Sustainable Maize Production in *Dactyledania barteri* AND *Alchornea cordifolia* Alley Systems

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Abstract
A field study was carried out in Onne (located between longitudes 4^0 and 5^0 N, and latitudes 7^0 and 8^0 E) in Southeastern Nigeria on a degraded ultisol which was planted with Dactyledania barteri and Alchornea cordifolia for twenty years and under natural re-growth. After the period (that is, 20 years), the trees were pruned and soil physicochemical properties were evaluated at depth of 0 – 15 cm. In a split-split experiment fitted into a completely randomized design (CRD), sustainable maize yield was obtained with Dactyledania barteri fallow recording 17.8 and 27.8 % higher grain yield than Alchornea cordifolia fallow and natural re-growth respectively. The systems were found to be sustainable as soil quality did not deteriorate at the end of the experiment.

Keywords: *Alchornea cordifolia, Dactyledania barteri, Maize Production, Sustainability,*

1.0 Introduction

Agriculture has been acknowledged as the bedrock of economic development of any nation. This is in Arthur Lewis assertion that without agricultural development, economic development remains stagnant. The economic strength of any nation depends on if the nation could fend for its citizenry in food, shelter and clothing provision, and also, provides raw materials for the industries. Agriculture achieves these in crop, livestock and fish production, and of course, in forestry. Modern agriculture emphasizes on such production that will not jeopardize the capacity of the resources on which production depends. Thus, comes in sustainable agriculture and of course, sustainable development.

Several definitions have examined the concept of sustainability, either as applied to agricultural systems or in a manner that can be applied to them (Ciriacy-Wantrup, 1968; Denny and Fuss, 1983; Dumanski, 1987; Barbier *et al*., 1990). There is a general agreement at present that within agricultural development, projects should be accepted not on the basis of the net present value, but on whether the resulting environmental benefits compensate for environmental damages caused

elsewhere. The attributes of sustainable systems as opposed to non-sustainable systems have been widely discussed (Conway, 1985; FAO, 1989; Keaney, 1989; Lal and Stewart, 1992). An initial goal in sustainability research was to examine these attributes and develop minimum data sets for assessing sustainability. A start has been made on this in few areas, such as soil quality changes (Dumanski, 1987; Dumanski *et al*., 1992); agro-climatic guidelines (Baier and Dumanski, 1991); and economic criteria (Lynam and Herdt, 1989).

In crop production, several systems of production have been evolved over the years. Conventional agriculture has resulted in environmental problems such as pollution and exhaustion of soil nutrients (Lawson and Sivakumar, 1991; Sakar *et al*., 1998). Sustainable crop production has refocused food production to include consideration for a safe environment. This has premised the International Institute of Tropical Agriculture (IITA) to concentrate its research efforts on developing sustainable management technologies that enhance food production and preserve natural resource base in line with BIFAD (1988) requirements that new technologies being developed must not only enhance food production but also maintain ecological stability and preserve natural resource base.

The most promising land use system is alley cropping (an agro-forestry technique) which is a land use system in which trees are grown in the same land as agricultural crops and/or animals, either in a time sequence or in a spatial arrangement and in which there are both ecological and economic interactions between the tree and non-tree components (Beets, 1989). Appropriate management practices are therefore tailored to specific crops, soil and agro-ecological zones (Cassel and Lal, 1992; Opara-Nadi, 1998). Bunch and Lopez (1994) in studying the adoption of resources-conserving practices observed that the practices helped in regenerating local economy.

Thus, since alley cropping is usually site and crop specific, this research was undertaken to determine the yield of maize in alley cropping systems under *Dactyledania barteri* and *Alchornea cordifolia* and evaluate the impact of such usage on soil properties in order to determine if the systems are sustainable or not.

2.0 Materials and Methods

2.1 Description of Experimental site

The research was carried out in the Rivers Institute of Agricultural Research and Training (RIART) at Onne, South-eastern Nigeria (between longitudes 4^0 and 5^0 N, and latitudes 7^0 and 8^0 E). The plots used have been under the fallows of *Dactyledania barteri, Alchornea cordifolia* and natural bush for twenty years.

