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Inclusion of Agroforestry on Agricultural Farming Systems: Revisited

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***Abstract**: Due to degraded arable land and poor land management in most outskirts of Sub-Sahara Africa countries experience crop failure, a lack of fodder, and poor agricultural productivity. Deteriorating soil fertility and climate change exacerbate agricultural farmland production to produce sufficient crops and livestock all year round. Food security is insufficient as a result of poor agricultural production, particularly in Sub-Saharan African nations. Intervention strategies must be implemented in order to boost the farming system's productivity. However, the inclusion of the tree species on agricultural land as a whole call for the growing of trees on agricultural farmland. Incorporating agroforestry into farming systems is inexpensive, provides protracted soil fertility, and supplies livestock with fodder. According to earlier research, agroforestry management strategies are required to boost agricultural productivity and output. However, this synthesis also aims to highlight the value of tree components in the implementation of farming systems. Wherefore it is crucial to evaluate the potential of agroforestry and create innovations that are customised to certain circumstances for agriculture. Finally, research on agroforestry systems requires a long-, mid-, and short-term investment approach.*

Keywords— Agriculture, Africa, Cropland, Fodder, Livestock, Production, Trees, Security,

1. Introduction

During the time of the green revolution, inorganic fertiliser has been utilised in modern agriculture, considerably enhancing productivity and farm output (Ahmad and Anjum, 2020). Negative input-output price ratios, limitations on market expansion, low application rates that result in declining soil fertility, and other problems all contribute to the sector's small market share (Ariga and Jayne 2009; Shaha et al., 2014; Kakar et al., 2020). According to Ariga and Jayne (2011), SSA countries, like the majority of the rest of the world, depend on global markets for fertilisers since domestic supply is constrained and is reliant on a state-run plant that requires extensive maintenance and upgrades.

In commercial, emergent, and subsistence farming, inorganic fertilisers have been used to grow crops (Vance et al., 2000; Fox et al., 2007; Ding et al., 2016). This is so that inorganic fertilisers may be used by plants with ease and are readily absorbed by them. It might, however, negatively impact the state or quality of the soil if not used properly (Ahmad and Anjum 2020). As a result, the uncontrolled use of inorganic fertiliser could reduce soil fertility by reducing nutrient levels and causing soil acidification (Satyanarayana et al., 2002; Khan et al., 2018). Due to their higher production costs, inorganic fertilisers cause agricultural production firms to earn less money (Khan et al., 2018; Rahman and Zhang 2018). The majority of smallholder farmers who raise food and rear livestock are unable to purchase enough inorganic fertiliser during the growing season due to resource constraints (Myeni et al., 2019). Inorganic fertilisers are becoming extremely expensive and hard to find, particularly in countries in Sub-Saharan Africa.

Several governments in Sub-Saharan Africa (SSA) have worked to improve local and regional manufacture to expand access to inorganic fertilisers (Muzari et al., 2012; Sheahan and Barrett 2017). This has the potential to boost productivity in smallholder agriculture while saving money and reducing currency swings on the international market. It is well accepted that the minerals derived from the soil nutrient pool have a substantial impact on how well agriculture performs. Lack of these minerals, which include calcium, phosphorus, nitrogen, and potassium, in the soil has a negative impact on crop development (Rahman and Zhang, 2018).

Ajayi et al. (2011), Mafongoya et al. (2006), as well as Mercer and Pattanayak (1999), suggest that new agricultural approaches have been proposed to reduce the high cost of inorganic fertilisers and their negative associated impacts. Therefore, it is imperative to solve the problem that unworkable soils and a changing climate make it impossible to achieve considerable agricultural yields year after year, jeopardising food security (Chavula and Hassen, 2022). Degradation of soil quality brought on by nutrient loss and depletion as a result of insufficient nutrient input and maintenance is a frequent problem (Patel et al., 2001; Dao and Cavigelli, 2003; Mishra and Patel, 2009). Therefore, it is crucial to implement newly developed technologies that increase soil fertility while minimising damage to the environment (Kaczan et al., 2013; Gitz et al., 2016).

Agroforestry is one of the newest agricultural technologies to improve soil fertility and agro-ecological coherence (Mubiru 2019; Chavula and Hassen, 2022). Agroforestry has been defined in a variety of ways by academics, including as "the spatial integration of tree components on farmland with animals and crops." The intentional coexistence of crops or animals on the same plot of land as woody perennials like trees, shrubs, palms, and bamboos, either in some kind of spatial arrangement or temporal sequence, is known as "agroforestry" (Leakey, 2014).The several elements of agroforestry systems are interconnected on an ecological and financial level(Sileshi et al., 2014). Agroforestry seeks to connect trees and agricultural components in meaningful ecological and economic ways (Akinnifesi et al., 2011; Xu et al., 2019). Before making agroforestry techniques available to smallholder farmers in rural areas of the majority of African countries, several professionals spent years conducting study on them (Franzel et al n.d.; Jama and Zeila, 2005; Franzel et al., 2014).

