crop rotation to allow the soil to recover. Most of the techniques are old and have been used for centuries, but land degradation is still increasing throughout the world, particularly in SSA. Currently, there are several different new emerging technologies used in different countries for the restoration of degraded land, however, they have either minimal utilization or even never utilized in some places in SSA countries. In this review paper, we intend to explore potentials for restoring and managing degraded land in Sub-Saharan Africa, focusing on enhancing plant nutrient availability, soil ecological services, and improving soil physical properties such as texture and reducing vulnerability to soil erosion. Then discuss the potential benefits of emerging technologies for a successful plan and implementation of conservation and restoration of degraded land [24,25].

## Methodologies

### Gathering Information

A PRISMA approach was deployed during the systematic search of the materials whereby Boolean operator ("OR" and "AND") with a combination of keywords was set and Scopus, PubMed, and Google Scholar reached via Research4Life databases and university repositories. In addition, article references were cross-checked and saved as the source of studies included in this review. Three databases were searched for relevant articles using the search string ("Land" OR "soil" AND "Restoration" OR "Remediation" OR "Rehabilitation" AND "Degradation" "degradation" AND "Sub-Saharan Africa" OR "Subsaharan Africa" OR "Africa Sub-Saharan" OR "SSA" OR "Africa south of the Sahara" OR "Sub-saharan Africa"). Numerous articles were drawn from the internet as shown in Figure 1. The search was limited from 2000 to 2022 Details on literature relevance using quality assessment, exclusion, and inclusion criteria are shown in Figure 1. In the end, 134 articles were considered in this review based on the selection criteria. In these sources, numerous pieces of knowledge on the restoration of degraded land were discussed. Therefore, results on techniques for restoring degraded land in Sub-Saharan Africa for understanding the potential of small holder farmers were gathered for writing this review paper.

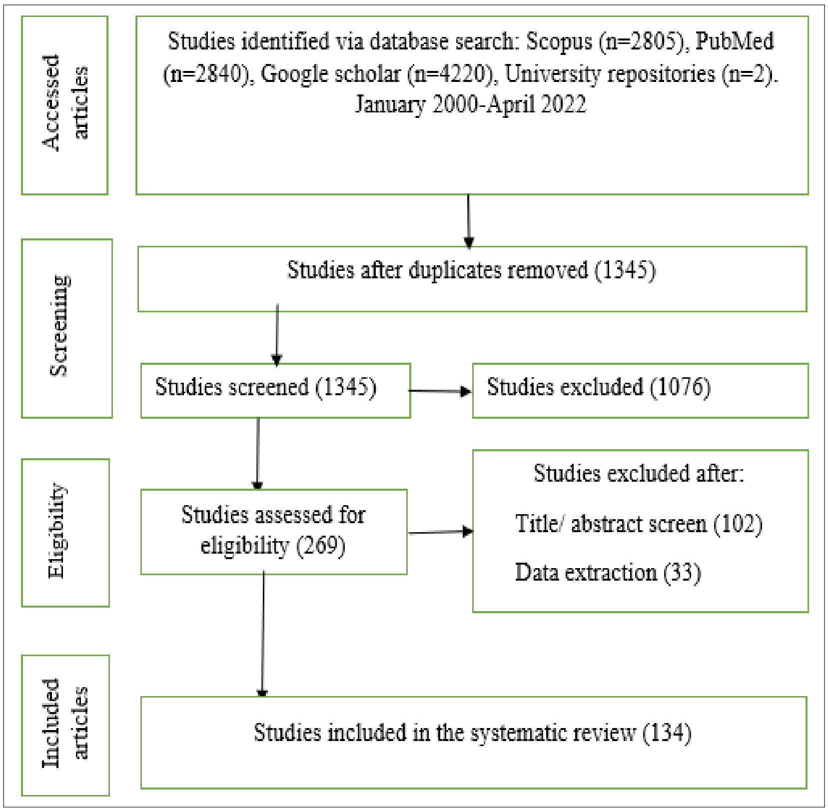

**Figure 1:** Literature Relevance Using Quality Assessment, Exclusion, and Inclusion Criteria

## Types and Main Causes of Land Degradation in Sub-Saharan Africa

### Types of Land Degradation

Studies show three types of land degradation existing in SSA are physical, chemical, and biological land degradation. The major common type of land degradation is physical soil degradation in the form of water and wind erosion. In SSA land degradation in the form of soil erosion has been reported as a more serious problem than in non-tropical areas. For the tropics to experience such severe levels of soil erosion, several reasons have been proposed. They include harsh climate, high erosivity of the soil, predominance of very fragile soils, steep slopes, inadequate land management, and primarily resource-poor farmers who cannot afford to implement conservation measures Although during the 1980s and 1990s, the first narrative that was widely known by policymakers and development organizations operating in SSA was that severe land degradation in the form of soil erosion was caused by ineffective land management brought on by ignorance and a lack of education [3, 26-31].