The climate here is characteristic of the humid tropics with high rainfall of annual mean of 2400 mm and high temperatures all year round with small diurnal and annual ranges. Notably, there is no month without rainfall. The vegetation is the rain forest type that has been altered by man's activities leading to the presence of secondary vegetation now. The soils here are the acid sands Ultisols with the characteristic poor chemical properties and classified as loamy, siliceous, isohyperthermic, Typic Paleudult (Hulugalle *et al.*, 1989).

2.2 Soil Sample Collection

Soil samples were collected initially before bush clearing for physico-chemical properties determination at depth of 0-15 cm for each conservation plot. This was done randomly using the auger and core, and bulked for the determination of various parameters. At the end of the experiment, soil samples were also collected from the experimental plots for the determination of the same physico-chemical properties, as were for the initial samples.

2.3 Land Preparation/Planting

After bush clearing, no tillage was undertaken before planting and the maize (OBA Super 2) was planted at a spacing of 50 cm apart as sole crop between hedgerows, which are spaced 150 cm. Two plants per stand were allowed to give a plant population of 40 plants per plot (26,667 crops per hectare).

2.4 Fertilizer Application

Fertilizer (urea) was applied at the rates of 0 and 150 kg N/ha at three weeks after sowing in bands.

2.5 Experimental Design

The experiment was laid out in a split–plot fitted into a Completely Randomized Design (CRD) with the fallows serving as the main plots while the fertilizer rates served as the sub-plots. The fertilizer treatments were replicated three times within the main plots.

2.6 Analytical Methods for Physical Properties

The Organic matter content of the soil was evaluated by determining the soil organic C using the wet oxidation method of Walkley and Black (1934) and multiplying the value by factor of 1.724. The total N content of the soil was evaluated by employing the micro-Kjeldahl technique as modified by Jones (2001). In the determination of available P, the Bray P.I extraction method was employed (Bray and Kurtz, 1945a). The exchangeable bases were extracted by the neutral normal ammonium acetate extraction method and the contents of Na and K were determined with the flame photometer whereas Ca and Mg contents were determined by EDTA titration. The soil pH was determined electrometrically with a pH meter.

2.7 Growth Rate (GR) of Maize

Heights of twenty (20) plants at three (3) weeks after planting in each fallow were measured and an average height for the plants determined for each fallow before the application of the fertilizer. At three weeks after fertilizer application (that is, six weeks after planting), heights of ten plants per treatment were measured and an average height determined for each treatment. Then, the growth rate (GR) for each treatment was calculated with the formula:

$$GR = \frac{H2-H1}{Time}$$

Where,

H2 = Height at six WAP

H1 = Height at three WAP

Time = 21 days (that is 3 weeks)

2.8 Leaf Area (LA)

This was determined by the application of the Montgomery (1911) technique

2.9 Stover Yield

The above ground parts of four crops per plot were harvested, dried and weighed. From this, the stover yield per hectare was estimated. This excluded the cobs which were taken to the laboratory and used for grain yield determination.

2.10 Maize Grain Yield

As stated above, the cobs from four crops per plot were harvested; the grains were shelled, dried in the oven and weighed. The results were expressed in tones per hectare for each treatment and recorded.

2.11 Data Analysis

Analysis of variance using the general linear models procedure of the Statistical Analysis Systems Institute (SAS, 1987) was used to determine the significant effects of plant (fallow) species and fertilizer rates on crop performance and soil physico-chemical properties, and the means were separated with standard error of the means (SEM).

3.0 Results

3.1 Soil Physico-chemical Properties of the Plots

The cumulative effect of species and fertilizer rates with depth on soil physico-chemical properties is summarized in Table 1.

Table 1 Cumulative Effect of Species and Urea Application on Soil Properties

Sources of Variation	df	OM	Tot. N	Ava. P	Ca	Mg	Na	K	pH(H_2O)
Species	2	**	NS	***	NS	**	NS	NS	NS
Fertilizer	1	NS	***	NS	NS	***	**	***	NS
SP.* Fert.	2	NS	NS	NS	NS	NS	NS	NS	NS

****, **, *** represent the degree of significance at p≤0.05***

Table 1 shows the cumulative effect of species and urea use on soil physico-chemical properties after the experiment while the significant effect of fertilizer on soil properties is shown in the Table 2, whereas Table 3 summarizes the overall effect of using the soils for crop production on soil sustainability. Such soil properties as total N, Mg, Na and K contents were significantly influenced by fertilizer use.

