ENHANCING FOOD SECURITY AND ENVIRONMENTAL QUALITY THROUGH “FERTILIZER TREES” IN SOUTHERN AFRICA: BRIDGING POLICY GAPS

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ABSTRACT
In many low income countries where seasonal food deficits occur, one of the greatest challenges is how best to integrate environmental quality and conservation of natural resources into food security and rural development policies. A number of natural resource management technologies exist that offer opportunities for achieving the two seemingly divergent goals because they have the characteristics to produce joint multiple outputs as they produce food and provide environmental goods and services. However, adoption of these technologies by smallholder farmers has generally been limited by policy and institutional failures, among other reasons. Drawing from natural resource economics framework, this study uses externality theory to provide environmental economic logic for developing incentives to internalize the environmental services “produced” by such multiple outputs technologies. Using agroforestry as a case study, this paper synthesizes empirical field studies carried out in the southern Africa region for over a decade, and discusses how the potential impacts of the technological advances made in research and development have been compromised by policy and institutional gaps. With particular cognizance of the socio-economic context in southern Africa, we identify options for removing institutional and policy constraints in order to facilitate the diffusion of agroforestry and, unlock its potential to satisfy both food production and global environmental goods.

Keywords: Adoption, Agroforestry, Environmental services, Land use practices, Science policy linkages, Zambia.
1.0 Introduction

In some low-income countries especially those that face recurrent seasonal food deficits, one of the greatest development challenges is how best to integrate environmental quality and conservation into food security policies. In the quest to reconcile environmental debt of tomorrow with the food deficit of today, there is the tendency to emphasize food production much more than environmental quality. Despite this challenge, there exist agricultural land use practices (LUPs) that produce multiple outputs that offer potential opportunities for achieving the two seemingly polarized objectives. However, the adoption and diffusion of such technologies among smallholder farmers have lagged behind scientific and technological advances made in such practices thereby reducing their potential impacts (Ayuk 2001). Focusing on southern Africa sub-region, the objectives of this paper are (1) to highlight agroforestry-based improved fallow practice as an example of a multi-output land use practice for achieving food production and environmental quality, (2) to present a method to examine how the differences between private and social benefits provides insights into field uptake and adoption of LUPs by smallholder farmers, (3) to identify policies to bridge the gap between actual and potential level of adoption of multi-output LUPs taking cognizance of the socio-economic context of smallholder farmers in the sub-region.

2.0 Background and description of “improved fallows” land use practices

“Improved fallows” (Sanchez, 1999) were developed in southern Africa region in the late 1980s for soil fertility replenishment in response to the continuous depletion of soil fertility and the challenges that smallholder farmers have to access inorganic fertilizer. The practice involves planting fast growing plant species, mainly nitrogen-fixing shrubs and trees; that produce large
quantities of biomass that easily decomposes to meet the nitrogen demands of crops such as maize (Kwesiga and Coe 1994). It builds on the fact that while nitrogen is the most limiting macro nutrient in the soil, it is highly abundant in the atmosphere. The trees replenish soil fertility by fixing atmospheric nitrogen in the soil, thus contributing to higher crop productivity and enhancing food security. A typical improved fallow begins by planting tree/shrub species as a pure stand or intercropped with food crops and allowed to grow for two or more years. After this, the trees are cut back and the biomass is incorporated into the soil during land preparation. The tree biomass easily decomposes and makes nutrients available for crops in the subsequent two to three years without adding external fertilizer. The technical details of improved fallows have been described elsewhere (Kwesiga and Coe 1994; Mafongoya et al., 2003; 2006). In addition to enhancing food production by replenishing the soil, improved fallows “produce” services that contribute to improving the environmental quality in several ways. First, some of the tree/shrub species reduce pests such as termites (Sileshi and Mafongoya, 2003; Sileshi et al., 2005) and noxious weeds including *Striga* species which limit cereal crop production (Kwesiga et al. 2003; Sileshi and Mafongoya, 2003; Sileshi et al., 2007). Second, improved fallows maintain soil animal biodiversity thereby further improving soil quality (Sileshi and Mafongoya, 2006). Thirdly, improved fallows have been shown to store large quantities of carbon stocks in plant biomass and in the soil (Kaonga, 2005; Makumba, 2003), and this is a potential strategy to mitigate the global greenhouse effect (Unruh et al., 1993). Although pure forests sequester higher amounts of carbon and contribute more to improved climate change, taking land out completely for forestation for many years to produce environment goods may not be attractive to smallholder farmers in food deficit nations because of the high opportunity cost (food production that will be forgone). Smallholder agroforestry farmers provide good strategy for protecting
biodiversity. Fourth, improved fallow reduces the effects of droughts in addition to improving the fertility and physical properties of the soils. This is because in tree fallows, soil aggregation is higher and this enhances water infiltration and water holding capacity which reduces water runoff and soil erosion (Phiri et al., 2003). Fifth, improved tree fallow fields provide farmers a source of fuel and other wood requirements for their households, and hence a potential to reduce cutting of wood from communally owned forests (Kwesiga and Coe, 1994).