### Major Causes of Land Degradation

The major causes of land degradation in SSA have been recorded to be overgrazing, deforestation, poor water management, population growth, conflicts and wars with large refugee populations, ineffective soil management, shifting cultivation, unreliable land tenure, variations of climatic conditions, intrinsic characteristics of fragile soils in various agro-ecological zones . It occurs through the interaction between human interaction and the biophysical environment. Biophysical factors including Soil, climate, topography, and vegetation cover play significant roles in the process of soil erosion. For instance, the erodibility of soils is determined by the fundamental characteristics of soils, such as texture, structure, organic matter concentration, clay mineralogy, and water retention properties. The rate of erosion is determined by topographic factors including slope steepness, length, and shape, whereas erosivity is influenced by rainfall features like intensity, amount, and frequency. Although these biophysical forces might interact to cause soil erosion, frequently need the involvement of human activities [3,26,27,29].

Although the land degradation problem is assumed to be known for its severity by the community and the responsible government authorities, the causes, drivers and indicators for this problem are site-specific. Therefore, there is a need to study critical causes and indicators for land degradation in different landscapes for the planning of management of land degradation [32].

### Land Degradation Assessment and Monitoring in SSA

Assessment and monitoring of land degradation are needed by decision-makers for monitoring and planning mitigation measures for sustainable land management practices. More specifically, monitoring land degradation regularly enables decision-makers to assess the impact of degradation and the effects of sustainable land management practices. This requires an effective method for assessing and monitoring land degradation. Using this information, decision-makers set attainable management goals for example; to attain land degradation neutrality by 2030 as addressed by the Sustainable Development Goal - SDG 15 [21,33].

Several methods have been developed by researchers to assess and monitor land degradation such as field observations/ measurements, expert/land manager knowledge, and remote sensing. Traditionally, evaluation of status and trends in agricultural land, productivity is used to assess land degradation. However, this approach is imprecise and is considered biased, since crop productivity can be affected by various factors other than degradation. These include climatic events, rainfall, pest, and diseases [34].

### Land Degradation Surveillance Framework (LDSF)

The LDSF is a geographically stratified, randomized sampling design that was created to offer a biophysical baseline at the landscape level and a framework for monitoring and evaluating the progression of land degradation processes and the efficacy of restoration initiatives. LDSF offers a biophysical assessment and monitoring of the process of land degradation and the effectiveness of rehabilitation strategies for the short and long term. It can also be used as part of a monitoring approach to detect vegetation changes over time. The outputs from the analysis are usually maps of 16 land degradation indicators that are useful in assessing the conditions of a landscape [35,36].

LDSF was developed by the World Agroforestry (ICRAF) in response to the need for consistent field methods and indicator frameworks to assess land health in landscapes. The method was successfully developed during land degradation research in Kenya's Lake Victoria basin, Mali, Southern Africa, and Madagascar. Currently, the framework has been applied in projects across the global tropics and is currently among the largest land health databases globally with more than 30,000 observations [36].

Use the data from a network of 114 LDSF sites (Figure. 1), each covering a 10 by 10 km (100 km2) area, which was surveyed between February 2010 and June 2013 to map soil functional properties and land degradation risk for SSA at a spatial scale of 500 m. Apply LDSF to evaluate the spatial and temporal patterns of indicators of land degradation as the basis for targeting sustainable land management practices. Uses the data collected using LDSF to complement qualitative data from farmers' perception of the study to assess how land degradation has changed over nine years in the Sasumua catchment, Kenya. use LDSF a multi- scale as- assessment of land health in their study which found that vegetation cover and above-ground biomass had strong positive effects on soil health by increasing SOC and reducing soil erosion in East Africa. In their study conducted in Ethiopia integrate LDSF in o develop predictive models and create maps of various indicators of land health that may be used to develop management recommendations [36-40].