Table 2 Effect of Urea Application on some Soil Properties

Urea	Tot. N	NO_3-N	NH_4-N	Mg	Na	K
100 kg N ha^{-1}	0.0682	112.483	559.761	3.039	0.125	0.1889
Zero	0.0544	88.056	502.592	2.612	0.116	0.2217
SEM ±	0.0022	4.538	16.774	0.091	0.0024	0.0043

Table 3 Overall Effect of Species on Soil Properties

Before Cultivation			After Harvesting			
Dactyl	**Alchor**	**Natural**	**Dactyl**	**Alchor**	**Natural**	**LS**
59.87	**60.10**	**58.90**	**52.64**	**53.54**	**58.72**	**NS**

3.2 Crop Performance under selected Fallow Species

Growth rate, leaf area, grain C, grain nitrogen (N uptake) and C: N ratio was not significantly affected by species and fertilizer. Figure 1 shows the effect of fallow species on maize leaf area. Maize Stover yield and grain yield were significantly affected by species and species * fertilizer interaction whereas the leaf area of maize was only significantly affected by species such that maize had significantly higher leaf area under *Dactyledania barteri* than under natural bush than under *Alchornea cordifolia*. It could therefore be asserted that the photosynthetic function of the leaf will be enhanced in the maize under *Dactyledaria barteri* fallow than those in ether *Alchornea cordifolia* or natural bush and products distributed all over the crop body. This is evident in the higher Stover and grain yield of maize under the *Dactyledania barteri* than under *Alchornea cordifolia* and natural bush. With respect to fertilizer application, grain yield was increase by urea application, although not significantly, while such application enhanced stover yield (Figures 2and 3).

It is thus obvious that fertilizer (urea) application to freshly cleared fallows of *Dactyledania barter*i and *Alchornea codifolia* may not be necessary unless the purpose of production would be for animal fodder as it will improve the protein content of the fodder. Kang *et al.* (1981) had reported similar response to N fertilization by maize on a land newly cleared of *Chromolaena odorata* fallow in an acid Ultisol at Onne.

