Advances in integration of agroforestry based crop-livestock systems in the hillsides of Nicaragua

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Introduction

Food insecurity and poverty are major problems in Central America, particularly for farmers who depend on maize-bean-livestock systems. Intensive use of agricultural lands and farming in not suitable areas, and limited use of soil conservation practices have led to an extensive degradation of natural resources. Earlier work in the region has shown that both the Quesungual Slash and Mulch Agroforestry System (QSMAS) and silvopastoral systems with improved forages can improve livelihoods by increasing productivity and profitability, while facilitating the generation of other ecosystem services (Wélchez et al., 2008; CIAT, 2009). This paper reports progress made by CIAT and its partners in an on-going research for development project on integration of agroforestry based crop-livestock systems. The main objective is to improve livelihoods of rural poor in sub-humid hillsides of Nicaragua by increasing eco-efficiency in rural landscapes, through enhancing the adoption of the Quesungual Slash and Mulch Agroforestry System (QSMAS) with improved maize (*Zea mays* L), bean (*Phaseolus vulgaris* L.) combined with forages (the grass *Brachiaria brizantha* cv. Marandú and legumes). Specific objectives include: (1) Integration of the above –mentioned options into QSMAS and naturalized pastures, respectively, to improve farm productivity and profitability; (2) Assessment of environmental benefits including ecosystem services (ES) adapted to climate change, and (3) Implementation of strategies and tools for adaptation and dissemination of eco-efficient agroforestry and livestock systems for the sub-humid tropics.

Materials and methods

Experimental plots with different land uses were established in May 2011 in 16 farms distributed within five communities of two regions in Nicaragua (Somotillo and Condega). The farms represent three altitude categories, low, medium and high (<800, 800-1200, and >1200 masl, respectively), to evaluate the performance of the land uses under different agroecosystems.

Baseline studies on ecosystem parameters in these plots included soil quality and fertility, detailed land use and forest cover maps, soil erosion, carbon stocks; and socio-economic-cultural surveys. On each farm experiments were established including the following nine land use systems (treatments):

1. Traditional production system of slash and burn (SB)
2. Improved system (no burning and use of residues) with traditional varieties (ITV)
3. Improved system (no burning and use of residues) with improved varieties (IIV)
4. QSMAS with traditional varieties (QTV)
5. QSMAS with improved varieties (QIV)
6. Native/naturalized pastures (NP)
7. Improved (drought tolerant) pastures (IP)
8. Silvopastoral system, including improved pastures and legume shrubs (SSP)
9. Secondary forest (as a reference/baseline treatment) (SF)

Agricultural systems included treatments 1 to 5 for maize-bean production (3 and 5 including improved varieties selected by farmers in 2010), and 6-8 for livestock (milk) production. These different management options were evaluated for agronomic characteristics, productivity, and different ecosystem services.

Results and discussion

There were no differences in maize grain yield between the two evaluation sites, but bean yields were significantly higher in Condega ($P<0.001$, Fig. 1). No significant effects of treatments on yields were found, although maize yields in Condega tended to be higher with improved varieties and improved management (treatments 3 and 5, IS and QSMAS plots, respectively). We expect these tendencies to become significant in the course of the project, when the effects of the different treatments (e.g., reduction of soil fertility from burning and higher vulnerability in traditional plots and improvement of soil conditions and resilience in QSMAS plots) become more marked. An altitude effect was found for maize yields, being significantly lower at elevations over 1200 masl ($P<0.01$). The pasture plots also showed effects from altitude in the year of their establishment (2011), with yields of 20 and 12 t ha^{-1} at low and high altitudes, respectively. Grazing trials have started at the onset of the rainy season of 2012, in which pasture biomass (primary production) and milk (secondary production) yield are being monitored.