Its cost-effectiveness and less time demand are among the advantages of using LDSF in monitoring land degradation and conservation strategies. Reported that through the integration of LDSF and with the development of soil spectroscope and health observation data, it is possible to estimate and map Soil Organic Carbon (SOC) concentrations with high precision, this allows to pinpoint regions for restoration and monitor interventions over time [41].

For a long time in SSA, different methods have been used to monitor and assess land degradation to help planners on selecting appropriate land degradation control strategies but still, land degradation is increasing. Regardless of the effectiveness and all the advantages of LDSF in assessing and monitoring land degradation, in SSA, especially in East Africa LDSF has not been effectively utilized.

### Utilization of GIS and Remote Sensing

Geographic Information systems (GIS) and Remote sensing (RS) are now reported as making important contributions to natural resource management, including land degradation and soil erosion rate determination. Land degradation estimation and its spatial distribution are now feasible with reasonable costs and improved accuracy across broader regions mainly due to the use of remote sensing and geographic information system (GIS) technology. The use of spaceborne multispectral data has demonstrated its potential for providing knowledge about the nature, extent, spatial distribution, and magnitude of different types of degraded lands. Remote sensing-based assessments and monitoring of land degradation have several benefits, including consistent data, reporting that is reasonably close to real-time, and a source for spatially explicit data. The assessment and monitoring of land degradation at local scales have enormous promise when high-resolution remote sensing data, digital elevation models obtained from satellite data such as Cartosat-1 and Cartosat-2, and Light Detection and Ranging (LiDAR) are combined with ground data [32,42-48].

Through the integration of RS, GIS, and Revised Universal Soil Loss Equation RUSLE, estimation of the amount of soil erosion loss on a cell-by-cell basis is achieved showed that the use of geostatistical approaches to integrate ground dataset, thematic mapper (TM), and digital elevation model (DEM) data produces noticeably better results than using conventional methods to forecast soil erosion loss. RS data has been reportedly used as a potential tool for developing a cover management factor by using land cover classifications while GIS technologies might be utilized to integrate the RUSLE factors for the calculation of soil erosion. GIS capability becomes more useful when used with empirical and predictive models in the assessment of soil loss. studied the uses of GIS in estimating soil erosion and concluded that GIS held enormous promise for enhancing soil erosion estimation compared to methods that did not use GIS [49-55].

To assess and monitor soil erosion in sub-Saharan Africa, several remote sensing datasets, including satellite data with coarse, medium, and fine spatial and spectral resolutions as well as image-derived products like Digital Elevation Models (DEM), have been used. For instance, in their study conducted in South Africa concluded that the Normalized Difference Vegetation Index (NVDI) and Transformed Soil Adjusted Vegetation Index (TSAVI) can successfully map continuous gullies with a moderate level of agreement when compared to traditional gully mapping method. A study done in Tanzania by using slope classes and vegetation cover data derived from DEM and Landsat images respectively successfully provides quick and proper soil erosion risk identification across a large special area. Moreover, in the study conducted by in the European continent showed that the Moderate Resolution Imaging Spectroradiometer (MODIS) datasets, which are available for free, have the potential to be included in environmental models that deal with soil erosion. Additionally, they showed how MODIS-derived products enhance the spatial and temporal monitoring of biophysical features such as vegetation over vast geographic areas such as continents [56-59].

RS and GIS technology give timely results in land degradation research as was evident in mapping salt-affected soils and other degraded lands in space and time with its distinct advantages of systematic, synoptic, fast, and repeating coverage. The use of GIS and RS technology in managing degraded soils has been significantly expanded worldwide due to its quick development and its capabilities with new tools and software. Studies conclude that combined RS and GIS applications have enormous potential for assessing, mapping, and monitoring land degradation across broader areas with lower costs and more precision than would otherwise be possible. But in Africa, their utilization in managing and restoring degraded land is still minimal [60].