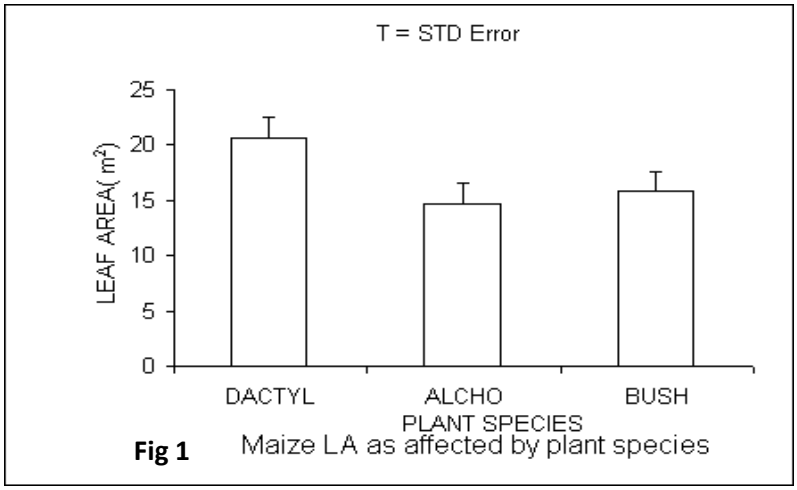

Fig 1 Maize LA as affected by plant species

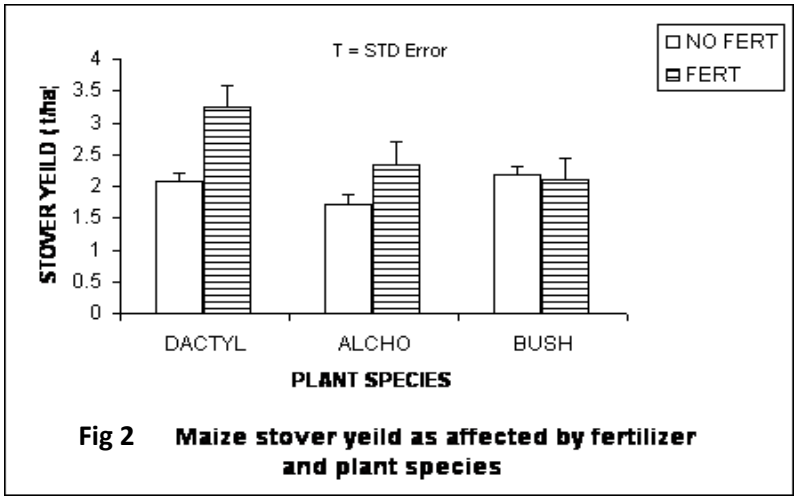

Fig 2 Maize stover yeild as affected by fertilizer and plant species

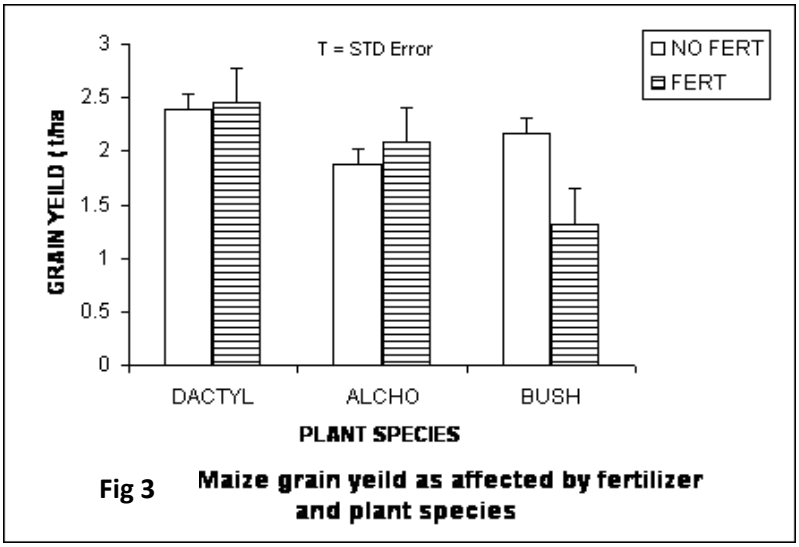

Fig 3 Maize grain yeild as affected by fertilizer and plant species

3.3 Discussion

The use of the fallow for crop (maize) production distorted the equilibrium of soil organic matter content with the value for the *Dactyledania barteri* fallow being lower than the initial value. For the *Alchornea* fallow, the application of N fertilizer (although not significant) enhanced the decomposition of the high quality litter, adding more organic matter to the soil and compensating for losses by deterioration due to the clearing of vegetation cover and leaching.

The application of fertilizer to the *Dactyledania* fallow could not possibly meet the biological N requirement for the decomposition of the low quality litter coupled with other N losses and could have rather enhance the deterioration of the soil organic matter leading to lower value of organic matter than the initial value while the subplot that did not receive N fertilizer, maintained the initial organic matter content possibly due to the protective cover of the litter that acted as mulch. With these intricate processes, *Dactyledania* fallow still significantly maintained the highest organic matter content. This is attributable to the long run stable organic matter accumulation during the fallow period.

Total N did not differ significantly due to effect of fallow species and species * fertilizer interaction but showed significant difference due to fertilizer effect at the end of the experiment (that is after harvesting). The value of total N in the soil at the end of the experiment for the *Dactyledania* fallow was lower than the initial value. This could be attributable to volatilization loss, crop uptake microbial immobilization and leaching. The values of total N under *Alchornea* fallow and natural re-growth were relatively higher than the initial values in soil. This could be attributable to N fertilization and partly, for *Alchornea*, to N mineralization during litter decomposition. This corroborates the findings of Ikpe (2003) that there was significantly higher total N content in soil under *Alchornea* than *Macaranga barteri* and *Inga edulis.*