Leakey (2014) asserts that agroforestry provides numerous potential to raise productivity and food output through nitrogen-fixing plants and shrubs. The goal of agroforestry systems is to improve sustainable soil management and lessen poverty in rural areas, according to Ajayi et al. (2007). Compared to natural fallowing, agroforestry innovations like enhanced fallows quickly replenish soil fertility (Phiri et al., 2003; Mafongoya et al., 2003; Akinnifesi et al., 2008). A rotating method known as a "improved fallow" alternates between employing particular nitrogen-fixing tree species as fallow species and using natural vegetation in rotation with farmed crops (Deans et al., 2003; Phiri et al., 2003). To enhance soil nutrition, plants like *Faidherbia albida*, *Sesbani*a *sesban,* and/or *Leucaena leucocephala* are purposefully scattered around croplands. On a harvested yield, gliricidia sepium alleyways reduce crop failure. Furthermore, it is well recognised that some tree species employed in agroforestry are adaptable and can provide fruit for human use, fuelwood for energy, and fodder trees for energy (Akinnifesi et al., 2006).

On farmland, trees utilised in agroforestry are known to provide a number of benefits, such as (1) supporting services, (2) provision services, and (3) regulation services. Use of multipurpose tree species in agroforestry can aid in soil restoration. To reduce shocks, give animals or cattle a folder. Additionally, it increases organic matter in the soil, which can improve microbial activity and soil structure (Love et al., 2006; Kharhu et al., 2011). The biomass of the trees' leaves provides a sizable surface area for improving soil nutrient and water retention (Fargione et al., 2009). The physical characteristics of the soil as well as nutrient and moisture retention are aided by soil organic matter(Barral et al., 1998; Allan, 2005).

Once inorganic fertilisers are applied excessively, the soil quality declines. Fertilizer's high price makes long-term viability difficult, particularly for smaller farms (Mwangi, 1996; Zhen et al., 2005). Soil fertilisation options that are affordable must be developed in order to increase agricultural output. The importance of more practical (and accessible) methods that smallholder farmers might employ in their farms to boost crop and animal productivity is highlighted by this synthesis study.

2. Overview of Agroforestry

Smallholder farmers that cannot afford or acquire a consistent supply of inorganic fertilisers employ organic food sources. A diversity of leaves, roots, and twigs cover the soil to avoid erosion and increase nutrient status. Multipurpose tree species provide above- and below-ground biomass to the establishment of soil fertility (Sayer 2006; Datta and Singh 2007; Singh et al., 2020).

Smallholder farmers that cannot afford or acquire a consistent supply of inorganic fertilisers employ organic food sources. A diversity of leaves, roots, and twigs cover the soil to avoid erosion and increase nutrient status. Multipurpose tree species provide above- and below-ground biomass to the establishment of soil fertility (Sayer 2006; Datta and Singh 2007; Singh et al., 2020). Common techniques for enhancing soil structure include allowing water to permeate and opening up the soil. The roots of multipurpose tree species penetrate the soil, promoting the development of soil fauna as well as other biological processes. In conclusion, multifunctional tree species improve soils by fixing carbon through photosynthesis, followed by carbon in the litter, and, below breakdown, nitrogen, nutrients from weathered rocks, and nutrients from their leaves, which are fixed by legumes. Additionally, legumes may fix nitrogen, take up nutrients from weathered rocks and their leaves, and capture atmospheric nitrogen (Nygren et al., 2000).

2.1. Case Studies of Agroforestry

To promote coppicing, Makangango et al. (2020) used recurrent harvesting at different cutting heights in the field to assess the biomass production and nutrient content of three agroforestry tree species. Smallholder farmers may benefit from agroforestry systems since they can aid them in overcoming difficulties like deteriorating soil and low livestock production. The study examined the effects of various cutting heights (0.3 m – 1.0 m) and repeated harvests (1 m – 5 m) on the biomass production and chemical composition of the leguminous trees *Acacia angustissima*, *Leucaena pallida*, and *Mimosa scabrella* Anthropic Ferralsol in Southern Rwanda. The highest levels of neutral detergent fibre (NDF) and acid detergent fibre were found in M. scabrella, while A. angustissima had the lowest levels of crude protein (CP) (ADF). A. angustissima and L. pallida should be cut at a lower cutting height (0.3 m) for better overall quality and biomass output even though all species produced high CP content feed at all cutting heights. The tree species are crucial to agriculture because they provide nutrients for growing cattle, claim Makangango et al. (2020). Tree species, however, also have a sizable capacity to repair damaged soils.

