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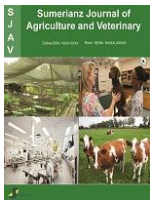

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Alley Cropping For Soil and Agricultural Sustainability in South Eastern Soils of Nigeria

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Abstract

The restoration and maintenance of soil fertility in south eastern soils of Nigeria is a basic critical environmental problem. It is especially serious because their soils lack plant nutrients and organic matter (OM) and intense rainfall experienced in the area erodes vulnerable top soil. The nitrogen fixing ability of tree legumes when used in alley cropping allows them to grow on difficult sites subject to erosion, low fertility or other adverse soil conditions. Alley once established can create conditions favourable for growth of other species leading to a balanced plant ecosystem. Tree legumes are a good source of OM for green manure their dry foliage contains about 2.5-5%N and leaf material incorporated into the soil improves soil fertility, moisture and nutrient retention and general tilth. At the same time by improving soil structure, erosion can be reduced.

Keywords: Alley cropping; Hedgerow; Inter cropping; Mixed cropping; Woody forage.

1. Introduction

The need to sustain the south-eastern soils of Nigeria for continuous crop production has become imperative following increase in population and hence more pressure on the available land. Most of the soils suitable for the crop production have either been taken up by residential buildings or industries therefore available ones require some effort to sustain their use on continuous basis. FAO [1], has developed a frame work known as FESLM meaning frame work for evaluating sustainable land management. A sustainable land management is one that combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously enhance

- Productivity
- Security (reduce risk of production)
- Protection of the natural resources
- Economic viability (profitability)
- Social acceptability

One of the most serious problem affecting crop production activities and agricultural sustainability in south eastern soils of Nigeria is the ineffective and unplanned nature of our farmers in the use of the agricultural soil, the soils are very fragile and therefore prone to erosion problems in that many of the lands suitable for agricultural activities have been overrun by gullies. Most of the soils are ultisols, with peculiar challenges. Though they tend to be well structured and important soil group for upland crop production they often have less than 10% soil volume as water storage pores thus they tend to be drought and pores less than 2 microns affect soil tilth. These south eastern soils have low cation exchange capacity (CEC), very low inherent fertility, multiple nutrient deficiencies and nutrient imbalance. Another challenge is that toxic levels of aluminium and or manganese are among the chemical constraints to crop production on these acid ultisols [2-4]. Thus to control soil erosion and maintain soil fertility are part of the management problems in using these soils for crop production. Also increase in human population and urbanization have equally increased the challenges of the soils for crop production, for they have resulted in the shortening of fallow periods which are needed to restore and maintain soil production and to control weeds. The resultant effect is reduction in crop yield even with improved seeds and cultivars. Hence the need to identify crop management practices that can adapt to the nature of south-eastern soils of Nigeria and maintain soil fertility under intensive land use that is continuous cropping without disastrous effect on the productivity of the soils and environmental health.

In recent times interest has increased in alley cropping as panacea to soil sustainability in southeast, Nigeria. The inclusion of trees especially leguminous trees in crop production systems helps the soil, growing crop and farmer in so many ways. They provide social and environmental services that include but not limited to soil production against erosion by water and wind, improve nutrient recycling for maintaining soil fertility and protection of watershed. The inclusion of herbaceous and woody forage legumes in crop production system according to Brewbaker, *et al.* [5], Sumberg [6] and Kang and Duguma [7] as source of mulch and green manure help to control

soil erosion improve soil structure and texture and supplementary browse to develop sustainable and low-input production systems.

Alley cropping whether in small holding or in compound farming will be more adaptable on low activity clay soils of south-east, Nigeria as tree crops are ecologically suited to the environment and cause little or no damage to soil. Traditional farmers retain certain trees and shrubs in their crop production systems to restore soil fertility exhausted by cropping [8]. Forage and grain legumes increase the OM and N contents of the soil. The extensive root systems of tree legumes enable them to adapt to sleepy sloping sites unsuited to conventional cropping or grazing thus stabilizing the sites from erosion and providing a measure of production which would not otherwise exist. The slopping agricultural land technology (SALT) developed in the Philippines according to Tacio [9] is a prime example of the use of the tree legumes in substantially reducing soil erosion and restoring moderately degraded hilly lands to a profitable farming system. Forage legumes and grain legumes, can fix atmospheric N when they are effectively nodulated and thus contribute to the N economy of cropping systems. This ability is effected by the help of bacteria in their root nodule that convert atmospheric N to ammonia (NH_3) $N_2 + 8H^+ + 8\bar{e}$ $2NH_3+H_2$ and finally to nitrate (NO_3^-) through the activities of nitrobacter and nitrosomonas bacteria, the two phases occur simultaneously in soil and the nitrate (NO_3) produced is either picked up by the companion crop or leached out of the soil [10] This potentials is currently still under utilized in south east soils of Nigeria. On low nitrogen soils the amount of N fixed is closely correlated with legume dry- matter production [11]. Thus the present work tends to review on the potentialities of alley cropping as soil restorative agent visa-vie its application in south eastern soils of Nigeria.