### Techniques Commonly used in the Restoration of Degraded Land in Sub-Saharan Africa

Restoration of degraded land is a tendency of bringing abandoned or previously degraded land back into useful or productive use and enhance the expansion of the productive area without compromising natural ecosystems. Restoration of degraded land requires different methods depending on the agent of degradation, sevearity, and the aim of restoration. Restoration of degraded agricultural land can be done to increase productivity, enhance ecosystem services, or restore the saline soil. Restoration techniques can be grouped into two categories: (i) agricultural conservation techniques and (ii) soil amendment techniques [5,61].

### Agricultural Conservation Techniques

### Conservation Agriculture

Conservation agriculture (CA) is a type of agricultural production system that is efficient in resources to ensure production intensification and crop yield improvement while enhancing natural resources through the improvement of soil nutrition and pest management. The main elements of CA for rainfed farming are reduced tillage, diversified crop rotation, soil cover, and soil moisture conservation, which when applied correctly result in enhanced soil health and contribute to crop yield sustainability. Tillage intensity reduction and residue retention are crucial CA components, but in small-scale farming systems in developing countries where crop leftovers can also be used as fodder and fuel wood, recycling or adding organic matter from outside sources may be an alternative. Many researchers have reported a positive contribution of CA on soil quality in Sub-Saharan Africa. The benefits of CA on soil quality vary from increasing productivity to improving soil infiltration, soil moisture, and soil organic carbon (SOC) [62,63].

An increase in crop yield was the major benefit of CA reported, according to yield gains of 5 t/ha on maize grain and 1 t/ha grain on cowpea after CA was applied in Zimbabwe and Zambia were recorded, considering that the average yield for maize has stagnated around 0.89 t/ha for the preceding two decades. This milestone has been contributed by benefits contributed by different components of CA. The application of mulching on CA covers the soil surface as a result it protects the soil from erosion. According to CA reduces soil erosion and surface runoff by 90% and 67%, respectively. Apart from protection from surface erosion, soil cover will also regulate soil temperature, control weeds and increase organic matter in the soil after decomposing. Studies on the physical and biological characteristics of soils in Zambia revealed that directly seeded CA systems had more stable soil aggregates (41%–45%) than the traditional approach (24%). Therefore, CA improved soil properties and nutrient availability and has the potential to reduce external fertilizer inputs in the long run [64-66].

### Agroforestry

Agroforestry is the intentional planting of trees and bushes alongside crops or pastures to create environmental, economic, and social benefits. Since its inception as a scientifically recognized discipline and practice, agroforestry's potential to enhance soil quality has been universally acknowledged as a significant benefit. For decades, both in the tropics and temperate areas of the world, agroforestry practices have been promoted for their proven advantages in enhancing not only soil quality but also other ecosystem services [67-69].

There are several agroforestry systems for restoring and enhancing land productivity while simultaneously fulfilling the demands of low-income farmers. To counteract soil erosion and promote soil fertility, trees can fix nitrogen, stabilize the soil, and be utilized in terracing contour cultivation, and strip cropping. Trees planted in windbreaks and shelterbelts can help to prevent soil erosion. To improve soil organic matter and nutritional status, trees can be planted in improved fallows and alley-cropping systems, with the branches clipped and treated as mulch. By blocking the flow channel, an agroforestry system may also decrease runoff and reduce its ability to transfer soil. Agroforestry can increase soil fertility, protect biodiversity, increase carbon sequestration, and help with climate change adaptation and mitigation [70-72].

According to some agroforestry trees, including the Leucaena, Acacia, and Alnus species, may fix up to 400–500 kg, 270 kg, and 100–300 kg of nitrogen per hectare per year, respectively. Furthermore, the annual major nutrients contributed by different agroforestry tree species range from 33.7 to 398 kg ha-1 year-1 N, 2 to 19.3 kg ha-1 year-1 P, 20 to211 kg ha-1 year-1 K, 14 to 98 kg ha-1 year-1 Ca and 5 to 17 kg ha-1 year-1 Mg. In Ethiopia, for instance, agroforestry increased infiltration and reduced surface runoff by up to 81. A synthesis of studies conducted in Africa (mostly addressing field-scale effects) suggested that, in about 60% of cases where the agroforestry-environment relationship was investigated, trees improved the delivery of ecosystem services. Agroforestry reported to improve crop yield, for example, an experiment conducted in Zambia, showed that maize yields increased by 88–190% when grown in an agroforestry system under the canopies of Faidherbia albida trees. Moreover, results show that soils are better-retained using tree hedges than in untreated terraces, and contour hedges have reduced runoff by about 70 percent. Agroforestry as compared to other restoration techniques, agroforestry offers multiple benefits at the same time such as restoring biodiversity and ecosystems while also delivering food and income [73-77].

