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Labor requirements and profitability of alternative soil fertility replenishment technologies in Zambia

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Abstract

Low soil fertility is a major concern in agricultural productivity and development policy discourse in sub-saharan Africa. The problem is exacerbated by government withdrawal from fertilizer input markets and the inability of private sector operators to fill the gap. This warranted a search for other nutrient sources to supplement chemical fertilizers. Based on field data collected in Zambia, this study assessed the labor inputs implications of “improved tree fallows”, continuous maize cropping with and without mineral fertilizer and, evaluated the financial profitability of the different land use systems. Results show that agroforestry-based land use systems are more profitable (NPV between \$233 and \$309 per ha) than farmers’ practice of continuous maize production without external fertilization (\$130/ha) but, they are less profitable than mineral fertilizer (\$499). When the effects of the 50% government subsidy on fertilizers are taken into account, the differences in the profitability of fertilizers over improved tree fallows falls from 61% to 13%. The returns per person labor-day is \$3.20 for fertilizer and \$2.50, \$2.40, and \$1.90 respectively, for the three agroforestry options evaluated and only \$1.10 for unfertilized maize. These returns compare with a daily agricultural wage of \$0.50 in the study area. Key determinants of financial attractiveness and by extension, potential adoptability of the land use systems were identified. Given the low rate (20%) of farmers in Zambia who have access to fertilizers, there is a large niche to integrate other soil nutrient replenishing options with fertilizer to improve food security and reduce poverty among resource-poor smallholder farmers in Africa.

Keywords: Agroforestry, “improved tree fallows”, financial analysis, Production economics, Southern Africa, Sustainable agriculture

Introduction

Low fertility of soils ranks as one of the greatest constraints to improving agricultural productivity and food security in sub-Saharan Africa (SSA) (Vanlauwe and Giller, 2006; Sanchez, 2002). The degradation of soils in many SSA countries is caused by two related factors: (i) increases in human population that have led to a reduction in the per-capita land availability and a breakdown of the traditional fallow system that farmers used to replenish the fertility of their soils; (ii) Little or lack of use of fertilizers in crop fields due to high costs especially after the removal of farm inputs subsidies and the collapse of para-state agricultural inputs market agencies in the 1980s and early 1990s. These challenges led to a search for technology options that can help resource-poor farmers replenish their soils within a short period of time. One of these options is “improved tree fallows”, which involves the planting of fast growing trees or woody shrubs species that (usually) fix nitrogen. Using nutrient recycling systems, the plant species (e.g. *Sesbania sesban*, *Gliricidia sepium* and *Tephrosia vogelli*) replenish soil fertility by transforming atmospheric nitrogen and

making it available in the soil and thus, allowing farmers to produce their own N nutrients through land and labor. The biophysical performance of “improved tree fallows” has been well documented (Kwesiga et al 2003; Akinnifesi et al, 2006), but apart from few studies (Franzel, 2004; Place et al., 2002), little information is available on the economics of the technology relative to other soil fertility management options (including fertilizers) in terms of in terms of profitability and returns to investment. Moreover, systematic information on the labor inputs requirements of “improved tree fallows” compared to other land use option is not available. This is an important information gap because labor is a more limiting factor of production (compared to land) in Zambia and, many policy makers and development workers have repeatedly asked for this information. The objective of this study is to quantify the labor inputs requirements for “improved tree fallows” and other land use systems, assess the financial profitability and returns to investment in different soil fertility management options.

Materials and methods

Sampling technique

The study used stratified sampling technique to select farmers. First a sampling frame consisting of all farmers who had “improved tree fallow” fields in eastern Zambia were drawn up. The list was stratified by the type of species planted and then by the year of establishment of the field. To ensure that we obtained information on the complete cycle of technology, we selected farmers who had fields that were at different stages of “improved tree fallow” cycle, i.e. fallow fields that were just being established, fallow fields established in the past two year, etc. To ensure pairwise comparison and minimize effects of differences in farmer management, all the maize fields owned by each selected farmer were monitored throughout the season. In all, 89 fields were selected.

Method of data collection

At the beginning of the farm season, all the farmers selected were given a notebook each to record detailed information (themselves or assisted by literate children) in the local language regarding field activities that they carried out each time an operation took place in their fields. The information included type of activity, duration of activity, number of workers (family, hired or group labor), quantity of inputs used, costs (cash or kind) incurred, and outputs obtained. Each week, research assistants aggregated the information in farmers’ notes and summarized them into a weekly data sheet that was designed for the study. To ensure cross consistency of information, the weekly data sheet used a “double entry” recording system e.g. where field operation is planting, provision is made for a corresponding record under “seed” cost. This approach aimed at avoiding problems associated with long memory recall methods which are relatively cheaper but produce less accurate information. Geographical Positioning System equipment was used to measure the size of all the selected fields.

