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ECONOMIC EVALUATION OF USING MULCH FROM MULTI-PURPOSE TREES IN MAIZE-BASED PRODUCTION SYSTEMS IN SOUTH-WESTERN NIGERIA

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SUMMARY

Cutting and carrying of mulch from established tree plots is an alternative to *in situ* mulch in agroforestry systems. Through the cut-and-carry method, the undesirable effects of tree-crop competition characterized by *in situ* mulching can be avoided. An economic evaluation of the cut-and-carry method of providing nutrients for maize production was carried out based on investigations in south-western Nigeria. The results showed that the use of mulch from multi-purpose trees (MPTs) through the cut-and-carry method contributed to higher maize grain yields than those obtained with fertilizer or in the untreated controls. However, because of high labour requirements and scarcity of land in the study area, providing nutrients for crop production by this method is unprofitable both in the short and the long term. This may serve as a constraint for the adoption of this technology by farmers. Alternative options requiring less labour and land requirements should be investigated in the quest to replace shifting cultivation.

INTRODUCTION

Shifting cultivation or slash-and-burn agriculture is still a dominant system of food production in the humid and subhumid tropics. However, it has become a major cause of deforestation and degradation (Juo and Manu, 1996; Barrow, 1991). Ideally, slash-and-burn agriculture is ecologically stable under very low densities of human population but, in great parts of the humid and subhumid tropics, increasing population pressure has reduced fallow periods for cultivation. This modification has led to the eventual breakdown of the system in the long term. Losses of mineral nutrients during the cultivation phase, through runoff, erosion, leaching and crop removal, can no longer be restored by short periods of bush fallow (Brady, 1996).

Land use intensification, an alternative to shifting cultivation, is only feasible if nutrients depleted during cultivation are replenished (Vanlauwe, 1996). Use of inorganic fertilizers has been promoted in various African countries in an effort to

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increase crop productivity. However, due to cost and distribution problems, the use of inorganic fertilizer in sub-Saharan Africa is still limited. Studies by Juo and Kang (1989) showed that application of fertilizers and lime can maintain crop yields under monoculture over a period of several years. However, long-term continuous cultivation on kaolinitic and oxidic soils in the high rainfall tropics often resulted in a rapid decline in soil pH and increases in soluble and exchangeable aluminium (Al).

In the search for alternative farming methods to replace shifting cultivation, efforts have been made by various research institutions to develop more efficient and sustainable food production methods. One of these methods is the integration of legumes into the farming systems. Legumes play an important role in cropping systems because of their ability to fix atmospheric nitrogen symbiotically. Thus, they can be widely used as sources of green manure, mulch and for nitrogen cycling (Tian *et al.*, 1992). There are three common methods of integrating legumes into cropping systems. These include (a) cutting and carrying the leaves and branches to mulch field crops (cut-and-carry), (b) intercropping grain legumes with other food crops, and (c) intercropping woody leguminous species with food or forage crops (for example, alley cropping). Studies by Ngambeki (1985), Ruhigwa *et al.* (1994), and Ehui *et al.* (1990) focused on the economics of alley farming in West Africa. The present study complements these studies by evaluating the economics of using mulch from multi-purpose trees (MPTs) through the cut-and-carry method in maize production. Three MPTs – *Gliricidia sepium*, *Leucaena leucocephala* and *Senna siamea* commonly used for mulching were evaluated against the use of inorganic nitrogen fertilizers and compared with non-application of either nitrogen fertilizers or mulch for maize production.

MATERIALS AND METHODS

Data were obtained from field experiments conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The experimental site was located in the forest savanna transition agro-ecological zone. Rainfall at the location is bimodal, with an annual mean of 1250 mm. The dominant soil type at the location is an Alfisol belonging to the Egbeda series. Maize is cultivated twice per annum in the study area. Field experiments were conducted in the 1995 (July to October) and 1996 (May to August) growing seasons. Despite the high population density in the study area, farm labour is in short supply because of out-migration of youths to cities. Labour availability is seasonal and poses a constraint especially during the growing season.