Besides its multiple benefits but its adoption is still low in SSA due to many reasons including high initial investment costs and delay or long-term return. To support sustainable land productivity, enhance biodiversity, and improve ecosystem services at the plot and landscape scales, effective agroforestry systems must be developed. This now calls for researchers to investigate the affordable and efficient agroforestry system for restoring SSA-degraded land [78].

### Cover Cropping

Cover crops (CCs) are any living ground cover growing to protect the soil, seeding, and soil improvement between times of normal crop production or between trees in orchards and vines in vineyards. These plants are often known as "green manure crops." Cover cropping is the process of planting crops to cover the soil's surface to reduce wind and water erosion. CCs can be any plants but mostly are legumes or non-legumes/grass. CCs improve crop productivity by improving soil's physical, chemical, and biological properties. Many studies have reported the potential of cover crops on soil qualities. CCs regulate soil heat and temperature hence creating a favorable environment for the microorganisms. When fallen leaves are decomposed, become sources of organic matter in the soil. CCs help to store moisture, reduce evaporation from the soil surface, reduce the kinetic energy of raindrops on the ground, and increase the amount of soil moisture. Additionally, CCs reduce soil erosion caused by wind and water, as well as particulate matter emissions brought on by wind and machinery [79,80].

According to soils planted with rye and oats as a CCs showed 54 and 89 % decrease in rill erosion after 3 years. Other researchers found that CCs reduce soil bulk density by approximately 4%, increase macropores by approximately 33%, and increase water infiltration by as much as 629%, compared to soil with no CCs. These improvements have been reported to lead to as much as 96% reduction in soil loss. CCs reduce penetration resistance (compaction indicator) by an average of 5% and improve wet aggregate stability by an average of 16%, macroporosity by an average of 1.5% across, and water infiltration by 62% Research done by showed an increase in microbial biomass carbon from 40 mg $kg^{-1}$ up to 200−250 mg kg-1 which ultimately improves the soil food web. Other researchers reported an increase of SOC by 15.6 – 17.9 g $kg^{-1}$. In addition, perennial legumes, including those referred to as legume cover crops, could produce up to 10 t $ha^{-1}$ dry matter and fix up to 120 kg N $ha^{-1}$ per season [81-86].

CCs are one of the important strategies for improving soil fertility in cropping land, but their impact on restoring degraded land when combined with other techniques such as physical structures is still not well documented. Therefore, there is still a lot of research that needs to be done to examine the influence of CCs when combined with physical structures on restoring the quality of degraded land in SSA.

### Crop Rotation

Crop rotation is the method of producing a variety of unrelated crops in the same area throughout several seasons to reap benefits including preventing disease and pest development that arises when one species is consistently. By balancing the nutrient demands of various crops, crop rotation prevents the loss of soil nutrients. Crop rotation has a long-standing component of replacing nitrogen with the use of green manure and legumes planted after cereals and other crops. Crop rotation can also enhance soil fertility and structure by alternating shallow and deep-rooted crops.

A study conducted in Ethiopia for the interaction of crop rotation and manure application intervention for three years resulted in improvement of the bulk density (BD), pH, cation exchange capacity (CEC), organic carbon (OC), total nitrogen (TN), available phosphorous (AP), and exchangeable potassium (EK) contents of the experimental soils on maximum average by 22.63%, 17.87%, 66.82%, and 88.89%, 150.00%, 88.87%, and 44.12%, respectively as compared to that of the initial status of soil properties before starting the experiment. interaction of crop rotation and manure application interventions in three consecutive rotation phases resulted in improvement. On the other hand, research done by in South Africa reported yield increases of 13 and 29 % for 2 years of soybeans - maize and 3-year maize - dry bean - wheat rotations, respectively [87,88].