To address climate change and variability, Tefera et al. (2019) examined the potential of agroforestry for carbon sequestration. Agroforestry is a distinctive, comprehensive endeavour that combines crop, animal, and woody plant features. As a result, agroforestry has drawn a lot of interest in recent years for its potential to mitigate the effects of climate change. As a result, agroforestry's ability to absorb carbon from the atmosphere and so reduce carbon dioxide emissions is its most significant contribution to battling climate change. This happens because agroforestry, as opposed to mono-crop agriculture, has a larger potential to boost carbon sequestration in areas where agriculture is the dominant economic activity (Tefera et al., 2019).

Oyebamiji et al. (2017) investigated the effects of moving tree leaf biomass and nitrogen fertiliser in Makera, Nigeria. The two main techniques for nutrient enrichment, particularly nitrogen enrichment, are legumeous tree crop cultivation and biomass transfer, which can also be employed as a source of organic fertiliser. The study looked at how urea affected the transfer of leafy biomass from Parkia biglobosa and Albizia lebbeck, two leguminous agroforestry trees, on the production of maize stover. Statistics indicate that the leafy biomass of Albizia lebbeck alone improved stover yield. But the 2009 addition of 120 kg N ha-1 urea to the EVAT increased the output of stover (Oyebamiji et al., 2017). As a result, the soil was amended with Albizia lebbeck biomass and up to 40 kg N ha-1 urea, which enhanced soil quality and increased stover yields.

Mango and Hebink (2016) investigated the assertion that agroforestry is a second paradigm for soil fertility in a case study of soil fertility management in Western Kenya. However, the results from researchers around the world indicate that there isn't a clear-cut solution to this question. As a result, agroforestry has been promoted in Western Kenya since the early 1990s through a number of programmes and organisations as an alternative strategy for restoring soil fertility. These practises coexist with improved fallows through a variety of interactions on farms, in villages, and with technical institutions, and they each influence the other (Mango and Hebinck, 2016). Agroforestry systems offer a range of soil fertility options depending on the various nutrient and other soil conservation concerns. The livelihoods of farmers will improve with the development of large-scale, low-cost methods for applying fertilisers to crops. Scientists realised that reducing the cost of restoring soil fertility is crucial for the future of agriculture in the region and the rest of the world.

Sileshi et al. (2014) claim that adding fertiliser trees to agro-ecosystems can maximise the natural nitrogen supply of the soil and increase total land output. Fertilizer trees contribute to ensuring multifunctional agriculture because they also give timber, fodder, shade, soil enhancement, and watershed management, among other benefits. Fertilizer trees allow more internal nutrient recycling and water availability in comparison to synthetic nitrogen sources, enhancing nutrient efficiency. Therefore, by reducing external inputs, especially nitrogen fertilisers, increasing resource and land use efficiency, and delaying erosion, they can considerably contribute to sustainable agriculture. In many parts of the world, the adoption of fertiliser trees has been slower than expected, but in others, there have been remarkable triumphs. Regional custom, economic factors, and land ownership have impacted the use of fertiliser trees in conventional agricultural systems (Sileshi et al., 2014). These old systems are deteriorating and becoming less effective, but they could serve as a model for fresh approaches to land management that place an emphasis on the contribution fertiliser trees make to raising yields of food, forage, and fibre.

A study from 2010 by Quinion et al. (2010) on biomass transfer, intercropping, relay cropping, and other fertiliser tree methods is also available. In Malawi, smallholder farmers that employ tree technology for their crops are more likely to practise sustainable agriculture, use low-input substitutes for inorganic fertilisers, and use complementary inputs to inorganic fertilisers, according to the study. According to Quinion et al. (2010), the study further examined how technology might help rural households of smallholder farmers in Malawi raise their level of life and increase their access to food. The size of the landholdings affects the technologies chosen, and greater landholdings are linked to more benefits. Quinion et al. (2010) claim that agricultural fertiliser tree technologies eventually help to reduce hunger and alleviate poverty. Therefore, the ability to establish livelihood stability, absorb and cope with shocks, and enhance overall wellbeing is what drives the adoption of technologies at the household level.