The experiments were set up in randomized complete block designs with three replications. Sources of mulch (treatments) included *Gliricidia sepium*, *Leucaena leucocephala* and *Senna siamea*. These were harvested from an established field and carried to the maize plots. Distance between the fields where MPTs grew and the experimental plots was about 150 m. At the time of planting maize, 5 t mulch dry matter ha^{-1} was applied. After three weeks another 3 t mulch dry matter ha^{-1}

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was applied. The fertilizer experiment included unmulched plots to which urea was applied at the rate of 90 kg N ha^{-1} in three split applications. Neither inorganic fertilizer nor mulch was applied to the control plots. The maize variety TZE Comp.3 × 4 CI was planted in all plots on the same day in July 1995 (late maize) and May 1996 (early maize) at a planting distance of 25 × 75 cm. Two seeds were planted per hill and later thinned to one plant per stand to give a plant density of 53 333 plants ha^{-1}. At planting and one week after germination 22.5 kg N ha^{-1} was applied. Six weeks after germination, the remaining 45 kg N ha^{-1} was applied. The size of each plot was 10 × 4.5 m. Prior to planting, all plots received basal applications of 30 kg ha^{-1} each of phosphorus (P) and potassium (K) in the forms of single superphosphate and muriate of potash respectively. Weeding was done twice on each plot; once at three weeks after planting (WAP) and the other at eight WAP. Maize was harvested at physiological maturity and grain yield was determined. Input use and costs for the treatments and controls were also recorded. Labour data were recorded for each plot and converted to man-days per hectare.

Analytical approach

Partial budgeting was employed to evaluate the profitability of using mulch from three MPTs through the cut-and-carry method compared with the application of nitrogen fertilizer and the non-application of mulch or fertilizers. Profitability was computed as the difference between total benefits and costs. The partial budgeting technique has been recommended for analysing agronomic data especially for providing recommendations for farmers (CIMMYT, 1988) and is widely used in farming systems research (Shaner *et al*., 1982; Dillon and Anderson, 1980). Partial budgets were developed to calculate benefits and costs associated with each treatment. Only costs that vary were included in the budget analysis. For instance, the cost of maize seed was not included since the same seed quantity was planted for each treatment. Costs that reflect present practice of maize cultivation in south-western Nigeria include labour and fertilizer costs. The costs and benefits associated with each treatment were valued at market prices. Labour cost for each operation was valued at the daily rate (cash plus food) paid to farm labourers (100 Naira d^{-1}) in Nigeria. In practice, cutting and carrying of mulch from MPT fields to crop fields was carried out at the time of planting or three weeks after planting. The first cutting and carrying of mulches coincided with land preparation for the cultivation of most food crops, while the second coincided with weeding operations. Thus, cutting-and-carrying of mulch to crop fields coincided with seasonal labour peaks in the study area.

In order to harvest the recommended quantity of each MPT mulch type, an area of 0.7 ha was required to plant the trees. Since land was becoming scarce in the study area, opportunity cost was assumed to be equivalent to the total land productivity for maize production. Thus, the opportunity cost was estimated by calculating maize yield based on gross land area. Following a similar approach by Ruhigwa *et al*. (1994) maize yield from each treatment was divided by 1.7. In the case of urea, the market price of 1000 Naira per 50-kg bag (US$12.50) was used for the analysis. This cost reflected the actual cost paid out by farmers despite the fact that there was a subsidy on inorganic fertilizers in the country during the time of this study.

Average yield from each treatment was deflated by 30% in order to arrive at realistic yield levels that could be obtained on farmers' fields. Also, aggregated labour input per hectare was discounted by 50%. These adjustments were expected to account for yield and labour differences arising from the management practices employed in the study and those that could be achieved on farmers' fields. In addition, they were intended to correct any errors that could have arisen through overestimation from the plot sizes. Costs and benefits were converted into US dollars using the average exchange rate over the two years.