### Practicing Organic Agriculture Help to Restore Degraded Land

Organic agriculture is a farming technique that avoids the use of agrochemicals like synthetic fertilizers and pesticides, as well as genetically modified organisms (GMOs) and a variety of other synthetic food additives (e.g., preservatives, coloring). The origins of organic agriculture can be traced back to the 1920–1930 period in North Europe (mostly Germany and UK) and it is now widely spread all over the world. Organic farming has evolved into a comprehensive strategy to combat contaminated food production, health security, biodiversity loss, disrupted soil nutrient cycles, soil pollution, and degraded agricultural land. The use of natural inputs, which do not deplete soil nutrients, the encouragement of soil microbial growth, and the management of soil from texture to ecosystem are today's organic farming ethics. Organic agriculture relies on several farming systems that take full use of ecological cycles to protect soil fertility. Crop rotation, intercropping, polyculture, cover crops, and mulching are all used in organic farming methods to improve soil fertility [89-94].

Soil properties are generally site-specific, however many studies have shown that organic farming performs better in terms of both biophysical (e.g., SOM, stored nutrients) and biological (e.g., biodiversity) aspects in conserving or improving soil quality  Zandi & Basu, 2016). It has also been suggested that combining organic and mineral fertilizers could be a viable strategy for addressing soil fertility reduction in SSA When a reference is made to Europe and the United States, a significant increase in SOM content as well as better biochemical performance indicators, there is no doubt that the adoption of organic farming would greatly reduce agricultural land degradation in SSA. Organic farming also dramatically reduces soil erosion by up to four times. In organic farming, techniques to reduce N loss such as manure application and conservation agriculture and increase N absorption efficiency are frequently employed, and many investigations show that organic farming reduces N leaching and increases N uptake efficiency. Organic matter in the soil plays an important role in soil sustainability, which is determined by the amount and type of organic matter applied. According to adding compost, farmyard manure, and slurry to the upper 10 cm soil cover increased SOM by 37 %, 23 %, and 21 percent, respectively. According to estimates, the soil can contain 10 – 11 liters of plant-available water per hectare of soil down to around 30 cm for every 1% of soil Organic Matter (SOM) concentration. Organic fertilizers are mostly made up of farmyard manure, green manure, and composts. For instance, reported that manure reduces water runoff by 70–90% and sediment loss by 80–95%. SSA being among regions with high livestock density the option of manure application to restore degraded agricultural lands would be easily encouraged. Soil erosion rates from soils under organic farming can be 30–140% lower than those from conventional farming [85, 95-105].

Microbes easily colonize organic additions, which improves other soil qualities while maintaining fertility stability. To constantly release nutrients for plant and microbial growth, a balanced ratio of microbial biomass and activity is required. Organic farming contributes to soil fertility stabilization by boosting nitrogen fixation, lowering nutrient leaching, improving SOM, soil cover, and improving soil structure.

According to several studies, organic farming is frequently connected with a much greater degree of biological activity, which includes bacteria, fungi, springtails, mites, and earthworms. Biodynamic and organic management significantly improved soil ecological performance in the long term. Studies have shown microbial biomass and activity increase under organic farming leading to increased root length of crops of up to 40% compared to the ones under conventional farming systems. Similarly, earthworm biomass and abundance were 30% to 320% higher in organic plots than in conventional plots [91].

### Transformation from Annual Crop to Perennial Crops Agriculturally based to Restore Degraded Land

Since the 1980s, several researchers have advocated for a shift from annual crop agriculture to perennial crop agriculture to reduce the negative effects of soil tillage and to eliminate or considerably reduce the use of agrochemicals. Perennial crops appear to provide a wealth of advantages: (i) can improve ecosystem functions such as water conservation, nitrogen cycling, and carbon sequestration by more than 50% when compared to conventional annual crops; they are reported to be 50 times more effective than annual crops in maintaining topsoil, reducing N losses by 30 to 50 times, and storing about 300 to 1100 kg C/ha per year compared to 0 to 300–400 kg C/ha per year as do annual crops, and it is believed they could help restrain climate change, (ii) lower management costs because they don't need to be replanted every year, requiring fewer passes of farm machinery as well as fewer pesticide and fertilizer inputs, reducing fossil fuel consumption. (iii) Herbicide expenses for annual crop production maybe 4 to 8.5 times those for perennial crop production, therefore less inputs in perennial systems mean lower monetary expenditures for the farmer and a considerably reduced environmental impact. However, additional work is needed to improve yields and post-harvest processing systems that can use more perennial crops. Most climate-change models anticipate that perennial crops will adapt better to temperature increases of the magnitude expected by perennial crops [91,106].

