RESEARCH DESCRIPTION

Integration of *Canavalia brasiliensis* into the crop-livestock system of the Nicaraguan hillsides: environmental adaptation and nitrogen dynamics

Introduction

In the rural poor areas of the Nicaraguan hillsides, population is increasing and making pressure on arable land resources. The expansion of cropland is only possible if fragile land is taken under plough and/or if cultivation is intensified. In the past, cropping cycles were followed by several years of bush fallows to restore soil fertility. However, as farm sizes decreased, the fallow period has been shortened to one cropping cycle or even completely eliminated. As smallholders have no other choice than sticking to continuous staple crop production on sloping lands that are prone to erosion, and as they can hardly afford fertilizers, soil organic matter and soil nutrients are depleted, resulting in an overall soil fertility decline. As a consequence, the productivity is decreasing, resulting in further expansion of cropland, which in turn further accelerates nutrient depletion. Altogether this feeds back to a decrease of income and an increase in food insecurity.

In the hillsides, more than 80 % of the production systems are crop-livestock systems. Crop production is limited to two short and successive rainy seasons, and livestock suffers forage shortage during the following five months of long dry season. Nitrogen (N) is the nutrient most limiting agricultural production in the area. To sustain agricultural production, the drought-tolerant cover legume *Canavalia brasiliensis* (canavalia) has been introduced as green manure and forage into the traditional maize-bean-livestock system.

Different aspects of this introduction were studied in order to check the sustainability of the proposed technology. Three types of questions were answered:

- Before the introduction: where is the most appropriate landscape position to plant canavalia? Is there any factor limiting a good agricultural performance?
- During the introduction: what is its net N input to the system? How does its use as forage or as green manure affect soil N balances? How do farmers want to manage it?
- After the introduction: how much does it benefit to the next crop? How much legume N remains in the soil after canavalia cultivation?

The results from this research were then linked to complementary socio-economic studies to allow a holistic reflection on the trade-offs at farm level when canavalia is used as green manure or as forage. Finally, various activities were undertaken to facilitate dissemination of project results and adoption of canavalia by smallholder crop-livestock farmers.

Environmental adaptation

The most suitable land for canavalia was defined by linking its above ground biomass production on 69 plots on-farm to the soil and topographic properties. The description of soil profiles and canavalia root system at ten contrasting sites completed the observations. Above ground biomass production varied highly and was significantly affected by the soil depth, the carbon and N content of the soil surface horizon, the amount of clay and stones in the whole soil profile, and slope position. The combination of chemical and physical soil properties with soil profile and topographic properties resulted in a holistic understanding of soil fertility heterogeneity and shows that a landscape perspective must be considered when assessing the expected benefits from multipurpose legumes in hillside environments (Douxchamps et al. 2012, J. Agr. Sci).

Nitrogen dynamics

In order to define the net N input to the system from canavalia, and to describe how does its use as forage or as green manure affects soil N stocks, N budgets were quantified on-farm over two cropping years for the traditional maize-bean rotation and the alternative maize-canavalia rotation. Canavalia derived in average 69% of its N from the atmosphere. Although canavalia increased the N balance of the rotation when used as green manure, the N budget remained negative without mineral fertilizer application. When used as forage, it bears the risk of soil N depletion unless N would be recycled to the plot by animal manure (Douxchamps et al. 2010, Nutr. Cycl. Agroecosyst. 88).

To study the benefits of canavalia for the subsequent crop, microplots were installed in a six-year old field experiment. Direct and indirect ^{15}N-labelling techniques were used to determine N recoveries in maize and soil from canavalia residues and canavalia-fed cows' manure compared to mineral fertilizer. Most of the amendments remained in the soil. Maize recovered 12% of canavalia residues. The N fertilizer value of canavalia-fed cows' manure could not be assessed as the indirect ^{15}N labelling technique failed due to a high N mineralization from the soil organic matter (Douxchamps et al. 2011, Plant Soil 341).

