ISSN:2372-0743 print
ISSN:2373-2989 on line
International Journal of Ground Sediment & Water
Vol. 15
2022

◆Research Paper

DOI: 10.5281/zenodo.5816755

Agroforestry as a Commendable Climate-Smart Agriculture Technology among Smallholder Farmers in Zambia: A Review

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Abstract: For over two decades, Zambian smallholder farmers have been exposed to agroforestry technologies that have been widely researched and implemented. Climate change and extremes are common throughout Sub-Saharan Africa, especially Zambia. When people are impoverished and vulnerable, as they are in this location, these elements can make life extremely difficult. In Zambia, agroforestry projects are being pushed among agricultural households to combat the problems given by climate change and variability. Despite all of the research and outreach efforts over the years, few farmers have accepted this technology. As a result, the study focuses on the effects of agroforestry adoption on the household welfare of smallholder farmers in Zambia. Adopters of agroforestry technologies generated greater overall income per household than they would have if they had not adopted the technologies, according to empirical studies. Non-adopters had lower total household income than in the alternative scenario. As a result, it is suggested that rural families foster the creation of associations (e.g., farmer cooperatives, farmer groups). Furthermore, strengthen educational foundation by increasing investment in the education and extension sector, particularly in rural areas. As a result, a comprehensive study is

required to use expenditure and consumption approaches to assess smallholder farmers' household welfare after they adopt agroforestry technologies in Zambia.

Keywords: Adoption, Agroforestry, Climate, Soil, Farmers, Welfare, Farmers, Africa.

Introduction

Agriculture is the primary source of food, income, and employment in developing countries, and it is the primary source of food, money, and employment for the rural population (Ondrasek, 1972; Nations, 2010). Despite accounting for a modest portion of the global economy, the industry remains vital to the lives of many people around the world (Jenkins *et al.*, 2016). In 2012, of the worlds' 7.1 billion people, an estimated 1.3 billion (19%) were directly engaged in crop and animal production activities (World Bank, 2012). The agricultural sector alone provides an approximation of 70% – 80% of employment opportunity to the global population and accounts for more than 40% of gross domestic product (GDP) from exports for most agricultural dependent countries (FAO, IFAD, UNICEF, WFP, 2020). Hence a vibrant agricultural sector, either at the local or at global level, is fundamental in securing poverty reduction, food security and nutrition leading to the attainment of sustainable development goals numbers number one (1) and two (2) which are 'no poverty' and 'Zero hunger' respectively. Statistics indicate that a huge percentage of agriculture-dependent countries lies in the Least Developed Countries (LDCs) that include Sub-Saharan African countries. According to Donelan (2019), Sub-Saharan Africa alone has more than 60% smallholder farmers and about 23% of GDP in Sub-Saharan Africa countries come from agriculture.

In the year 2012 Food and Agriculture Organization (FAO), established that middle and low-income countries in Sub-Saharan Africa, Zambia inclusive, largely depend on agriculture to achieve their economic growth. It further states that 35% of GDP comes from the agricultural sector, which also employs about 70% of the population (Chapoto *et al.,* 2013). The agriculture sector in Zambia alone contributes approximately 18% of Gross Domestic Product (GDP) and about 70% of employment (Mwanamwenge and Cook, 2019).

The agricultural sector should be prioritized to attain economic growth, poverty reduction, food security, good nutrition and creating employment opportunities. Hence, the government of Zambia through the ministry of agriculture and livestock focuses on increasing diversification of crop and livestock production in addressing challenges that have worsened due to rapid population increase and climate change impacts(Chapoto *et al*., 2013). Population increase has increased demand for food and settlement area resulting in a tremendous amount of pressure on the land and land-use systems (Phiri *et al*., 1999; Katanga *et al.*, 2007). Whereas climate change has negatively affected agricultural production due to changes in climatic conditions that negatively affect the agricultural systems(Howden *et al*., 2007). Therefore, improving the agricultural sector ensures food security and contributes towards a nation's economic growth a necessary deliberate policy that supports the attainment of SDGs especially goal number one (1) and two (2) (UN, 2015).