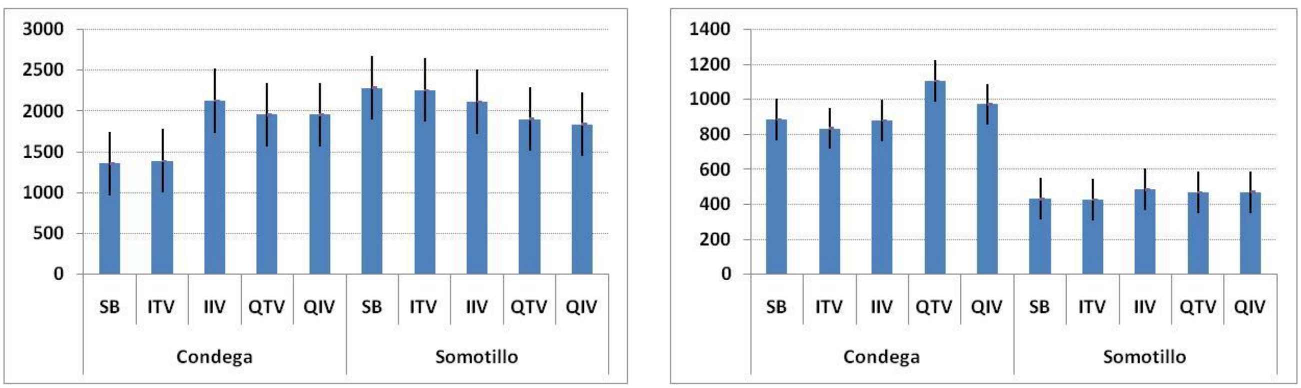

Figure 1: Grain yields (kg ha^{-1}) of maize (left) and bean (right) in the different treatments involving crop production systems. Bars represent the Standard Error.

At both research sites the soils were characterized through key variables including organic matter content, bulk density, infiltration, pH and nutrient (nitrogen [N] and phosphorus [P]) availability. Organic matter content was highest in secondary forest and QSMAS plots, bulk density was in general lower in QSMAS plots when compared to the traditional maize and bean plots (1 and 1.2 g cm^{-3}, respectively). Soils are slightly acidic, with pH varying between 5.3 and 6.8. N requirements vary between sites, for instance for maize between 0 and 112 kg ha^{-1}. Average P availability varied strongly between the two research sites, being 3.5 ppm in Condega and 1.0 ppm in Somotillo. Apart from serving as baseline data this information has been used to adjust soil fertility management, particularly in the maize and bean plots. A second monitoring is planned at the end of 2012 / beginning of 2013, to assess the effects of the different treatments in these characteristics and complementary soil quality indicators. This participatory data collection and field experimentation has improved the knowledge of farmers, technicians and representatives of the other project partners.

Erosion was measured in treatments 1, 5, 7, 8 and 9 using painted metal rods in fields (Becerra Moreno, 2005). Extent of soil erosion depended on rainfall intensity, management system and soil characteristics. In agreement with earlier work (Baltodano and Mendoza, 2007), it was found that the systems with higher soil cover reduce soil erosion and improve soil conditions (Figure 2).

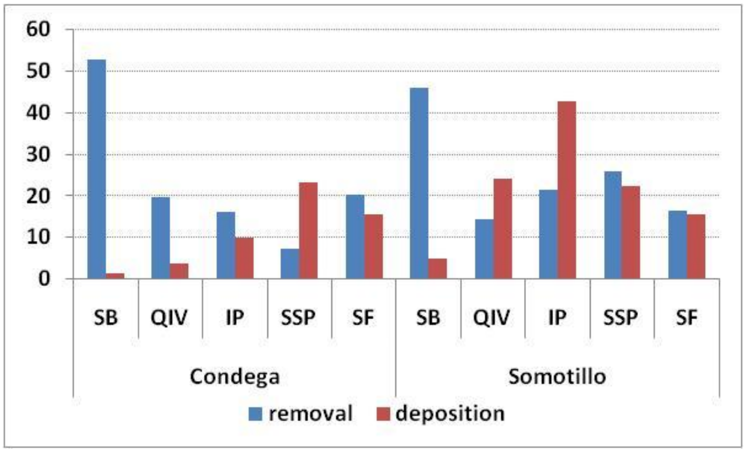

Figure 2. Soil loss and deposition within plots at the Condega and Somotillo research sites in the different land use systems in evaluation (t ha^{-1}).

These preliminary data confirm the benefits of agroforestry systems (especially silvopastoral with improved pastures) in reducing soil losses, in comparison to the traditional SB production system.
Local indicators related to soil quality and other ES were identified in treatments 1, 5, 6 and 9, respectively. Soil biological, chemical, physical and morphological parameters were measured and correlated with soil macrofauna. Soil macrofauna was more abundant in QSMAS plots, and a strong association between macrofauna and soil physical status was found, suggesting that compaction by livestock strongly limits the activity and diversity of soil macrofauna. Different species of soil macrofauna were identified as preliminary indicators of ES.

Using an Extrapolation Domain Analysis (EDA), other potential areas in Nicaragua that are suitable for the dissemination of QSMAS were identified. The analysis was validated by local partners, who either confirmed or refuted the possibility of adaptation of the system according to their knowledge of different regions of the country. Based on that feedback, another EDA was performed using not only the whole country but also the 8 special areas as target regions mostly based on biophysical conditions. A final validation of this analysis will be done in a workshop with the participation of different local stakeholders, and by on-ground verification.

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