RESULTS

Grain yield

Grain yield from the plots mulched with materials from MPTs were higher than those from the fertilized and non-fertilized experiments during the two years (Table 1). Maize yield in plots treated with *L. leucocephala* or *G. sepium* mulches were not statistically different from each other in either of the years. During the first year, there was no significant difference in maize yield from plots mulched with *S. siamea* or *G. sepium*. Also, yield from the nitrogen fertilizer experiment was similar to that obtained from plots mulched with *S. siamea*. Annual differences in maize yields for the two years were observed. In all treatments, grain yield was higher in 1995 than in 1996. Maize yield from plots mulched with *G. sepium* and *L. leucocephala* in the first year dropped by 22 and 25% respectively during the second year. Among the mulch treatments, the greatest decrease (45%) in maize yield during the second year was observed from plots mulched with *S. siamea*. As expected, the lowest maize yield was obtained from the untreated control plots.

Labour input

Table 1 also shows the total labour requirement for each treatment. All the

Table 1. Maize grain yield (t ha^{-1}) and labour input required (man-days ha^{-1}) for each treatment.

	Grain yield				Labour	
Treatment	1995	1996	Average	Adjusted†	Average	Adjusted‡
Gliricidia sepium	6.07	4.69	5.38	3.78	202.01	101.00
Leucaena leucocephala	6.04	4.55	5.30	3.72	199.30	99.65
Senna siamea	5.13	2.91	4.02	2.81	134.48	67.24
Untreated control	2.93	0.73	1.83	1.28	11.34	5.67
Nitrogen fertilizer (90 kg N ha^{-1})	4.20	2.23	1.28	2.25	14.58	7.29
L.s.d. (p = 0.05)	1.64	0.92				

†Average yield reduced by 30%; ‡average labour deflated by 50%.

mulched plots required higher labour input to achieve the necessary yield advantage over the fertilizer and the untreated control experiments. In the case of maize plots mulched with *G. sepium* or *S. siamea*, 96% of the total labour used was for the collection and management of mulch, while only 4% was for weeding. Cutting-and-carrying the mulch and management on field accounted for 98% of the total labour input for the *L. leucocephala* treatments. For the fertilizer treatment, about 22% of the total labour required was to apply the fertilizer. Weeding labour requirements were highest in the control, followed by the fertilizer treatment. Number of man-days required for weeding on mulched plots was lower than for the fertilizer and control experiments. Plots mulched with *L. leucocephala* or *S. siamea* required only about five man-days per hectare for weeding. Those plots mulched with *G. sepium* required about eight man-days per hectare of weeding.

Economics of using MPTs as mulch

Partial budget analyses showing the costs and benefits of using the three mulches compared, with the application of nitrogen fertilizers and the untreated

Table 2. Partial budgeting for the multi-purpose trees (MPT) as mulch, for untreated controls and for plots given nitrogen fertilizer.

	Treatment				
	Gliricidia sepium	*Leucaena leucocephala*	*Senna siamea*	Untreated control	Fertilizer (90 kg N ha^{-1})
Maize grain yield (t ha^{-1})†	3.78	3.72	2.81	1.28	2.25
Gross benefit (US$ ha^{-1})†	945.00	930.00	702.50	320.00	562.50
Maize grain yield (t ha^{-1})‡	2.22	2.19	1.65	1.28	2.25
Gross benefit (US$ ha^{-1})‡	555.00	547.50	412.50	320.00	562.50
Labour cost (US$ ha^{-1})	126.25	124.56	84.05	7.90	7.24
Cost of fertilizer (US$ ha^{-1})	0.00	0.00	0.00	0.00	50.00
Total variable cost (US$ ha^{-1})	126.25	124.56	84.05	7.90	57.24
Net benefit (US$ ha^{-1})					
Yield†	818.75	805.44	618.22	312.10	505.26
Yield‡	428.75	422.94	328.22	312.10	505.26
Mulch (5 t ha^{-1})†	511.72	503.40	386.39	na§	na
Mulch (5 t ha^{-1})‡	267.97	264.34	205.14	na	na
Marginal rate of return (%)					
Yield†					
From fertilizer use to:	454.27	445.90	417.75	na	na
From control to:	428.09	422.89	400.79	na	na
Yield‡					
From fertilizer use to:	−110.87	−122.28	−654.73	na	na
From control to:	98.56	95.01	21.11	na	na
Break-even yield (t ha^{-1})	2.53	2.52	2.36	2.05	na