In Zambia, smallholder farmers' input accounts for more than 80% of rain-fed agricultural activities whether it is crop and/ or animal production(Central Statistical Office, 2011). Most of these smallholder farmers are in a state of adverse poverty and are unable to meet the expenses of industrial inputs to improve production(World Bank, 2000). The high cost of inputs has contributed to food insecurity and poverty faced by smallholder farmers in Zambia (Mafongoya et al., 2006). Additionally, over-dependence on rain-fed agriculture by smallholder farmers means climate change poses a great challenge as far as agricultural production is concerned (Adem and Bewket, 2011; Khadka and Pathak, 2016). Islam and Kieu (2021)espoused that impacts of climate change on crop production are not limited to total rainfall and average temperature effects. For instance, a "false start" to the rainy season, droughts, flooding or erratic rainfall can be disastrous for crop establishment. Further to that, the variations in variability to impacts depend on location, adaptation capacity and other socio-economic and development factors(Morton *et al*., 1994). The vulnerability of poor farmers to climate change and extreme weather events is further worsened by lack of access to land due to the traditional land tenurial arrangements, adequate water, low levels of technology holdouts, and education and institutional mismanagement (Mbilinyi and Kazi, 2013). These challenges contribute to production problems compounded by environmental degradation and loss of valuable natural assets such as woodlands and forests, which directly and indirectly support agricultural production (Howden *et al*., 2007; Tadesse, 2010). Furthermore, traditional farming systems such as shifting cultivation and low rate of adoption of strategic natural resources management technologies leads to land degradation, and loss of soil fertility (FAO, 2018). The need to improve soil fertility and to adopt new farming technologies has become a very important issue in development policies under the agricultural reforms in most developing countries (Ndalama *et al*., 2015).

To combat loss of soil, fertility and folder shortage governments and non-governmental organizations have stimulated smallholder farmers to adopt agroforestry technologies (Miller *et al.*, 2020). Hence, agroforestry is the deliberate integration of multipurpose tree species and shrubs with crops and livestock to maximize production (Ajayi *et al*., 2007; Mafongoya, and Ajayi, 2017). In contrast conservation agriculture is an approach to managing agro-ecological systems for improved, sustained productivity, increased profits, food security while preserving, enhancing the resource base and the environment (FAO, 2018). Conservation agriculture improves the efficient use of natural resources through integrated management of available resources combined with external inputs similar to agroforestry. Agroforestry and conservation agriculture are sustainable land-use systems that largely help in addressing land degradation and loss of soil fertility (Phiri *et al*., 1999). According to FAO, (2018), the adoption of agroforestry technologies is normally anticipated to increase household food security, income and mitigate the impact of climate change. Arising from this importance, the promotion of agroforestry has been prioritized by the Zambian government as one of the key components in extension service delivery (Kabwe *et al*., 2009; Arslan *et al.*, 2015).

According to Ndalama *et al.* (2015) agroforestry tree species, growing on farmland reduces water losses, help to retain water for crops and provide protection to watersheds. Integration of agroforestry tree species into agriculture systems can capture a much larger amount of rainfall (Workman *et al*., 2012). The integrated tree species in an agroforestry system may provide valued products (e.g. fruits, rubber, and timber) whilst practising root and shoot pruning may increase the efficiency of water use whilst providing economic benefits (*World Agroforestry into the Future*, n.d.). On the other hand, tree species planted alongside crops are capable of fixing nitrogen, facilitating nutrient mining and producing biomass that improves soil fertility through a humic substance (Muneer, 2008). According to Young (1994), tree and shrubs benefits on farmland soils include; amelioration of erosion primarily through surface litter cover and understorey vegetation; maintenance of soil organic matter; enhancement of physical properties (e.g. soil structure, porosity and moisture). In addition, tree species extensive root system and canopy cover; favour efficient nutrient recycling that would otherwise be lost through leaching(Young, 1994; Lasco and Pulhin, 2003). Studies by Nkhuwa *et al*. (2020) and Ajayi *et al*. (2011) found that continual application of leaf biomass to depleted soil increases organic matter, water holding capacity provides a good environment for soil microbes and soil nutrients during decomposition. In turn, this could help in addressing food security issues by potentially improving crop productivity, enhancing crop yields, improving animal feed availability, increasing crop diversification, and diversifying smallholder farmers' income while at the same time, protecting the environment(Lasco and Pulhin, 2003; Jamnadass *et al*., 2011).

The increased adoption of agroforestry technologies by smallholder farmers reduces pressure on forests, improved welfare and other natural resources whether in non-protected or protected conservation areas (Phiri *et al*., 1999; Ajayi *et al*., 2007). However, unless farmers widely adopt these technologies as part of their farming system, the potential benefits of agroforestry on livelihoods and the environment will not be realized.

Literature review

Agroforestry adoption

Agroforestry is a joint forest production system whereby land, labour, and capital inputs are combined to produce trees and crops (and/or livestock) on the same unit of land (Binam et al., 2017). Agroforestry technologies incorporate tree crops in farming systems that benefit farmers with fodder for animals, fruits, reduce erosion, reclaim soil fertility (Naya *et al*., 2014; Zerihun *et al*., 2014; FAO, 2018; *World Agroforestry into the Future*, n.d.).

