Modelling Landscape Effects of Agroforestry on Watershed- and Ecosystem Functions in a Small Catchment in Nicaragua

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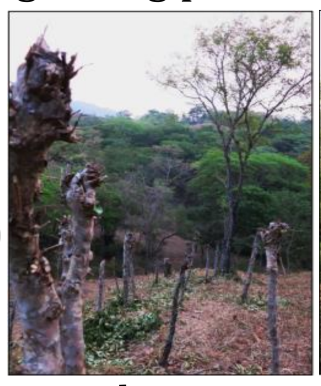
The Quesungual Slash & Mulch Agroforestry System (QSMAS)

Slashing and burning in hillside areas of Central America has led to severe deforestation and aggravated the loss of soil fertility through SOM mining (Hellin et al. 1999). The Quesungual Slash and Mulch Agroforestry (QSMAS) was developed in Honduras by farmers and FAO during the 1990's as an environmentally friendly alternative to Slash & Burn (Wélchez and Cherrett, 2002). Native trees are conserved in cropping fields, but are heavily pruned twice a year before maize and bean sowing to provide mulch and light for crop growth. Two QSMAS designs can be distinguished regarding pruning intensities:

1) Estacas: High density of small trees (left)
   - Heavy pruning
2) Dispersed trees: Low density high timber trees (right)
   - Occasional thinning



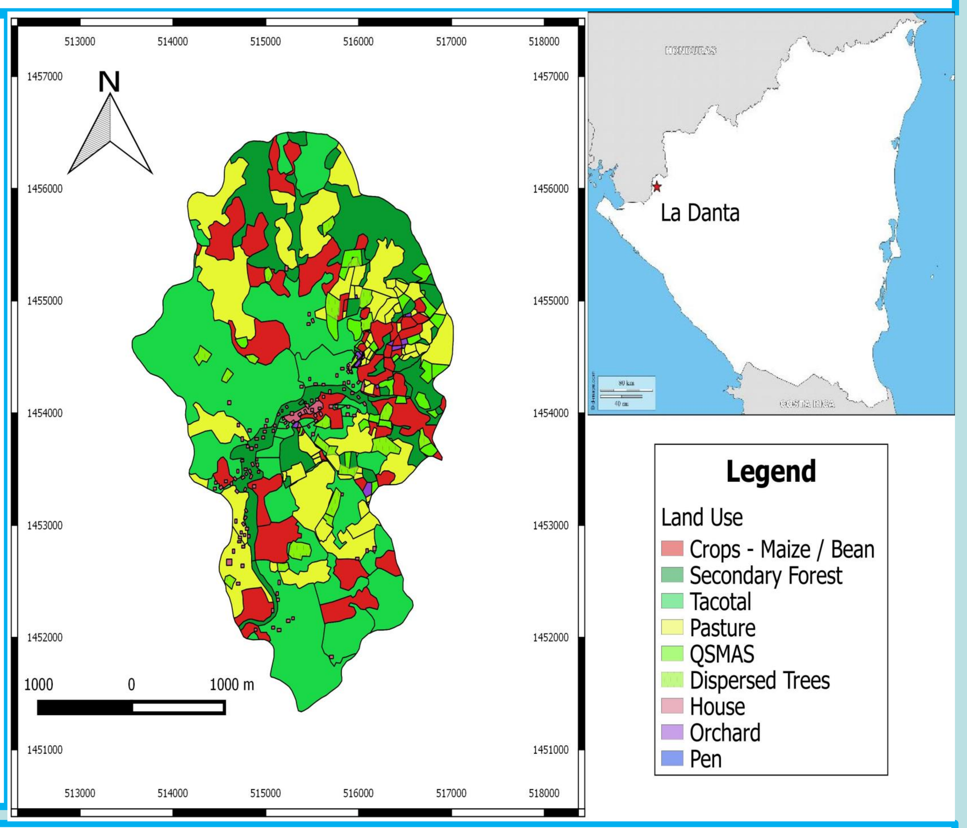

Ecosystem services provided by QSMAS include e.g. improved nutrient cycling, ground cover, crop water productivity, C accumulation compared to slash and burn (Rivera et al., 2010). Burning was banned by law in the study area - the conventional cropping system is a slash & mulch - or crop residue system without trees. Pictures: Gangloff, 2015

Objectives

Main goal of this study was comparing landscape effects of QSMAS and the conventional slash & mulch system expansion at the cost of forest – within the topography of a small watershed. In order to minimze negative egological impacts of crop production on ecosystem- and watershed functions. Focus was set to catchment SOC stocks.

Study area

La Danta watershed is a small catchment in northwest Nicaragua around 10 km². The area is characterised by a sub-tropical dry forest climate (Holdridge, 1947) with pronounced dry and wet seasons. Entisols are distributed in higher parts of the watershed, Mollisols and Alfisols mostly in valleys.



Material and Methods

LUCIA is a spatially explicit and dynamic process based Land Use Change Impact Assessment model (Marohn et al., 2010).