2. Concept of Alley Cropping

When trees or shrubs are planted in series of rows across the slope (on the contour) and crops are planted between them, it is called alley cropping. The shrub or tree rows are called the hedgerows and the space between where the crops are grown are the alleys [12]. Alley cropping or hedgerow intercropping is an agro forestry practice in which perennial preferably leguminous trees or shrubs are grown simultaneously with arable crops. During the cropping phase the trees are pruned and the pruning used as green manure or mulch on the crop to improve the organic matter status of the soil and to provide nutrients, particularly nitrogen to the crop [13]. However, crop yield response in alley cropping is largely dependent on the amount and quality of hedgerow pruning applied, time of application, and field management of the pruning the regulate nutrient [14-16]. The hedgerows are allowed to grow freely to shade the inter-rows when there are no crops. Alley cropping retains the basic restorative attributes of the bush fallow through nutrient recycling, fertility regeneration and weeds suppression; and also combines these with arable cropping so that all processes occur concurrently on the same land, allowing the farmer to crop the land for an extended period. In effort to replace or improve the traditional bush fallow cultivation Kang and Duguma [7] opined that investigations have been carried out on alley cropping and agro-forestry system in which arable crops are grown between rows of woody shrub or tree fallows that during planting period these trees in order to prevent shading of crops they are pruned periodically. Trees and shrubs grown in the hedgerows recycle nutrients and provide green manure, fire wood and staking material just like in the bush fallow system. Alley cropping has the advantage over the traditional system of combining the cropping and fallow phases. Kang and Duguma [7], reviewed the important characteristics of trees and shrubs suitable for alley cropping. Leguminous crops like forage legumes, grain legumes and tree legumes meet most of the required characteristics for the humid and sub-humid tropics like Albizia, peagon pea, cassia, cowpea, bambara groundnut, groundnut, Inga and sesbaina. A study by Nweke [17] have indicated that leguminous crops improved soil physical parameters such as texture, bulk density, moisture and soil chemical properties and gave better protection against erosion. Information about some of these fast-growing nitrogen fixing trees has been documented by national academy of sciences [18]. Among the Albizia species, Albizia lebbek is the most commonly grown it can be pruned continuously and provides green material even in dry season [19]. Many cassia species and pigeon pea species are used for fodder in some tropical countries they are commonly used as hedges in Nigeria and have also been recommended as a shade tree and for soil improvement. Vamoah [20], observed that bambara groundnut, pigeon pea, suppressed weed growth and increased maize yields in alley cropping with maize on an Alfisol. Cowpea and bambara groundnut have been widely tested in alley- cropping system and both species are suitable for alley cropping on the less acid Alfisol and associated soil. Their leaves can be used for mulch; green manure and supplementary high quality browse for small ruminants, particularly during the dry season [6]. On acid soils (pH < 5.0), however, both species grow poorly and require liming and phosphate fertilizer to improve their yield [21].

One vital component of alley cropping is the contour hedgerows which have been proven to be effective in reducing soil erosion and restoring soil fertility. It results in improvements in soil chemical properties and nutrient recycling in addition to providing fodder, stakes and firewood [22-24]. Incorporation of legume pruning into the soil may increase decomposition and **N** releases rates, resulting in greater **N** available to the associated crops. However, high N available early during the cropping season when the crop nutrient demand is low may increase the risk of loss through leaching. Isaac, *et al.* [25] reported high organic N in soils on which leucaena pruning had been mulched on the surface for seven seasons than in soils in which pruning were incorporated into the soil, Mofongoya, *et al.* [16] observed N recovery by maize crop when pruning of different multipurpose trees were incorporated into the soil than the surface applied pruning. Thus, more information are needed to better understand the effects of placement methods of legume pruning on yield and N recovery of an associated crop under continuous cultivation. Many studies have demonstrated the importance of amount, quality and placement methods of hedgerow pruning on yield and N uptake by annual crops under sub humid and semiarid conditions [26]. Similarly, studies have shown that increased pruning frequency reduced hedgerow vigour, but decreased competition with the crop [14]. Pruning done

late in the growing cycle of the crop is less likely to benefit the crop with nutrient being released too late for the crop uptake.