Table 1 summarizes the multiple direct and indirect effects of improved fallow LUP. Often, several of the items listed as cost and benefits occur on the same fallow depending on the type of tree planted. Many of the items listed in the table were identified based on previous studies conducted in the sub-region (some of which have been cited in this paper) while others were personal observations made by the authors. For many of these items, a more rigorous study will be needed to quantify their economic value. While we do not rule out the existence of negative spill over from agroforestry land use practice (Ajayi and Kwesiga, 2003), we expect the overall effect of the land use practice to be positive.

Insert Table 1: Multiple effects of an agroforestry-based land use practice

2.3 Financial profitability of land use practices

Taking account of food production (for example maize yield) only, recent data obtained from 193 maize fields in different LUPs in Zambia show that improved fallow options yield a consolidated net profit (Net Present Value) ranging from $233 to $309 per hectare (Table 2). This compares with a net benefit of $499 per hectare when fertilizer was subsidized and $349 when fertilizer was valued at non-subsidized market prices. The result shows that based on maize yield (food security) criterion alone, the relative profitability and potential adoptability of the
different LUPs by farmers favour subsidized mineral fertilizer option over improved fallows land use practice. When environmental “outputs” of the LUPs which largely accrue to the public are considered, two classes of land use can be recognized: the one that offers benefit primarily to farmers and another which offers greater benefit both to farmers and the society. The adoption of the latter LUPs will provide greater levels of social benefit. But in making adoption decisions, smallholder farmers may not always opt for such LUPs and, the society may not always obtain the potential contributions that such LUPs can provide. This is presented in detail in section 3.0

Insert Table 2 here: Net profit of maize production ...in Zambia

3.0 Method for assessing the potential of multi-output LUPs to enhance food security and environmental benefits

In figure 1, the cost of adoption of a LUP that produces a single product (e.g. maize yield only) is represented by the “cost” curve and it follows the normal production cost curve. The benefits of the LUP (i.e. value of crop produced) is represented by the “private benefit” line. It has a constant slope because the value of crop output increases commensurately with the physical quantity of crop production (i.e., assuming a perfect competition market scenario). The optimum level of adoption is obtained at point “A” where the marginal increase in cost and benefit are the same (i.e., where the slope of cost and benefit lines are parallel). At adoption level below “A”, a farmer gets higher net incremental benefit than cost from the use of the technology and so it pays to adopt more of that LUP. The opposite occurs when adoption level is beyond “A”. Thus for LUPs that produce only single product, the rationale domain of adoption for an individual farmer lies between O and A only.

Insert Figure 2 here: Assessing the adoption potential of multi-output LUPs
For multi-output LUPs however, the benefits of their adoption shifts from the “private benefit” line to the “social benefit” when the additional environmental “outputs” that they produce are considered. With the addition of the environmental benefits, marginal benefit equals marginal cost at a higher level and as a result, the social optimum of adoption increases to “B”. The optimum level of adoption of multi-output LUPs from community perspectives is always higher than that of the individual. The shift in the level of adoption of multi-output LUPs from “A” to “B” may require some facilitation and incentive supports through public investment that is commensurate to the value of benefits generated by the land use practice to the society. One of the reasons is because private discount rates are much higher than social discount rates. Hence, immediate objective that are geared towards satisfying basic household needs in the immediate may not coincide with long-term (environmental) goals of the society (Ayuk 2001; Izac, 1997; Izac, 2003). Such facilitation supports will contribute to meeting the challenge of ensuring food security and environmental quality and ensure that the adoption of multi-output LUPs by smallholder farmers keep pace with scientific and technological advances achieved regarding such practices.

4.0 Policies and strategies for enhancing adoption of multi-output LUPs.

Land users make decisions on alternative agricultural practices based on the incentives they perceived as individuals, without necessarily considering the environmental benefits that the various LUPs may offer (Pagiola et al. 2004). Due to several reasons including differences in the rates of time preference between individuals and the society, failure of market to aggregate individual preferences, and occurrence of externalities that extend beyond farm households that are associated with different land use practices (Ayuk 2001; Izac 1997; 2003), there is a rationale
for the public sector support for multi-output LUPs. We proposed below some examples of strategies to help align smallholder food production decisions with environmental quality.