In the early 1990s, agroforestry interest arose rapidly in temperate regions when the research community discovered the complex land management systems developed by rural landowners in North America and Europe, including forest farming, alley cropping, shelterbelts, riparian buffers rehabilitation, and silvopastoral technologies (Zerihun *et al.*, 2014). During the mid-1990s, agroforestry pioneers argued among themselves with increased emphasis on research to understand the adoption decision process of agroforestry technologies (Kuyah *et al*., 2019). For instance, (Lal, (1997) and Doshi *et al.* (2015) stated, "there is a need to develop a predictive understanding of how households make decisions regarding land use as essential in the understanding of the competition between tree component and crop component roots."

Studies relating to the impacts of agroforestry have recently proliferated throughout the world (Rosenstock *et al*., 2014; Mbow *et al*., 2014). Most studies conducted so far deployed dichotomous choice (logit or probit) regression models approach to explain how various characteristics of farms, farmers, policies and development projects influence the adoption decision of agroforestry(Coe *et al*., 2014; Iiyama *et al.*, 2014). Unfortunately, many of these previous studies failed to link their empirical analyses to the underlying theory of an influencing incentive towards decision making on adoption. Instead, emphasis was on reporting several factors correlated with the adoption of specific technologies in particular locations, which neglects the gist of unleashing a general predictive understanding of the farming household decision-making process(Minang *et al*., 2014; Gyau *et al*., 2014).

In Latin America empirical studies reviewed that farming households' limitation to credit access; risk aversion; immediate result orientation; short term priorities; insecure land tenure; and poor extension services, as factors to poor adoption of agroforestry, conservation agriculture, and other sustainable agriculture practices (Mbow *et al*., 2014; Luedeling *et al*., 2014).

In rural communities of Sub-Saharan African (SSA) countries, most households live under high levels of poverty (Minang *et al*., 2014; Lasco *et al*., 2014; Mbow *et a*l., 2014). According to Kalaba *et al*. (2009) in Zambia, over 90% of rural households experience regular hunger periods during the rainy season between November and March. Sileshi *et al*., (2007)) reported similar findings in Malawi, Zambia and Mozambique. This implies that most households grieve from food insecurity, offering enough evidence of the high prevalence of rural poverty. Therefore, results of recent studies conducted in the southern African region show that smallholder farmers do appreciate agroforestry and its potential linkage to combat food insecurity, and household welfare indicators, but they face some challenges to adopting agroforestry(Smith and Mbow, 2014). Challenges to low uptake of agroforestry technologies in SSA countries include; land constraints, property rights (e.g. insecure land tenure), unavailability of germplasm, and knowledge-intensive nature of the technology and/or systems. Farmers' acceptability and improved adoption of the technology is influenced by the extent to which efforts are taken to meet these challenges(Mbow *et al*., 2014). The adoption process of agroforestry technologies is more complicated as compared to annual crops and modern agricultural development packages based on synthetic inputs (because of the multi-complexity and multi-years through which testing, modification and "adoption" of agroforestry take place (Namirembe *et al*., 2014; Nair and Nair, 2014; Ofori *et al*., 2014). Ajayi *et al*. (2003) synthesis study on the adoption of agroforestry indicated that the adoption of agroforestry is not directly related to the advantages of the agroforestry system alone. The broad category of agroforestry systems are specific (e.g. soil type, management), household factors (e.g. resource endowment, household size, age, farmer perceptions), policy and institutions context within which agroforestry technologies are disseminated (e.g. input, output prices, property rights, land tenure), and geospatial (e.g. tree species performance across biophysical conditions, location of region)(Franzel *et al.*, 2014; Iiyama *et al*., 2014; Zerihun *et al.*, 2014).

El Tayeb Muneer, (2008) alluded that one way to enhance agroforestry technologies adoption is to target them to their biophysical, social niches, facilitate appropriate policy and institutional context for the dissemination of the technologies, understand the broader context and dynamics of the adoption process. Several factors influence this adoption process; among them are household preferences, land tenure and inheritance rights and the availability of germplasm. Access to germplasm is a critical factor that affects the adoption of agroforestry technologies. In the absence of the germplasm, rural people abandon the technologies despite their superiority that can be established scientifically (e.g. many farmers using Gliricidia-maize intercropping is relatively low as compared to those using Tephrosia spp., *Sesbani*a s*esban* and *Cajanus cajan*).

In Zambia, agroforestry emergence occurred in the late 20th century when farmers started experiencing economical, ecological and/or climatic issues (Lufumpa, 1991). During this period, the major focus of agroforestry aimed at helping smallholder farmers to sustain surplus production levels that would allow them to become and remain active participants in the agriculture sector sphere. These projects were designed, developed and implemented to embolden agroforestry taking among smallholder farmers across Zambia. Recent studies have emphasized the impacts of agroforestry adoption on smallholder farmers' household welfare through income(Mafongoya *et al*., 2006; Kalaba *et al.,* 2010; Kuntashula *et al.,* 2015; Jama *et al*., 2019; Nkhuwa *et al*., 2020).