†Value for land used to grow MPT not considered; ‡value for land used to grow MPT considered; §na = not applicable.

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control experiment, are shown in Table 2. The marginal rate of return (MRR) which shows the returns on investments in the cut-and-carry technology for each MPT mulch instead of applying nitrogen fertilizers is also depicted in Table 2. If the value of the land used to cultivate the MPTs is not considered, net benefits from maize plots mulched with MPTs were higher than those from the plots supplied with nitrogen fertilizer and the unfertilized control plots. Among the three mulch treatments, the highest net benefit was derived from plots mulched with *G. sepium* (US\$818.75 ha^{-1}), followed by those mulched with *L. leucocephala* (US\$805.44 ha^{-1}). The net benefit from the maize harvest taken from plots mulched with *S. siamea* was the lowest (US\$618.22 ha^{-1}) of the three mulch treatments. As expected, the unfertilized control experiment yielded the lowest net benefit of US\$312.10 ha^{-1}.

The above results assumed no cost for land used for mulch production. However, land is a scarce resource in south-western Nigeria, mainly as a result of high population density in the area. An opportunity cost for the land on which the MPTs were cultivated was therefore included in the calculations. It was further assumed that the farmers' main objective was to maximize monetary income. Where this was the case, net returns obtained from maize plots mulched with materials from the MPTs declined considerably. For instance, the results showed that net benefits from the mulched plots dropped by almost 48% to US\$428.75 and US\$422.94 ha^{-1} for *G. sepium* and *L. leucocephala* respectively and to US\$328.22 ha^{-1} for plots mulched with *S. siamea*.

The marginal rate of return (MRR) which shows additional profit or loss accrued by changing from the use of one technology to another is also depicted in Table 2. It is estimated as the change in net benefit divided by the change in cost, expressed as a percentage. When land used to cultivate the MPTs was not included, results from the marginal analysis showed that profits of US\$3.54 and US\$3.45 would be derived for every US\$1 invested to mulch maize plots with *G. sepium* and *L. leucocephala* respectively. Similarly, US\$3.17 would be derived from every US\$1 invested to mulch maize plots with *S. siamea*. Changing from the unfertilized control to mulch maize with either *G. sepium* or *L. leucocephala* resulted in similar profit margins. When the cost of land used to cultivate the MPTs was considered, the MRRs became negative if farmers were to change from the application of nitrogen fertilizers to mulching. The negative MRR showed the magnitude of loss associated with the change and the negative marginal rates inferred that changing from fertilizer use to mulching with MPTs through the cut-and-carry method was an unprofitable venture.

In order to show the yield level at which production costs were equal to revenues for the mulch treatments, break-even yield ha^{-1} was estimated. These yield levels are also shown in Table 2. At the break-even yield, marginal revenue obtained from the maize is equal to the marginal cost of production. In the case of maize plots mulched with *G. sepium* the break-even yield was 2.53 t ha^{-1}. For those plots mulched with *L. leucocephala* the break-even yield level was 2.52 t ha^{-1}, while for plots mulched with *S. siamea* the break-even yield was 2.36 t ha^{-1}. Where

Table 3. Nutrient contents (%) and carbon–nitrogen ratios of the leaves of multi-purpose trees.