(1) Appraise current national policies that have direct and indirect effects on land use practices: In many countries, some LUPs are often subsidized by the government through various price and institutional supports. Over several years, these government policies have created structural shifts and path dependences that make multi-output LUPs less financially attractive to smallholder farmers. Short term improved fallow soil fertility technologies were considered impractical in some parts of west Africa some years back because mineral fertilizer prices were (artificially) low and this made them a cheaper and more rationale options at that time (Sanchez, 1999) from the perspective of an individual farmer. Similarly, institutional arrangements such as land tenure will become important and need to be improved upon for the expansion of land area devoted to and wider uptake of multi-output LUPs by more farmers. This is because the financial returns to some multi-output LUPs are obtained in the medium and long run, and it is most likely that farmers will be cautious to invest their scarce resources in such practices when they have not known how long they would stay on the land. Relevant national and regional policies need to be reviewed to assess and quantify their direct and indirect (dis)incentives to the adoption of multi-output LUPs.

(2) Targeted incentive-based system for the production of environmental “goods”: There is the need for appropriate mechanisms for incentives to reward adopters for the environment services produced by multi-output LUPs. Such incentives could be built into the revision of national policies following appraisal of the same as mentioned in (1) above. The ratification of the Kyoto Protocol on Climate Change and its coming into force in 2005 gives rise to new opportunities to highlight issues on carbon trading and incentives for multi-output LUPs. A recent study in
southern Africa show that carbon stored in improved fallow LUP varied between 2.5 to 3.6 tons ha\(^{-1}\) year\(^{-1}\) (Paramu Mafongoya, personal communications, 2005). At carbon prices estimated at about $5 per ton, the potential for improved fallows to increase small-holder farmers’ incomes by $12.5 – $17.5 per hectare (or $6 - $8 per hectare assuming transaction cost of 50%). This is an important income for smallholder farmers in the study area as it is equivalent to the wage rate for 20-30 man-days (or 10-15 man-days assuming 50% transaction cost). This represents a big boost in smallholder farmers’ potential income and, provides incentives for them to make decisions in favour of multi-output LUPs, and to “produce” more environmental services. In a continental-wide survey to identify cases of successes in African agriculture, incentives were cited as the second most important trigger for inducing change towards success in the continent, surpassed only by expansion of production possibilities (Gabre-Madhin and Haggblade, 2004).

(3) Cushioning the effects of time lag between investment and accrual of benefits: while most multi-output LUPs are profitable over time (positive net present values), their break-even point occurs somewhere between 2 to 3 years. This implies that smallholder farmers must absorb net losses for at least two years before receiving profits from adoption. This poses a challenge for farmers especially in a sub-region where the cost of capital and discounting factor is high. During the “waiting” period, smallholder farmers are at their most financially vulnerable state and may need some support. A targeted and time-bound assistance to farmers in the early years of adoption will be important to assist in cushioning the effects of the time lag between investment and accrual of benefit.

(4) Information and training supports to farming communities: Many multi-output LUPs are incipient technologies, relatively new phenomenon compared with conventional land use practices which farmers have known, been used to and have received training for a much longer
period. Given the “new” status of multi-output LUPs in the sub-region, human capacity, infrastructure and institutional support for such technologies are low in national extension programs and thus the need for increased support to reach many more farmers to adopt the technologies. Such supports may include improving input and output market to enhance access of small-holder farmers to ensure that they get the price premium for their produce. In addition, unlike annual crop production technologies and conventional LUPs, most multi-output LUPs are relatively more knowledge-intensive, requiring skills in terms of management of the technology. The costs of providing information greatly decrease over time, but they are critical when helping farmers get started with the practice.

(5) New institutional forms of science policy linkages: There is need for initiating new institutional forms to bring science and policy together with representation of broader public viewpoints to examine food security through a sustainable multi-faceted development lens. Such forum will provide a knowledge base for dialogue between policymakers, researchers and other stakeholders. The need for the participation of broader public stakeholders is important because policies emerge from policy processes that are themselves embedded in political processes, and the political feasibility of expected institutional changes.