Results and Discussions

Labor inputs for different land use system

Overall, more than 90% of the labor inputs used in maize fields production is sourced from within the household. Communal or rotational group labor is virtually non-existent (less than 1%) while use of hired labor (“*ganyu*”) was less than 10%. In terms of sex, adult female members of the households alone contributed the greatest share (36%) of all labor inputs

used in the maize fields. Three operations accounted for 70% of the total labor inputs used for all field operations: land preparation (23%), weeding (29%) and crop harvesting (18%).

The quantity of labor inputs that farmers used in the different land use systems is presented in Table 1. Quantity of labor is lowest in the continuous maize fields (without fertilizer) because some activities were either, not done (e.g. second weeding) in such fields or less time was spent doing them (e.g. less time spent to harvest due to lower yield). This land use typifies a low-input, low-yield production system. The amount of labor used in *Tephrosia* fields was low because the seeds were sown directly and this eliminated the need for operations like nursery establishment, watering and transplanting. The use of labor inputs in “improved tree fallows” is concentrated in the first year when fallow was establishment and in the third year when the fallow is cut down and the field sown with maize. In the second year of fallow phase (year 2), labor inputs in “improved tree fallows” land use system is low because the labor input required to maintain the fallow is minimal. Aggregated over a five-year period, the quantity of labor used in “improved tree fallows” was lower than that in fields where fertilizer was applied. The lower labor use was due to lower maize yield recorded in improved tree fallow fields than for mineral fertilized field which imply a lower labor requirement for harvesting.

In addition, through “learning by doing” process, farmers in Zambia have come up with innovations and adaptations to the technology that helped them to reduce labor use in improved tree fallows fields. Details of such innovations have been documented in Kwesiga et al (2005). In a study carried out in the same area, Franzel (2004) estimated that labor use in improved tree fallow fields was 11% lower than that of fertilized maize fields. The results do not provide evidence for the popular notion that improved tree fallows are more labor intensive as, the quantity of labor used per unit cultivated land area is not higher than in fertilized fields. The perception of “labor constraints” do not necessarily imply that higher quantity of labor is required for improved tree fallows, but the introduction of the technology into the farming system obliges farmers to provide *additional* labor for nursery and establishment of the trees within a short period, over and above the labor that they normally use in their crop fields (Ajayi, 2007) In some cases,

the timing of labor use in for improved tree fallow fields coincided with the demand for labor in other important fields (e.g. cotton, groundnut) owned by the household and which depended on the labor supplied by the same household members. The average size of improved tree fallow fields in the study area was small, only 0.2 ha, and in many cases, it was easy for household members to cope with the additional labor demand for such small field. As the size of land planted to improved tree fallows increases, the extra labor requirement to manage the trees will most likely become more critical. Technological improvements aimed at shifting some of the labor demand for improved tree fallows to the off season will be helpful as it will be expected to ease this competition and enhance the adoptability of “improved tree fallow” among small scale farmers in Zambia.

Profitability of soil fertility management practices

Major financial ratios and the profitability of the five different land use systems are presented (Table 2). Continuous maize production system using fertilizer is more financially profitable than all the other land use systems. The table shows that over a five-year period, a one hectare of maize field in which inorganic fertilizer was used gave a net benefit of US\$ 499. This compares with a net benefit of US\$ 269 for *Gliricidia sepium*, US\$ 309 for *Sesbania sesban* fields, US\$ 233 for *Tephrosia vogelli* and only US\$ 130 in fields that farmers cultivated continuously without applying fertilizer. However, in terms of returns per unit of investment, the three variants of improved tree fallows are financially more attractive than continuous maize production with or without fertilizer. The reason is because the higher net profit obtained in fertilizer field was achieved through a higher investment cost. Different price and other policy scenarios affect the financial attractiveness and potential adoptability of maize production systems even when technical/agronomic relationships between inputs and outputs remain the same.

Fertilizer option is the highest performer at current subsidized rates, but at the full market cost, the magnitude of the difference in the profitability of fertilizers over improved tree fallows practices decreases from 61% to 13% (Ajayi et al., 2007).