Reported that perennial crops significantly increase soil organic carbon (SOC) content by 4% and SOC stock by 11% at 0–100 cm depth across the period of five years. Furthermore, in Kansas USA reported a significant increase of SOC stock from the perennial crops switchgrass and miscanthus by 0.8 and 1.3 Mg ha− 1 yr− 1. Moreover, five-year research done in German by reported an increase in average soil organic carbon contents, by 1–2% at two of the three study sites, and the soil microbial biomass increased from 13% (Virginia mallow) to 27% (tall wheatgrass) compared to annual crop treatment and improvement of earthworm activity (cast production) on perennial crops compared to annual crops. In their research on environmental impact assessment of perennial crops on marginal soils, suggest that perennial crops provide benefits regarding soil properties and erodibility with an average score of 2.2 and 5.6, respectively [8,107-109].

### Soil Biotechnology for Restoring Degraded Land

Soil biotechnology is defined as "the study and manipulation of soil microorganisms and their metabolic activities to maximize agricultural productivity". It is a discipline of soil science that has become increasingly important in recent years due to its huge potential for enhancing plant nutrient availability, physical characteristics, xenobiotic chemical degradation, waste management, plant-beneficial symbiosis, and the control of soil-borne plant diseases. The soil biotechnological method can be utilized in soil management practices by activating soil microorganisms to produce biofertilizers, natural growth regulator chemicals, increase soil organic matter, and improve soil structure, especially in compacted soil management or non-tillage agriculture [110-114].

Biotechnology and agricultural techniques have evolved together to solve a variety of problems and enhance agricultural sustainability as awareness of agroecosystem functioning and optimum management practices has grown Bacterial and fungal microbes are vital in soil restoration. Inocula of bacteria and fungi are important in the restoration of degraded soil. According to cyanobacteria fix atmospheric nitrogen in deteriorated soils and release extracellular polysaccharides, which are metabolized by soil microbes. Other bioactive substances produced by these bacteria also have a good impact on soil fertility, reduce soil pathogens, and so increase crop development by supplying N, biological N2-fixing bacteria promote the growth and survival of other soil microbial groups in the rhizosphere. Most bacteria are known to release extracellular polysaccharides that facilitate soil aggregation and some mobilize soil P, K, and Fe that are fixed or inaccessible to plants and other microorganisms. Furthermore, bacterial inoculate release phytohormones (Auxin/Indole Acetic Acid) that help plants grow and develop. Ectomycorrhizal and Arbuscular Mycorrhizal Fungi (AMF) also improve soil nutrient and water transport by exploring the soil with their hyphal network/pipelines and producing organic acids to mobilize fixed nutrients. Studies done by. In Iran reported that the runoff coefficient was reduced by 96 %, the peak reduced by 83 %, the start time delayed by 168 %, and the time to peak reduced by 34 % compared to the control [113,115-123].

AMF can mobilize N, P, K, Fe, and other nutrients in the soil and transfer these nutrients to the host plants through a translocation process by the hyphal network. AM fungi can reduce N and P losses through leaching and N2O emission and enhanced nutrient interception of AM fungi rooting systems. Microbial inocula control nutrient cycling and determine whether nutrients are available to plants as a result of these activities. These microbial inocula can restore deteriorated soil to acceptable levels by doing so. Found that using biofilm-based fertilizers made from N2 fixer bacteria enhanced both N2 fixation and soil organic carbon content. As a result, these fertilizers encouraged ecosystem functioning and aided in the sustainable restoration of degraded agricultural soil in the tropics within a few months. Microbial communities found in these biofilm-based fertilizers significantly increased microbial biodiversity, resulting in agroecosystem and environmental sustainability [122,124-126].

Moreover, bacteria carry out the majority of soil processes, such as organic matter stabilization, decomposition, nutrient mobilization, translocation and mineralization, and aggregate formation and stability. Due to the diverse microbial variety in these soil habitats, the above-mentioned soil functions have not been adequately explored to achieve sustainable productivity in agroecosystems. As a result, it's critical to continue researching undiscovered microorganisms that can thrive in a competitive ecosystem in field conditions and help restore degraded soil fertility and production to meet rising global food demand while also ensuring environmental sustainability.

