Trade-offs between smallholder welfare and environmental services in the eastern Brazilian Amazon: technology and policy options

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Abstract
For more than a century, smallholders in the Zona Bragantina (Northeast of Pará, Brazil) have depended on fallows as a natural nutrient source for annual food and cash crop production in a slash-and-burn system. Productivity losses due to negative soil nutrient balances are now a problem faced by many smallholders in the region and they have developed various strategies for dealing with it. One strategy is the adoption of mechanical land preparation technologies combined with the use of chemical fertilizers. This paper examines two types of mechanical land preparation (plowing and secondary fallow mulching) that are currently being tested in the study area. This paper first presents and discusses the baseline results of the farm-level linear bioeconomic models developed to simulate smallholder decisions regarding land use, product mix and technology choice under market and production risk. The model is then used to examine the effects on farmer income and carbon stocks of the introduction of plowing and secondary fallow mulching. Results suggest that the use of mechanical plowing is profitable and would likely improve farm-household income, while leading to large losses in below- and above-ground carbon and to an increase in unproductive fallow land. The introduction of mechanical mulching of secondary fallows, on the other hand, will likely positively influence carbon sequestration and fallow conservation, but is unprofitable to smallholders. Policy instruments such as a tax on land that is slashed and burned or payments for environmental services such as carbon sequestered could be used to maintain carbon stocks without halting technological change and the economic benefits it brings to smallholders. Estimates of the levels of land taxation and payments for environmental services required to facilitate the adoption of these technologies by smallholders are provided. The relevance of research results for a broader set of policy issues is discussed.

1 Introduction
Apart from representing the world’s largest carbon and bio-diversity pools, tropical rain forests provide a living for many thousands of rural inhabitants. Converting forests to agriculture and other purposes provides private economic benefits, but it also entails social cost in the form of biodiversity and carbon losses. Consequently, policy research in tropical agriculture has increasingly been focusing on the role of public policy in influencing land use and land cover change to achieve socially optimal outcomes as regards economic growth, poverty alleviation and environmental sustainability (Vosti et al. 2002). A great deal of this research had its regional focus on the ‘hot spots’ of deforestation in the western Amazon, alongside the Trans-Amazonian highway, and in the south of the federal state of Pará.
This study focuses on one of the oldest colonization areas in the Eastern Brazilian Amazon, the Zona Bragantina, in the hopes of better understanding agricultural and forest management options
in area that has long ago lost all primary forest. Despite its historical, socioeconomic, and ecological peculiarities, the Bragantina case may well represent the ‘future’ for many of today’s agricultural frontiers in and around tropical moist forests. As a research site, the Bragantina also has the benefit of having achieved an agricultural and economic steady-state situation that is not influenced by dramatic demographic (e.g., migration) and ecological (e.g., loss of pristine forest) processes.

The emergence of two technological alternatives to the traditional land preparation technique slash-and-burn, namely mechanical plowing and mechanical mulching of secondary fallows, has motivated us to take a systematic look at the implications of agricultural technology change on indicators of environmental and economic sustainability. Two key questions have guided our analysis:

1. What are the trade-offs between environmental and economic development objectives involved in promoting two mechanical alternatives to slash-and-burn agriculture?

2. In the presence of trade-offs, how can policy action make the two objectives more compatible?

2 The study area, data, and methodology

Over the period October 2002 to February 2003, 270 randomly selected farm-households in three districts responded to questionnaires that covered household socioeconomic characteristics, product mix, production technology and land use. In addition, detailed biophysical and agronomic plot-level data were collected from two plots operated by each farmer. The farm-households were grouped using a cluster analysis based on indicators for the intensification of land use, life-style, and market integration. Five representative farm-household groups emerged, of which group II contained slightly more than 50% of sample households. Farms in this group show characteristics of the typical smallholding in the Bragantina. On lots of approximately 15 ha, they employ a mixed farming system with low input annual and high input perennial cash crops using slash-and-burn for land preparation. Most of the results presented in this paper refer to analyses done on this subgroup that is considered representative for the dominant type of small-scale agriculturalists in the area.

For the dominant farm type, a bioeconomic model was developed using dynamic linear programming techniques (see also Vosti et al. 2002). The MOTAD approach was used to account for price risk faced by farms in the region.

3 Results and Conclusions

Table 1 shows long-term trends in sustainability indicators from the model baseline simulation.