5.0 Conclusion

Southern African countries face the challenge of implementing policies to attain increased agricultural production while ensuring environmental quality and protection of the natural resources base. The potential of multi-output LUPs to meet this challenge has not been fully exploited, and their adoption has generally lagged behind technological advances attained with respect to LUPs thereby reducing their potential impacts. Land users generally receive no
incentive for the services that their agricultural production practices generate, and therefore have little economic incentive to take these services into account in making decisions about land use. There is need for appropriate national and sub-regional policies and strategies to align smallholder farmers’ incentives with those of society as a whole, and encourage them to take cognizance of environmental quality and natural resource management in making their agricultural production decisions.

Acknowledgement: The financial assistance provided by Canadian International Development Agency (CIDA), Rockefeller Foundation and Swedish International Development Agency (SIDA) to support the research and development activities on agroforestry and soil fertility in southern Africa for several years is gratefully acknowledged. The usual disclaimer applies.

References


Table 1: Multiple effects of “improved fallow” land use practice

<table>
<thead>
<tr>
<th></th>
<th>Private</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>• Land</td>
<td>• Incidence of pests e.g. Mesoplatys beetle and root-knot nematodes (in <em>Sesbania</em> species)</td>
</tr>
<tr>
<td></td>
<td>• Labour</td>
<td>• Reduction of free grazing area during dry season</td>
</tr>
<tr>
<td></td>
<td>• Tree seeds and nursery establishment</td>
<td>• Risk of uncontrolled fire outbreak</td>
</tr>
<tr>
<td></td>
<td>• Increased pest control (e.g. in <em>Sesbania sesban</em> plant)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Working equipments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Risk of fire outbreak</td>
<td></td>
</tr>
<tr>
<td><strong>Benefit</strong></td>
<td>• Yield increase of subsequent crops</td>
<td>• Carbon sequestration</td>
</tr>
<tr>
<td></td>
<td>• Increase in fodder and maize stubble (for livestock)</td>
<td>• Suppression of weeds</td>
</tr>
<tr>
<td></td>
<td>• Fuel wood- available in field, and so reduces time spend searching for wood</td>
<td>• Improved soil infiltration and reduced runoff</td>
</tr>
<tr>
<td></td>
<td>• Leaves of <em>Tephrosia vogelii</em> used as “pesticides” in crop and livestock production.</td>
<td>• Enhanced biodiversity</td>
</tr>
<tr>
<td></td>
<td>• Suppresses the growth of weeds</td>
<td>• Serves as wind breaks</td>
</tr>
<tr>
<td></td>
<td>• Potential to mitigate the effects of drought during maize season</td>
<td>• More fuel wood available to reduce deforestation</td>
</tr>
<tr>
<td></td>
<td>• Stakes for curing tobacco leaves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Opportunity for farm diversification (e.g. compatible with fish farming and growing of high-value vegetables)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Ajayi and Matakala (2005)
Table 2: Profitability of different land use practices for maize production in Zambia

<table>
<thead>
<tr>
<th>Land use system</th>
<th>Description of land use system</th>
<th>Net Profit (US$ / ha)</th>
<th>Benefit-Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous, NO Fertilizer</td>
<td>Continuous maize for 5 years, no fertilizer</td>
<td>130</td>
<td>2.01</td>
</tr>
<tr>
<td>Continuous + Fertilizer (subsidized at 50%)</td>
<td>Continuous maize for 5 years with fertilizer (fertilizer subsidized at 50%)</td>
<td>499</td>
<td>2.65</td>
</tr>
<tr>
<td>Continuous + Fertilizer (at non-subsidized market price)</td>
<td>Continuous maize for 5 years (at normal market price of fertilizer)</td>
<td>349</td>
<td>1.77</td>
</tr>
<tr>
<td>Gliricidia sepium</td>
<td>2 years of <em>Gliricidia</em> fallow followed by 3 years of crop</td>
<td>269</td>
<td>2.91</td>
</tr>
<tr>
<td>Sesbania sesban</td>
<td>2 years of <em>Sesbania</em> fallow followed by 3 years of crop</td>
<td>309</td>
<td>3.13</td>
</tr>
<tr>
<td>Tephrosia vogelli</td>
<td>2 years of <em>Tephrosia</em> fallow followed by 3 years of crop</td>
<td>233</td>
<td>2.77</td>
</tr>
</tbody>
</table>

The figures of net profit per year for the LUPs can be divided by five to obtain average yearly profit.
Figure 1: Assessing the adoption potential of multi-output LUPs under different reward systems

Cost, Benefit

Benefit (Social)

Benefit (private)

Cost

O

A

B

Private optimum

Social optimum

Adoption of agri-environment land use option