According to Kalaba et al. (2010), improved fallows that mimic shifting farming and other improved agroforestry systems (AFS) aid rural livelihoods, an improvement in socioeconomic standing, and the ecological efficiency of land-use systems. This is according to a study on the contribution of agroforestry to enhancing biodiversity and rural populations' means of subsistence in Southern Africa. The project sought to address problems with biodiversity and socioeconomics by domesticating a variety of significant native fruit tree species and evaluating soil fertility replenishing agroforestry systems on farms or in communities. Compared to conventional farming, AFS provides value by generating revenue from the sale of a range of products(Kalaba et al., 2010). The report examined how natural forest resources and AFS may enhance smallholder farmers' socioeconomic well-being and advance biodiversity preservation using data from studies conducted in southern Africa over the previous two decades.

To determine the soil nitrogen mineralization, nitrogen uptake, shoot biomass, and grain yield of the crop, Pandey and Rai (2007) studied the impact of Gliricidia sepium leaf biomass on maize output. They obtained equivalent results. The outcomes of the experiment demonstrated that the addition of leaf biomass two weeks after sowing resulted in the highest rates of soil nitrogen mineralization, nitrogen uptake, shoot biomass, and grain yield in maize, while the addition of leaf biomass four weeks after sowing resulted in the lowest yield. Within 15 days, the leaves began to release up to 50% of their nitrogen, and over the next 60 days, they steadily released the remaining 48%–49%. Pandey and Rai

(2007) went on to say that although considerable amounts of nitrogen can be taken in the form of leaves, the nitrogen recovery rate by the associated crops was found to be fairly low, ranging between 10 and 20%. One of the reasons for these low readings may be a mismatch between the crop's need for nitrogen and the nitrogen emitted from the leaves. Within 15 days, the leaves began to release up to 50% of their nitrogen, and over the next 60 days, they steadily released the remaining 48%–49%. Pandey and Rai (2007) went on to say that although considerable amounts of nitrogen can be taken in the form of leaves, the nitrogen recovery rate by the associated crops was found to be fairly low, ranging between 10 and 20%. One of the reasons for these low readings may be a mismatch between the crop's need for nitrogen and the nitrogen emitted from the leaves. *Brassica olereaca's* nitrogen needs were slightly out of sync with the experiment because it was transplanted after the leaf biomass had degraded for 14 days. Based on the research, it was concluded that vegetable growers might use the Gliricidia sepium leaf biomass transfer method in place of inorganic fertilisers to increase vegetable production.

Masinde and Omolo (2007) tested the effects of Sun hemp, cowpeas, and delichos biomass on the development of cabbage in Kenya. The factorial design was used to set up the experiment with these three legumes, which occurred during a protracted wet season. After the harvest of the legumes, cabbage was grown during brief showers or with irrigation. The results showed that the yield of cabbage was low when no legume was used.

Farmers in some parts of Southern Africa, conferring to Mafongoya et al. (1997), harvested leaf litter from Miombo woods as a source of nutrients for their crops. On the other hand, because it enhanced soil quality, leaf litter proved to be a sustainable farming technique. Cropland productivity increased as smallholder farmers adopted the strategy. A more cost-effective method of agricultural production resulted in a steady rise in household income. However, constantly cutting down trees for their foliage had a negative impact on keeping Miombo or any other forest in good condition. This could be a good substitute for inorganic fertiliser.

Gachengo (1996) found that introducing green biomass from Tithonia diversifolia into a field was very successful in supplying maize with the right amount of nitrogen, phosphorus, and potassium. In several cases, tithonia biomass increased maize yields more than inorganic fertiliser. A trial was conducted to compare the impact of fresh T. diversifolia biomass against inorganic fertiliser on maize yields, according to Jama et al. and Ademiluyi and Omotoso (2007). (2000). The experiment showed that maize grown without any input (control) produced the least grain per hectare (0.8t). While tithonia biomass enhanced maize productivity by 58 percent over control, chemical fertiliser increased it by 63 percent above control. This suggests that there was no discernible difference in the impacts of tithonia and chemical fertiliser on yields. The experiment's findings suggested that leaf biomass may be used to grow maize because there was no discernible change in output. The tithonia tree species can easily grow and take root on farms.

3. CONCLUSION

The synopsis study draws attention to the value of trees in farming systems as its conclusion. Smallholder farmers can therefore afford to grow low-maintenance agroforestry tree species on their land using cuttings or seeds. The adoption and use of this technology may be influenced by the information that farmers receive from the results that are presented. Agroforestry tree species, which also encourage long-term growth and agrobiodiversity, can considerably benefit any farming system. Technology based on agroforestry tree species helps with climate change adaptation, mitigation, and resilience activities. Agroforestry multipurpose tree species technology must be promoted in least-developed countries, particularly in Sub-Saharan Africa, in order to achieve the three objectives of climate-smart agriculture. Finally, the supply of building pegs and animal feed, as well as the type of fertiliser tree, determine how well depleted and deteriorated soil may be restored.

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