### Soil Management Techniques

### Application of Manure and Mineral Fertilizers

Manure and fertilizer applications are crucial for restoring degraded agricultural land. They supply vital nutrients to the soil which enhances crop growth. Fast-growing crops will cover the soil quickly and give more yield. Inorganic fertilizers supply plants with vital nutrients like nitrogen, phosphorus, potassium, and sulfur. Instead of using only inorganic fertilizers, it is better to apply both types of fertilizers together. The major sources of organic fertilizers are composts, green manure, and farmyard manure. Research done by in Mulerwa Zimbabwe reported an increase in nitrogen levels from 40 - 60% and 17 - 38% concerning control for Norfolk sandy soils and Cecil sandy loam soils, respectively following the application of manure. According to  the addition of manure in the soil reduces water runoff by 70 to 90% and sediment loss by 80 to 95%. A study done by in Ethiopia reported a high yield in millet grains and straw when crop wastes and fertilizers were used to restore degraded agricultural areas. Furthermore, reported that the addition of manure in the soil may contribute nutrients concentrations ranging from 0.5 to 2.5% N, 0.4 to 3.9% P2 O5, 1.2 to 8.4% K2 O and 0.3 to 5.4% CaO. Green leaves of legumes range from 2.9 to 4.4% N, 0.13 to 0.30% P, and <1 to 2.8 K [127-130].

Despite previous research demonstrating application of manure and fertilizers increases crop yields in SSA the multiple benefits of manure for soil fertility in degraded land are still not well understood. Most of the research on manure and fertilizers in sub-Saharan Africa has mainly focused on its role in supplying the N required by crops, with little attention given to its ability to improve soil quality in the degraded soils of SSA [2,96].

### Physical Soil and Water Conservation (PSWC) Measures

Physical structures are long-lasting features composed of dirt and stones that are used in agricultural land restoration to protect the soil from uncontrolled runoff and erosion and to hold back water where it is needed. Cutoff drains and retention ditches are some examples of physical structures used to restore degraded land. Cutoff drains are constructed to properly capture surface runoff and transport it to an outlet, such as a canal or stream, cut-off drains are constructed across a slope. Their principal function is to divert water from gully heads and preserve cultivated land from uncontrolled flow. Retention ditches absorb and hold incoming runoff water until it sinks into the ground, retention ditches are built along contours. When there is no adjacent channel for the water to be discharged, they serve as an alternative to cut-off drains. Retention ditches are occasionally utilized for water gathering in semi-arid regions.

According to physical soil and water conservation techniques reduce surface runoff by an average of 13 – 71%. Level Fanya juu and Fanya chini terraces reduce runoff by 71% while tied-ridges, bench terraces, trash lines, and stone buds reduce runoff by 51 – 57%. Their effectiveness varies from place to place depending on different factors such as soil types and rainfall. For example, in Tanzania, researchers reported that level Fanya juu reduced surface runoff by 54–95% whereas level soil bunds in Ethiopia reduced the surface runoff by 17–94%. Apart from the reduction of surface runoff, physical soil, and water conservation structures reduce soil loss. The average soil loss reduced by PSWC range from 39–83%. Tied ridges can manage more than 60% of soil loss on average, compared to level Fanya juu in Kenya, Tanzania, and Ethiopia, where it can control more than 70%. The effectiveness of these techniques varies from place to place depending on soil type and environmental conditions. These technologies must be tested in different environments before being adopted by farmers to improve their specific performance. Furthermore, research should be done to evaluate their effectiveness when combined with other soil conservation strategies such as cover crops and grass strips in sloping lands [131-138].

## Conclusion

Land degradation has been observed to increase due to intensive agriculture which is associated with poor soil and water management practices coupled with unsustainable agricultural practices. For a long time, different restoration and conservation techniques have been promoted, but due to their low adoption and inefficiency to restore and conserve degraded land, land degradation is increasing. There is a need for the agent action to transform existing conventional agriculture into agricultural practices which ensure sustainability. Due to this fact, it's time now to incorporate the existing techniques with the emerging techniques for the restoration and conservation of degraded land in Sub-Saharan Africa. The emerging techniques proposed in this review paper are the use of biotechnology for restoring degraded land, the use of LDSF for assessment of land degradation status or evaluation of the effectiveness of soil conservation and restoration practices, and transformation from annual crops to perennial crops and organic agriculture.

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