- A paired plot approach comparing QSMAS and S&M (Warth, 2015) was the basis for crop and tree parameterization of the model. Soil data measured at these plots, as well as crop yields and litter data of experimental farms were used.
- Upscaling to landscape level was undertaken with data from a biomass and biodiversity survey in La Danta (Siles et al., 2016 unpubl.).

In this study, no intercropping module was implemented to simulate trees and maize / beans crop rotations growing together at plot level. Instead, the AFS were modelled as a tree plantation with regular planting pattern. The intercropping module is currently under development. The model was calibrated and validated for tree biomass, mulch at pruning dates and crop yields.

Validation and modelled scenarios

Biomass growth of AFS were visually validated in order to meet expected disturbed growth patterns through pruning. Crop yields were captured well by the model (**Fig. 1**).

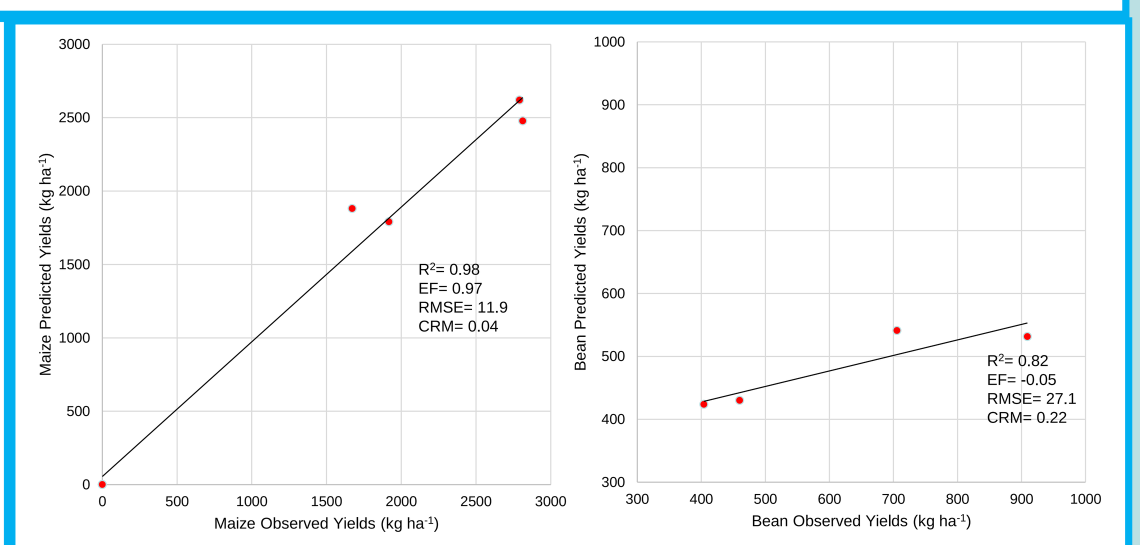


Figure 1: Validation of S&M crop yields [kg ha^{-1}]

Three land use change scenarios over 20 years were implemented:

1) Baseline: No land use change (Forest preservation)
2) QSMAS Expansion: Spatial Expansion of Estacas and dispersed trees QSMAS systems, respectively. Annual rate of 20 % of total QSMAS area.
3) S&M Expansion: Spatial expansion of the conventional cropping system at the cost of forest with same expansion pattern as for the previous systems.

Model outputs

Under different expansion scenarios, S&M expansion led to the largest loss of watershed SOC stocks after 20 years. As compared to baseline and QSMAS expansion, where SOC stocks stabilised after ten years. (**Fig. 2**)