2.1. Benefits of Alley Cropping

Some of the beneficial effects that have been claimed for allay cropping include:-

- Improved crop performance due to the addition of nutrients and organic matter to the soil
- Reduction in the use of chemical fertilizer
- Improvement in the physical nature of the soil. The addition of mulch can lower soil temperature, reduce evaporation and improve soil fauna activity resulting in better infiltration, reduced run off and improved water use efficiency.
- On sloping land, the tree rows act as physical barrier to soil and water movement, resulting in significant reduction in erosion losses [27].
- The provision of additional such as forage, firewood or stakes when multipurpose tree legume is used as the hedgerow.
- Improvement in weed control during the fallow period shading of the interspaces may reduce weed growth. While in cropping phase, the mulch may inhibit germination and establishment of weeds [28].

Experimental evidence supporting claims of beneficial effects of alley cropping is provided by a number of studies conducted largely in humid and sub humid regions on high base soils, Kang, *et al.* [24] increased maize grain yield from 1.9t /ha in an unfertilized control plots to 3.5t/ha in plots mulched with *Leucaena leucocephala* (leucaema) from 4m wide rows. A similar magnitude of response was obtained by Dofeliz and Nesbitt [29] in the Philippines again with leucaena at 4m row spacing. Atta-Krah and Sumberg [30], recorded 2.42t/ha of maize while the control plots yielded 1.74t/ha in a degraded alfisol soil in Nigeria using *Gliricidia sepium* in alley system. Although the results from alley cropping in humid regions (on high base status soils) have been quite positive, the performance of the system in other agro ecological zones has been less encouraging. In the semiarid lowland tropics, Singh, *et al.* [31] reported that yields of castor, cowpea and sorghum alley cropped with Leucaena hedgerows spaced at 10m for a period of 4 years were lower than in the control treatment. Yield decline from 30 to 15% of the sole crop yield as the distance from the hedgerows decline from 5m to 0.3m. According to Ekwealor [13] these authors attributed much of the yield decline to severe moisture competition. In Peru, Szott [32] alley cropping trails using Inga edullis and Cajanus on a Typic Paleudult. He observed that yields of alley cropped cowpea, maize and rice were extremely low and were equal to or less than that of the control treatment. Evensen and Yost [33], initially reported positive results from the alley cropping of upland rice and cowpea with rows of *Paraserianthes falcataria* on a Tropeptic haplorthox in West Sumatra, Indonesia, particularly with addition of a low rate of lime. However, yield decline after 4 years and were restored only after fertilizer input was increased.

2.2. Effects of Alley Cropping on Soil Property

An important benefit of alley cropping is the addition of large amount of organic material from the pruning or green manure which can have favourable effects on soil physical and chemical properties, on microbiological activity and on soil productivity. Several studies have demonstrated significant positive effects of alley cropping on soil fertility parameters such as organic C levels, total N and extractable P levels over a range of climate and soil conditions [22, 34].

The magnitude of these effects, however, varied with hedgerow spaces and management as this influences the quality and quantity of pruning. Factors such as CN ratio, lignin and polyphenol content influence the decomposition rate of the mulch, the subsequent release of nutrient and their uptake by the crop. Studies conducted by Gutteridge [35] showed mulches from *Sesbania sesban Gliricidia* and *Leucaena* were effective sources of N for maize growth while those from *Calliandra calothyrus, Acacia cunninghamii* and *A. fumbriata* were ineffective in the short term. This may have been due to high polyphenol and /or lignin content of the latter species. Guevara [36], found that only about 38% of N in *Leucaena* pruning was recovered by a maize intercrop while Evensen [37] noted that compared with urea, mulching with *Leucuena* leaf was only 41% as effective in supplying N to maize. The efficiency of utilization of N from the pruning can often been improved by incorporation. Read [38], noted that incorporation of *Leucaena* leaf produced a high N uptake than when applied as mulch. Evensen [37], increased the efficiency of mulched *Leucaena* leaf to 63% that of urea by incorporation. Kang, *et al.* [24], also found that incorporation improved maize yields both in the presence and without additional nitrogen fertilizer.