Species	Carbon (C)	Nitrogen (N)	C:N	Phosphorus (P)	Potassium (K)
Leucaena leucocephala	45.98	4.56	9.86	0.20	1.80
Gliricidia sepium	45.98	4.20	10.96	0.21	2.13
Senna siamea	47.82	2.74	17.48	0.14	1.15

land is scarce, the break-even yield for each mulch type is higher than the estimated yield.

DISCUSSION

This study, which included plant residues with a wide range of chemical compositions, provides evidence that additions of organic materials are important for maize production. The increased maize yields from plots mulched with MPT materials can be attributed to improved maize nutrition demonstrated by the high concentrations of nutrients particularly in the leaves of *G. sepium* and *L. leucocephala* (Table 3). Tian *et al*. (1993) found that mulches from *G. sepium* and *L. leucocephala* significantly increased maize growth and grain yield. They attributed the increased growth and grain yield to the high nutrient concentrations and fast nutrient release and decomposition of the mulches. The ability of plant residues to decompose and release nutrients is determined by the litter quality which in turn is a function of the chemical composition of the plant materials. Leaves of *S. siamea* decompose slowly and therefore adequate amounts of nutrients are not made available to the crop; thus, maize yield was not significantly increased.

Although mulches from MPTs increased maize yields, cutting, transporting and managing mulches on crop fields required high labour inputs to achieve the yield increase. Where farm labour (especially family labour) is readily available at no additional cost, the technology proved to be profitable, even where land was scarce. However, considering that farm labour is one of the most constraining inputs in African agriculture, the high labour requirement and the associated cost makes this technology unattractive and may serve as a disincentive for its adoption by farmers. In monetary terms, the higher maize yield did not compensate for the high labour cost, especially when revenues obtained from fertilizer application were compared and land value was considered. In promoting this technology, farmers may require additional resources to invest in labour and land. However, results from the marginal analysis indicated that it was unprofitable to invest in the cut-and-carry method in places where land and labour were scarce. Under similar conditions, even a change from the untreated control to mulching through the cut-and-carry method marginally improved the rates of returns.

Applying lower rates of mulch will certainly require lower labour input and thus lower labour costs per hectare. Implicitly, lower doses of mulches will lead to lower yields. Assuming that a linear relationship exists between the quantity of mulch applied and yield, reducing the mulch quantity from the recommended 8 to 5 t ha^{-1} will lead to a decline in yield by almost 1.4 t ha^{-1} for plots mulched with either *G. sepium* or *L. leucocephala* where land is abundant. Net benefits obtained from plots mulched with *G. sepium* will also decline to US$511.72 ha^{-1} and US$267.97 ha^{-1} where land is abundant and scarce respectively. These net benefits are slightly (US$6) higher than net returns obtained with fertilizer nitrogen. Net benefits for plots mulched with *L. leucocephala* or *S. siamea* were much lower than those of the fertilizer treatment. These results indicate that lowering the level of treatment below the recommended level does not increase profitability but instead renders the technology less attractive in terms of monetary gains.

From the foregone analysis and discussions, it can be concluded that the cut-and-carry method of providing mulches from MPTs for crop production is only profitable in land- and labour-abundant areas. However, in areas where land is a scarce resource, the technology is unprofitable both in the short and long term and does not justify cash investments by farmers as indicated by the negative MRRs. These results do not justify the promotion of mulching with pruning from established tree plots for crop cultivation in areas where land and labour are scarce. Since this technology is not the only strategy available to farmers for improving soil fertility and crop yields, other more economical options such as cultivating grain legumes in rotation with cereals or the use of herbaceous legumes for short fallow stabilization should be promoted. In areas where land and labour are abundant, the technology has some potential in the short term, but diminishes in the long term as land and labour become scarce resources.

CONCLUSION

The study has shown that the cut-and-carry method of providing mulch from MPTs for maize production is not profitable in south-western Nigeria where labour and land availability are major constraints to crop production. The study also shows that there is little potential for the adoption of this technology especially in the study area. It is therefore suggested that future research on the use of mulches from MPTs should focus on management practices that reduce labour and land requirements.

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