The returns to a person labor-day is \$3.20 for mineral fertilizer option, while it is only \$1.10 in unfertilized maize fields. For the three improved tree fallows options that were investigated, the returns to labor was

\$2.50, \$2.40, and \$1.90 respectively. These figures compares favorably with the daily agricultural wage of about \$0.50 that was obtained in the study area. High maize price resulting from shortage of maize in Zambia during the year of study contributed greatly to the favorable financial ratios for maize production in the different land use systems.

Elasticity of profitability of maize production in land use systems

Changes in profitability of maize production in the different land use systems was highest for price of maize grain, labor wage rate, cost of fertilizer and timeliness of delivery of fertilizer than other input/output items. These four items are the most influential determinants of the financial attractiveness and potential adoptability of maize production for the various soil fertility options. An increase in discount rate by 1% led to a decrease in the net benefit of maize production by 0.45% in unfertilized fields and 0.56% in maize fields where mineral fertilizers were used. Discount rate is much more critical for the financial performance of improved tree fallows fields as the same level of increase in discount rate leads to a fall in net revenue by between 0.84% and 0.94%. An increase(decrease) in the producer price of maize increases(decreases) net worth of all the land use systems to varying levels depending on the magnitude of the increase(decrease): 61% for fertilized fields, 49% for *Gliricidia* fields, 46% for *Sesbania* fields and 54% for *Tephrosia* fields.

Conclusion

There is no conclusive evidence that improved tree fallows are more labor demanding compared with continuous maize production systems with fertilizer, but farmers still perceive labour investments in the establishment and cutting of fallows, as well as the nursery labour time, as additional burden. The popular notion of “labor constraints” in “improved tree fallow” fields is due to the timing of labor demands and not higher *absolute* quantity of labor use per unit land area. This suggests that both the quantity and temporal distribution of labor are important to farmers. In southern African region where farmers depend largely on uni-modal rainfall regime which limits the farming season to only about five months in a year, the timing of labor requirement becomes even more critical. Any improvements in the design and modification of the technology to shift some of the labor inputs to the “off

season” is expected to ease this competition and enhance the adoptability of “improved tree fallows” among small scale farmers in Zambia. Improved tree fallows are more profitable than farmers’ *de facto* practices of continuous crop production without external fertilization, but less profitable compared with mineral fertilizer. There exists a niche for improved tree fallows among some smallholder farmers in certain geographical areas and, efforts should be made to properly target the technology to geographic and social niches where it can make desirable impacts on food security among small holder farmers. In addition, the potentials for integrating the technology into the existing (re-introduced) partial fertilizer support program with the view to exploring the synergy between improved tree fallow and mineral fertilizers (Akinnifesi et al., 2007) for the improvement food security and reduce poverty should be explored. To raise improve the net profit of investments in soil fertility management technologies (and by extension, their potential adoptability) in Zambia, efforts should be made to introduce high value crops into the farming systems in addition to maize which is the staple but low-value crop. There is also need to ensure that policies address and send appropriate signals to farmers regarding key strategic factors that influence the profitability of soil fertility management practices, many of which are “external” to the households.

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Table 1: Labor inputs use (person-days ha⁻¹) in different land use systems in Zambia

Type of land use system	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Continuous, no fertilizer	104	95	88	88	87	462
Continuous, with fertilizer	110	121	101	103	97	532
<i>Gliricidia sepium</i> fallow	130	2	132	125	45 *	389
<i>Sesbania sesban</i> fallow	111	45	128	121	116	521
<i>Tephrosia vogellii</i> fallow	105	40	118	117	113	493

* Field was gutted by fire

Table 2: Profitability (US \$ ha⁻¹) of maize production systems using tree fallows and *subsidized* fertilizer options over a five-year cycle

Production sub-system	Description of system	NPV	VCR
Maize <i>without</i> Fertilizer	Continuous maize for 5 years	130	2.01
Maize + fertilizer at market prices	Continuous maize for 5 years	349	1.77
Maize + fertilizer at 50% government subsidy	Continuous maize for 5 years	499	2.65
<i>Gliricidia sepium</i>	2 years of <i>Gliricidia</i> fallow followed by 3 years of crop	269	2.91
<i>Sesbania sesban</i>	2 years of <i>Sesbania</i> fallow followed by 3 years of crop	309	3.13
<i>Tephrosia vogellii</i>	2 years of <i>Tephrosia</i> fallow followed by 3 years of crop	233	2.77

Market price for fertilizer include a 50% subsidy by the government

Figures based on prevailing costs & prices and an annual discount rate of 30%