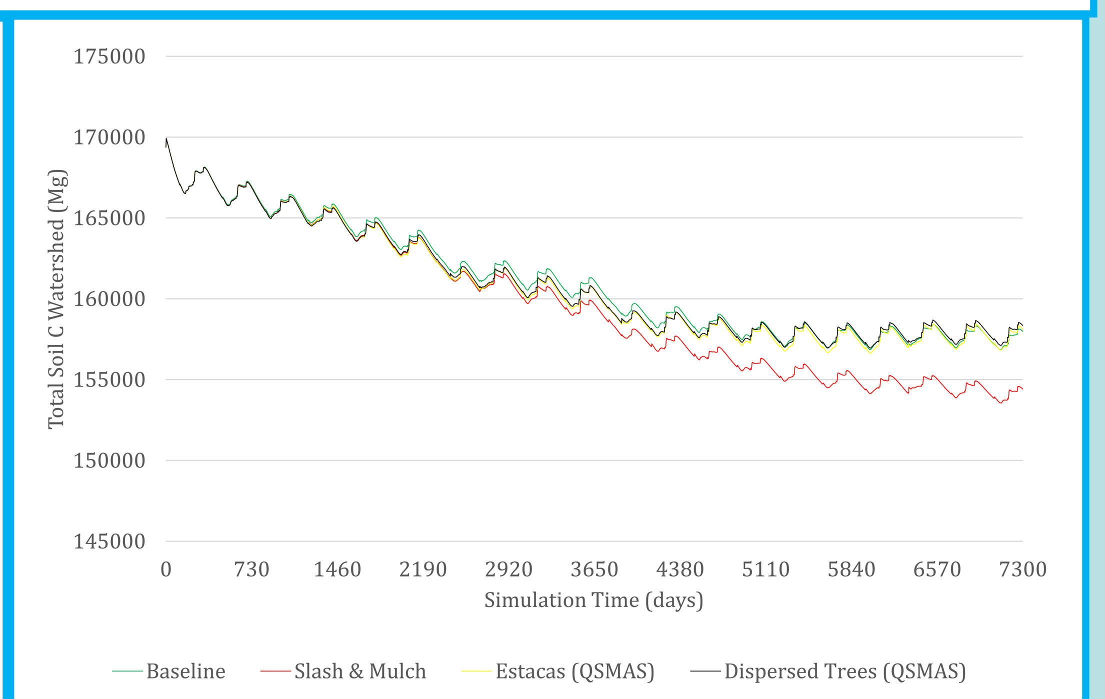


Figure 2: Total watershed soil organic carbon (Mg) content after 20 years under three land use change scenarios and baseline without land use change

Top- and subsoil carbon balance in the area of land use change was lowest under Slash & Mulch expansion (**Fig. 3**, center of pictures). Baseline- and QSMAS expansion outputs suggest an even or slightly positive balance after 20 years (**Fig 3**).

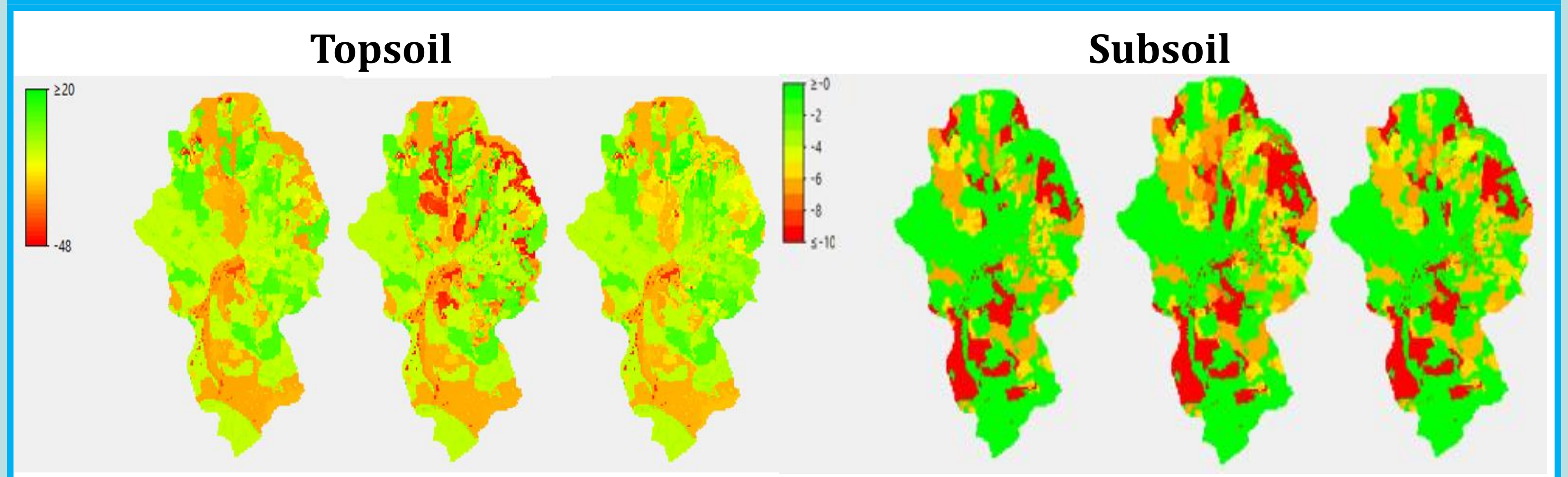


Figure 3: Topsoil and subsoil carbon balance (Mg ha^{-1}) after 20 year runs under baseline (left), conventional slash and mulch system expansion (center) and QSMAS expansion (right)

Discussion and Conclusion

The simulated Quesungual agroforestry system seems to attenuate the decline of SOC stocks, compared to the conventional system. Model results suggest the QSMAS to maintain SOC stocks at an equal level as the baseline under forest. However, regular heavy pruning of trees will most likely diminish viability once growth reserves are exhausted. The productive potential of trees might be a key determinant of the systems capacity in providing ecosystem services. Thus, long term studies will give deeper insights into the QSMAS productive cycle and neccessary fallow periods.

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Acknowledgments
This research was part of the project *Addressing the challenges of smallholder farming communities: Restoring Degraded Agroecosystems*, funded by BMZ through GIZ.
We thank the farmers in La Danta, Nicaragua, for the cooperation, Instituto Nicaragüense de Tecnología Agropecuaria, Somotillo, Universidad Nacional Agraria, Managua.

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