Synthesis reflection

The results showed that canavalia had the potential to provide benefits to the traditional crop-livestock system. Canavalia can restore degraded soils through high biomass production and tolerate drought. When used as green manure, canavalia increased the N balance of the maize-canavalia rotation and benefited to the next crop. However, farmers faced a short-term net annual income decrease compared to the traditional system. When used as forage during the dry season, canavalia increased milk yields and net annual income, but there was the risk of a soil N depletion. As observed during the workshops organized during this research project, farmers will most likely use canavalia as forage. However, recycling of animal manure to the plot is not yet current practice and the fertilizer value of this manure has not been determined. In these conditions, the best way for mitigating soil nutrient depletion and at the same time increase livestock productivity would be (i) to use canavalia first for forage production, (ii) then to improve animal manure management and (iii) to use canavalia regrowth during the dry season as green manure.

Impact development

In close collaboration with the local partners involved in this research, the adoption of canavalia by smallholder crop-livestock farmers in the Nicaraguan hillsides was facilitated through two activities: (i) disseminating the information gathered on canavalia during the research project through development and distribution of booklets for farmers and extensionists, and (ii) facilitating the seed production and release process by local authorities in Nicaragua. First steps are encouraging, as farmers outside the research project area want to be involved in seed production and validation trials. Government and other local institutions like NGOs and cooperatives have already expressed repeatedly their interest in integrating canavalia in forage production and soil fertility enhancement programs. Scaling up and out of this legume technology to other suitable areas in the tropics is just one step away…

LIST OF REFERENCES

Peer-reviewed publications

S. Douxchamps, I. M. Rao, M. Peters, R. van der Hoek, A. Schmidt, S. Martens, J. Polania, M. Mena, C. Binder, R. Schöll, M. Quintero, M. Kreuzer, E. Frossard, A. Oberson (2012) Trade-offs between alternative uses of tropical legumes in smallholder crop-livestock systems at farm level: The case of *Canavalia brasiliensis*. Manuscript in preparation.

S. Douxchamps, E. Frossard, N. Uehlinger, I. Rao, R. Van der Hoek, M. Mena, A. Schmidt and A. Oberson (2012) Identifying factors limiting legume biomass production in a heterogeneous on-farm environment. Journal of Agricultural Science, Online first (DOI 10.1017/S0021859611000931).

S. Douxchamps, E. Frossard, S. M. Bernasconi, R. van der Hoek, A. Schmidt, I. M. Rao, and A. Oberson (2011)Nitrogen recoveries from organic amendments in crop and soil assessed by isotope techniques under tropical field conditions. Plant and Soil, 341: 179-192 (DOI 10.1007/s11104-010-0633-6).

S. Douxchamps, F. Humbert, R. van der Hoek, M. Mena, S. M. Bernasconi, A. Schmidt, I. Rao, E. Frossard, and A. Oberson (2010) Nitrogen balances in farmers fields under alternative uses of a cover crop legume - a case study from Nicaragua. Nutrient Cycling in Agroecosystems, 88: 447-462 (DOI:10.1007/s10705-010-9368-2).

Booklets

S. Douxchamps, M. Mena, R. van der Hoek, A. Benavidez, and A. Schmidt (2011) *Canavalia brasiliensis*. Forraje que restituye la salud del suelo y mejora la nutrición del ganado. Manual de uso. INTA-Instituto Nicaraguënse de Tecnología Agropecuaria, CIAT-Centro Internacional de Agricultura Tropical, ETH-Zurich. Managua, Nicaragua.

S. Douxchamps (2010). Integration of Canavalia brasiliensis into the crop-livestock system of the Nicaraguan hillsides: environmental adaptation and nitrogen dynamics. Diss. ETH N° 18859, Zurich, Switzerland.

Conference papers

R. van der Hoek, A. Schmidt, M. Mena, S. Douxchamps, M. Peters (2010) Herbaceous multipurpose forage legumes in Central America – Status after 10 years of CIAT involvement. Tropentag, Zürich, Switerland, September 14-16, 2010, ISBN 978-3-86955-455-6, p. 578.

S. Douxchamps, E. Frossard, S. Bernasconi, R. Van der Hoek, A. Schmidt, I.M. Rao, and A. Oberson (2010) Estimation of nitrogen recovery by maize from organic sources using isotopic techniques under tropical field conditions, 5th International Nitrogen Conference (N2010), New Delhi, India, December 3-7, 2010.

S. Douxchamps, E. Frossard, C. Binder, M. Kreuzer, M. Mena, A. Mosimann, I.M. Rao, A. Schmidt, R. Schöll, R. van der Hoek, and A. Oberson (2010) Realizing the benefits of cover crop legumes in smallholder crop-livestock systems in the hillsides of Central America – a case study with *Canavalia brasiliensis* . Book of abstracts, Innovation and sustainable development in agriculture and food, ISDA2010, Montpellier, France, p.45.