After harvesting, there was no significant difference in Ca content between fallow types even with respect to N fertilization. The value for this parameter seems to be higher than the initial value. This could be as a result of contribution of organic matter as more litter decomposed, which have been acknowledged by several research workers (Kang *et al*., 1990; Agboola, 1990; Opara-Nadi, 1993; Hamadina, 1995; Stangel, 1995; Gbaraneh *et al.,* 2006). Magnesium content in the soil was significantly influenced by the fallow species and fertilizer application such that higher value were noticed under *Dactyledania* fallow than *Alchornea* fallow, and the subplot that received N fertilizer had higher Mg content than the ones that did not receive N fertilizer; the higher value associated with the fertilizer plots could be due to enhanced mineralization of more organic matter in the plots. Sodium and K were significantly influenced by fertilizer application although species effects were not significant on them. The significant effect of fertilizer on Na and K content could be explained by the same reason as for Mg content.

The higher values of the parameters at the end of the experiment than the initial values could be due to positive shift in the establish equilibrium of the nutrient status sequel to the enhanced mineralization of organic matter to release the nutrients contained when the vegetation cover was cleared, possibly due to environmental conditions that encouraged the activities of the micro-organisms such as sunlight and energy which the vegetation had been shading them from.

Although growth rate, grain nitrogen, grain C and C;N of grain showed no significant difference among the treatments, the performance of maize in this alley cropping system was actually impressive. Grain yield which is the common reason for maize production in the area was considerably increased, recording 2.41, 1.98 and 1.74 tha^{-1} for *Dactyledania, Alchornea* and natural fallows respectively against averages of 1.32 and 1.65 tha^{-1} reported by Gbaraneh *et al.* (2006) for maize that did not receive manure and maize that was manured respectively during comparable growing season at Onne. Powell and Ikpe (1992) had also reported increase in the yield of millet when organic matter was applied to a sandy Sahelian soil as animal manure. Thus, increase in maize yield corroborated other reports that organic materials in various forms applied to crops increase yield (Opara-Nadi, 1993; Kang *et al.*, 1993; Steiner, 1991; Araki, 1993; Akobundu, 1993; Hauser and Kang, 1993; Mulongoy *et al.*, 1993; Ruhigwa *et al.*, 1993; Hamadina, 1995).

Stover yield and leaf area of maize were also increased by the alley cropping system using *Dactyledania barteri* and *Alchornea cordifolia* with *Dactyledania* having significantly higher Stover yield and leaf area than *Alchornea* and natural re-growth. The significant effects of species * fertilizer interaction on crop (maize) performance are illustrated in figures 1 to 3. The enhanced performance of maize particularly with respect to yield (stover/grain) (figures 2 and 3) suggests that alley cropping using *Alchornea cordifolia* and *Dactyledania barteri* can sustain crop productivity and soil quality as soil physio-chemical properties did not deteriorate. This is in agreement with Driessen (2007) that a land use system is considered biophysically sustainable if the compounded sufficiency of relevant land attributes does not deteriorate under the applied land use. This finding also corroborated the holistic sustainability concept as enshrined in several definitions of sustainability –a sustainable system (Conway, 1985; WCED, 1987; FAO, 1989; Keaney, 1989; Young, 1989; Lal, 1991; Okigbo, 1991; Lal and Stewart, 1992; Spencer and Swift, 1992; Akobundu, 1993) and contributing to the development of data required for the stepwise assessment of the sustainability concept as advocated by Spencer and Swift (1992).

Conclusion

The results of the research have shown how the use of agro-forestry shrubs, *Dactyledania barteri* and A*lchornea cordifolia* on an acid Ultisol at Onne Southern Nigeria can uphold the holistic sustainability concept that is recently advocated in modern Agriculture by improving the soil fertility and productivity, and maintaining acceptable crop yield as associated with the socio-economical spheres in the area. The system also provided other services such as source of firewood, which the people fetched from the pruned vegetative cover.

Recommendations

i. An agro-forestry technique is site and crop specific, therefore, other crops such as cassava and yam should be used in substantiating the sustainability of the system because these crops are major staples of the people of southeastern Nigeria.
ii. The system requires to be subjected to more than one season cropping in order to holistically conclude of its sustainability, particularly, with respect to different crops and possibly, under mixed cropping systems.

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