Nkhuwa *et al.* (2020) conducted a study to estimate the effects of soil organic resource management practices (e.g. cover crops, residue retention, improved fallows, compost, & green manure) on maize yields and household income in Chipata district Zambia. The study used matching algorithm strategies on data from 303 households and the results showed that only cover crops and improved fallows significantly increased maize productivity by 16%-21% and 22%-31%. However, only green leaf manure and improved fallows increased household income by 26%-28% and 48%-67% respectively(Nkhuwa *et al*., 2020). Based on the findings from this study it can be concluded that improved fallows, as an agroforestry technology, showed a significant positive influence on maize production. Hence, anticipation is made that; this will trigger the adoption rate of the practice in the study area leading to spillover effects of increasing the adoptability potential of the practices(Nkhuwa *et al*., 2020).

Nandi *et al*. (2019) on the other hand, evaluated income share from improved fallows technology adoption impacts among cotton smallholder farmers ' households. The study unleashed that increased land per capita negatively affects improved fallow adoption among smallholder cotton farmers in Zambia (Jama *et al*., 2019). Even so, improved fallow technology adoption increased cotton yield and household income. The determinants of improved fallow adoption among the cotton farmers were examined through the probit model while the impact of the technology on cotton production and income was evaluated by using the propensity score matching and the endogenous switching regression models. Hence, it was found that improved fallows technology adoption had positive impacts on increased housed income(Jama *et al.*, 2019).

Kuntashula *et al.* (2015) assessed improved fallows adoption impacts on adopters and non-adopters farming households' in Chongwe district, Zambia. The study tested the hypothesis that households who embraced improved fallows used less fuelwood from communal woodlands and since the technology provides wood as a by-product (Kuntashula *et al*., 2015). The estimates from ordered probit and propensity score matching showed that the technology had significant causal effects of reducing the consumption of fuelwood from communal woodlands in the same vein improving the soil quality. However, surplus fuelwood by-products increased adopters' household income share.

Kalaba *et al*., (2010) discussed the contribution of natural forest resources and agroforestry systems (e.g. improved fallows) to enhance the socio-economic livelihoods of smallholder farmers and the promotion of the conservation of biodiversity drawing on evidence from research conducted in southern Africa(Kalaba *et al*., 2010). Improved agroforestry systems (AFS) such as improved fallows that mimic shifting cultivation and other AFS provide benefits that contribute to rural livelihoods. Therefore, the survey results indicated that AFS provide benefits such as contribution to rural livelihoods; and improved socioeconomic status and ecosystem functioning of land-use systems. Additionally, AFS provide benefits to smallholder farmers in southern Africa through income generation realized from selling diverse products compared with subsistence agriculture, especially in rural areas.

Lastly, empirical studies conducted by Ajayi *et al*. (2011) and Ajayi *et al.* (2006) showed that fertilizer tree systems (FTS) are inexpensive technologies that significantly raise crop yields, reduce food insecurity, enhance environmental services, and resilience of agro-ecologies. Increased crop yields enable farmers to sell surplus produce; hence improving household welfare. Based on the results, it was recommended that smallholder farmers would benefit if rural development planners emphasize the merits of different fertility replenishment approaches and took advantage of the synergy between FTS and mineral fertilizers rather than focusing on 'organic versus inorganic' debates (Ajayi *et al*., 2011).

Conclusion and Recommendations

Climate change and unpredictability pose significant development concerns, especially in Sub-Saharan African nations like Zambia, where the bulk of the population is dependent on climate-sensitive activities like agriculture and animal production. Concerns about the additional challenges that climate change poses to agricultural development to meet poverty reduction and food security goals have risen sharply in recent years on the international and national policy agendas, and agriculture are regarded as one of the most effective ways out of poverty. Climate-smart agricultural technologies, such as agroforestry, are a vital strategy for enhancing agricultural production, achieving food self-sufficiency, and alleviating poverty among Zambia's smallholder farmers to meet this problem. Smallholder farm households in Zambia have been embracing various agroforestry practices for a long time, yet acceptance of these technologies has not always been ideal. The advantages of farming households who chose agroforestry have been vividly outlined in peer-reviewed publications. Adoption of agroforestry technology-enhanced household income and agro-ecological parameters on farmland.

Furthermore, agroforestry technologies have a significant impact on farmland, enhancing both agricultural and animal output while also having a significant impact on the surrounding biological diversity. As a result, policymakers in the Ministry of Agriculture and international organizations must pursue a variety of policies and strategies to encourage the adoption of agroforestry technologies to boost productivity, improve food security, and raise the living standards of rural farming households.

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This paper DOI: 10.5281/ zenodo.5816755

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