1 In the Bragantina region a typical slash-and-burn cycle involves two years of predominantly annual cropping followed by 5-10 years of fallow. A ten-year-old secondary fallow may contain up to 40 tons of biomass per hectare, and labor costs associated with manual fallow clearing can be up to R$/ha 150 (41 Euro).

2 Mechanical plowing converts the fallow system to a continuous or semi-continuous production system that does not have a fallow cycle but rather critically depends on external inputs in the form of chemical fertilizers. Tractor service is increasingly available in the region at a cost of approximately R$180/tilled ha (50 Euro).

3 With mechanical mulching of secondary fallow, the fallow-annual cropping system is maintained in its traditional form, but manual slashing and burning is substituted by mechanical slashing and mulching. Fertilizer application is necessary to counteract nutrient immobilization. The technology was adapted and tested by the SHIFT project and estimated per hectare mulching costs ranged from R$ 300 to R$850 (83 – 233 Euro) depending on field conditions and the type of equipment used.

4 Two-stage sampling was applied with random selection at the village and household levels.

5 The survey was conducted as part of the SHIFT Program and funded by the German Federal Ministry of Education and Research and the Brazilian National Research Council.

6 Mean Of Total Absolute Deviations is a technique developed by Hazel (1971) as an alternative to Mean-Variance analysis in the absence of efficient non-linear optimization algorithms. For large multi-year programming models it is still a useful method to reduce solving time and approximate a Mean-Variance solution.
The table shows that household non-essential consumption levels (net income) remains constant over time indicating that, ceteris paribus, the actual farming system is at least weakly sustainable. However, the average fallow age (an indicator of the diversity of tree species) and the amount of sequestered below- and above-ground carbon decline significantly over time. Incomes are maintained despite a depletion of system-wide carbon by partial substitution of a long-fallow cassava production with a fertilized short-fallow bean production system.

Figure 2 presents percentage changes from the baseline in indicators of environmental and economic performance after the introduction of technological alternatives to slash-and-burn. Since mechanizing land preparation requires the use of fertilization, slash-and-burn with fertilization was included here as a benchmark, although fertilizers are not commonly used in the traditional system.

It is easy to see that fertilization and the two technological alternatives to traditional slash-and-burn examined here bring about private economic benefits in terms of a higher net income and additional job opportunities at the village/regional level. Yet, other than fertilization and plowing, mulching is only adopted if service costs are highly subsidized. The necessary cost reduction for the adoption of mulching increases if both mulching and plowing are available alternatives, which shows that mulching and plowing are competing technologies. As long as mulching costs are significantly higher, farmers can be expected to prefer plowing or slash-and-burn with fertilization.
The results confirm that switching from traditional slash-and-burn to mechanized land preparation involves trade-offs in terms of negative environmental and positive economic effects. Plowing generates high private economic returns, but it will, more than other alternatives, reduce secondary forest cover and average vegetation age and increase carbon emissions from farms in the area. Both mulching and slash-and-burn with fertilization also contribute to reducing average fallow age, but their impacts on land cover and carbon emissions are much lower.

Model simulations yielded additional insights with regards to existing and planned policy action in the Amazon. First, we found that, as currently promoted, both the forest conservation standards (reserva legal) and the environmental credit program Proambiente would considerably reduce net-farm income of smallholders and would not likely bring about the desired environmental effects. The simulations suggest that forest conservation standards are welfare neutral only if combined with improved technology access as they tend to increase income variation by forcing farmers to switch from fallow-based farming to intensive cash-crop production. Moreover, the model showed that a general ban on the use of chemical fertilizers, as planned under Proambiente, will considerably reduce farm income. Simulations, in which the fertilizer ban only applied to annual production, have shown to be income neutral, thus increasing the chances for the program to be adopted.

Second, two of the policy instruments tested using the model would likely reduce the environmental costs of technology change and at the same time capture some of its economic benefits. Since the model predicts a coexistence of slash-and-burn with mechanical land preparation, improved technology access should be combined with a tax on slash and burn. A tax of at least R$ 400/ha/year would significantly increase on-farm carbon sequestration, while lifting net income and hired labor above model baseline levels. Alternatively, set aside payments also represent a better option than standards to achieve fallow conservation and could be coupled to a tax on slash-and-burn. Model simulations show that a payment of R$/ha/year 50 is enough to induce forest conservation on a farm with improved technology access.

References


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7 1 Euro ~ R$ 3,5 (Brazilian Reais in 2003)