S. Douxchamps, E. Frossard, R. van der Hoek, A. Schmidt, I.M. Rao, and A. Oberson (2010) Integration of *Canavalia brasiliensis* into the crop-livestock system of the Nicaraguan hillsides: environmental adaptation and

nitrogen dynamics. Conference proceedings, Tropentag, Zürich, Switerland, September 14-16, 2010, ISBN 978-3-86955-455-6, p.95.

S. Douxchamps, E. Frossard , S. Bernasconi, R. Van der Hoek, A. Schmidt, and A. Oberson (2009) Crop N uptake from organic N sources assessed by ^{15}N isotope techniques under tropical field conditions, Proceedings of the 16th Nitrogen Workshop, June 28-July 1 2009, Turin, Italy. p.43, ISBN 978-88-902754-2-5.

S. Douxchamps, E. Frossard, R. van der Hoek, A. Benavidez, M. Mena, A. Schmidt, A. Oberson (2009) Edaphic and topographic factors explaining *Canavalia brasiliensis* biomass production in the Nicaraguan hillsides, Proceedings of the Tropentag conference, Oct. 2009, Hamburg, Germany, p. 351.

F. Humbert, S. Douxchamps, R. van der Hoek, A. Benavidez, M. Mena, A. Schmidt, I. Rao, S. Bernasconi, E. Frossard, A. Oberson (2008) Impact of *Canavalia brasiliensis* on nitrogen budgets in smallholder crop-livestock farms of the Nicaraguan hillsides, Proceedings of the Tropentag, Universität Hohenheim, Germany, Oct. 2008, p. 319.

R. van der Hoek, S. Douxchamps, A. Benavidez, M. Mena, I. Rao, A. Schmidt, A. Oberson, E. Frossard, M. Peters (2008) Potential of *Canavalia brasiliensis* as a dry season supplement in Central American mixed crop-livestock systems. Tropentag Conference, Universität Hohenheim, Germany, 7-9 Oct. 2008, p. 332.

S. Douxchamps, R. van der Hoek, A. Benavidez, F. Humbert, M. Mena, A. Oberson, I.M. Rao, A. Schmidt, E. Frossard (2008) Realizing the benefits of cover crop legumes in smallholder crop-livestock systems of the hillsides of Central America, Paper presented at the Annual Conference of the North-South Center of the ETH Zurich and EAWAG "Water for development: prospects for integrated water resources management, June 4, 2008, Zurich, Switzerland.

S. Douxchamps, E. Frossard , I.M. Rao, A. Schmidt, M. Kreuzer, and A. Oberson (2007) Realizing the benefits of cover crop legumes in smallholder crop-livestock systems of the hillsides of Central America, NIDECO Colloquium "Selected Aspects of Sustainable Development" - 16.05.07 - ETH Höngerberg, Switzerland, http://www.nideco.ethz.ch/news/past_events/colloquium_2007/Douxchamps_Abstract.pdf.

S. Douxchamps, E. Frossard , I.M. Rao, A. Schmidt, R. Van der Hoek, M. Mena and A. Oberson (2007) Effects of *Canavalia brasiliensis* on nitrogen dynamics in crop-livestock systems of the Nicaraguan hillsides, Conference proceedings, 4th International Nitrogen Conference – Oct.07 – Bahia, Brasil. p.74.

Reports

S. Douxchamps, R. van der Hoek, A. Benavidez, F. Humbert, N. Uehlinger, M. Mena, A. Schmidt, I. Rao, S. Bernasconi, E. Frossard, A. Oberson (2010) Realizing the benefits of *Canavalia brasiliensis* in smallholder crop-livestock systems in the hillsides of Central America, In: CIAT Annual report 2009. Tropical grasses and legumes, Cali, Colombia, in press.

F. Humbert, S. Douxchamps, R. van der Hoek, A. Benavidez, M. Mena, A. Schmidt, I. Rao, S. Bernasconi, E. Frossard, A. Oberson (2009) Impact of *Canavalia brasiliensis* on biomass availability, milk yields and milk quality, In: CIAT Annual report 2008. Tropical grasses and legumes. Improved multipurpose forages for the developing world, SBA3, Cali, Colombia, p. 100.