Hedgerows have the ability to recycle nutrients although the aspects have not been widely studied. Hauser [39], demonstrated this phenomenon in alley cropping system with *Leucaena*. He found higher concentration of N, K, Ca and Mg in the surface soil than in the subsoil under the hedgerows. This was attributed to leaf litter fall and nutrient uptake by the trees from the subsoil. Also in the centre of the alley plots, the reverse situation occurred with lower nutrient levels in the surface soil due to crop uptake and higher levels in the subsoil due to leaching. This result shows that alley cropping can reduce the downward displacement of nutrients.

2.3. Effects of Alley Cropping on Soil Erosion

A large nutrient of experimental results have confirmed the significant role of alley cropping in reducing run off and soil erosion [39, 40]. Studies conducted by Lal [34] showed that erosion in plots tilled and alley cropped with *Gliricidia and Leucaena* was reduced by 73% and 83% respectively compared with a tilled control treatment. Rows of *Leucaena* planted at 5 or 10m intervals across the slope were as effective as conventional contour banks in

reducing erosion on a 10% slope in southeast Queensland. In a trial that lasted 3 months on Typic tropudalt, erosion greatly reduced by the presence of Desmanthus virgatus hedgerows spaced at 6m intervals [41]. A total of 1.424mm of rain fell during the experimental period. Total soil loss was 127t/ha in the control treatment, 41t/ha with Desmanthus hedgerows and contour cultivation, and 0.2t/ha with hedgerow pruning as mulch, and zero tillage. Young [40], attributed the beneficial effects of alley cropping in controlling soil erosion partially to the barrier effects of the hedgerows, but mainly to the presence of pruning applied as mulch.

2.4. Management of Alley Cropping

Biologically, the effectiveness of alley cropping systems depends to some extent on the soil type and agro ecological zone in which the system is used but it also very dependent on management strategies adopted. Factors such as choice of tree species, orientation, layout and manipulation of the hedgerows and crop husbandry practices are all important in determining the outcome of the alley cropping system. The choice of tree species for alley cropping is extremely important and to a large extent determines the success or failure of the system. Rachie [42] noted a number of attributes which should be considered when selecting a tree species for alley cropping. These include:-

- rapid growth rate
- ability to withstand frequent cutting
- good cropping (re-growth after cutting)
- ease of establishment from seed or cuttings
- nitrogen fixing capacity
- deep-rooted with different root distribution to the crop
- multipurpose (such as forage and firewood)
- ability to withstand environmental stresses (drought, water logging, and extremes of pH)
- high leaves to stem ratio
- small leaves or leaflets
- ability to retain leaves in the dry season and
- freedom from pest and diseases.

A wide range of tree species has been used in alley cropping experiments or demonstrations but Leucaena has been by far the most favoured species [43]. A number of comparative trials in humid/sub-humid zones on high base status soils have shown Leucaena to be superior to other species and may partly explain its widespread use [44]. However, on acidic low base status soil leucaena has not been successful as species such as Fleminga macrophylla [12] and Erythrina peoppigiana. There is a need for a wide range of tree species suited to low activity, acid infertile soils.

2.5. Influence Alley Cropping

The biological merits of alley made it an important conservation farming practice for smallholder farmers. One of the major benefits of alley cropping is the mulch provided by the hedgerow species in form of pruning to the associated crop. Factors such as cutting height and frequency, hedgerow spacing and intra-row density will all influence the quantity of pruning produced [45]. In humid and sub-humid areas, tree row spacing range from 2-7m with 4- 6m most commonly used [45]. Tree spacing within the rows should be as close as possible and experience with species such as Leucaena, Gliricidia and Sesbania sesban indicated that trees should be spaced at 10 – 15cm or as possible to a solid hedge along the row.

This helps to favour leaf production over stem, provides a more effective barrier to soil movement on sloping lands and creates a better microenvironment for crop growth. Closer spacing both within the row and between the rows also allows for improved distribution of nutrients to a greater of the intercrop. On the other hand, close spacing between the hedgerows reduces the amount of land available for the crop and can result in increased competition for the growth factors of light, moisture and nutrients between the hedgerow and crop [46].

3. Conclusion

Alley cropping production for restoration and maintenance of soil productivity must provide sufficient qualities of organic materials to sustain the physical, chemical and biological processes essential for developing and maintaining a suitable soil surface. Soil fertility is greatly affected not only by quantity but also quality of OM; to maintain good soil structural stability and ensure soil fertility alley cropping as soil management system for south eastern soils of Nigeria is hereby advised and emphasised.

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