N_2-Fixation and Water Stress in Beans in Agroforestry or Slash & Mulch Systems in Nicaragua

Kampermann, I.[1], Marohn, C.[1], Siles, P.[2], Pulleman, M.[3,2], Cadisch, G.[1]

[1]University of Hohenheim, Inst. of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), Germany
[2]International Center for Tropical Agriculture (CIAT), Nicaragua
[3]Wageningen University and Research, The Netherlands

Quesungual Slash & Mulch Agroforestry System (QSMAS) and Mulch cropping system (S&M)

Drought and soil degradation are challenges for agricultural production in Central America. Slash and Burn (S&B) agriculture, which was used to intensify production, has led to severe soil degradation through soil organic matter loss, run-off and erosion. The Quesungual Slash & Mulch Agroforestry System (QSMAS) and the Slash and Mulch (S&M) system were established in Honduras and Nicaragua since 1990 as sustainable alternatives (Wélchez and Cherrett, 2002).

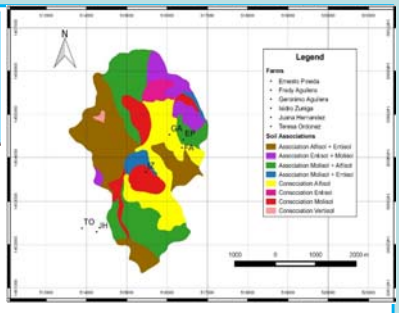
- **QSMAS**: Auxiliary native trees in a maize-bean rotation are heavily pruned twice a year (at sowing time) to reduce light competition and provide mulch for sustainable management of the soil. The tree canopies reduce transpiration in this drought-prone area.
- **S&M:** Is a conventional system without trees; crop residues are used as mulch.

The role of trees for crop water supply is not clear (reduced crop evapotranspiration vs. competition). In a previous study no differences in soil water availability could be found between the two systems (Warth, 2015). It is also not known in how far biological N fixation by trees facilitates crop growth.

Objectives

- We tested whether water stress of bean plants differed between QSMAS and S&M due to microclimate and competition effects induced by the trees.
- To compare nitrogen fixation capacity and nitrogen yield of bean plants between QSMAS and S&M.

Study area



La Danta is a catchment (around 10 km^2) in northwest Nicaragua with sub-tropical dry forest vegetation (Holdridge, 1947) and tropical dry savannah climate with pronounced wet season (Köppen-Geiger). Soil is characterized as Alfisols, Mollisols and Entisols (Calero 2008). La Danta is a community in the watershed and La Flor is a community approximately 1 km next to La Danta in south-western direction.

Methods

A paired-plot approach was taken to measure parameters. On six farms in La Danta and La Flor adjacent QSMAS and Slash & Mulch plots were sampled.
Bean leaves and seeds were analysed for:

- Water stress determined with the ^{13}C isotope discrimination method
- Nitrogen fixation using the ^{15}N natural abundance method.

Other measurements:

- Temperature and precipitation data of 2015 were measured in La Danta and combined with long-term observations and a rain data sequence of 2005-07; 2011–14.
- Yield of the bean plants in 2015, compared to previous years (2011-2014).

For statistical evaluation one-factorial ANOVA analyses and linear regressions were used.

Results

Climate: Low rain fall in 2015 (730 mm total) compared to the long-term observations (1974 mm).
Yield: No significant difference (p: 0.071) between the systems in 2015. SED value was high (69.4 kg/ha) and indicates big differences in yield among the farms. The yield was low compared to previous years (Tab. 1).

Table 1: Bean yield [kg/ha]

	Year	QSMAS Kg/ha	S&M Kg/ha
Yield	Ø 2011 - 2014	774	657
	2015	379	221

Water stress:

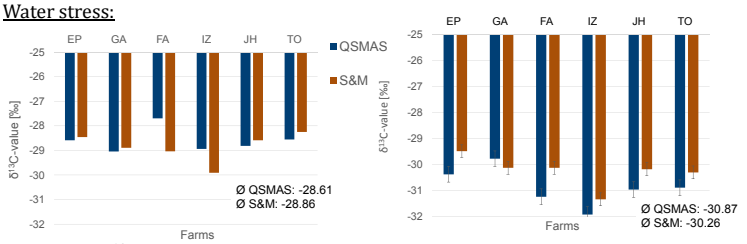


Figure 1: $\delta^{13}C$-value in bean seeds (left) and bean leaves (right) [‰] on six farms

Water stress during early growth, as indicated by $\delta^{13}C$-values in bean *leaves,* was significantly (p: 0.0002) higher in QSMAS but not at later stages to final harvest (i.e. bean *seeds, p*: 0.43) (Fig. 1). It is known that bean seeds developed during a dry period and bean leaves during a period of sufficient water supply.

There was a significant (p: 0.002) relationship between tree density (respective leave biomass) in QSMAS and water stress of the bean seeds (Fig. 2).

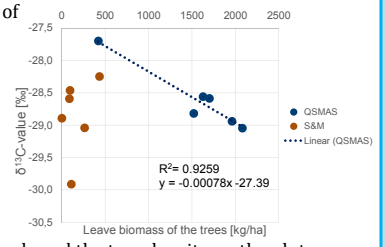


Figure 2: Correlation $\delta^{13}C$-values in bean seeds and the tree density on the plots

Nitrogen fixation:

Table 2: Nitrogen yield of bean leaves and bean seeds [kg/ha]

	QSMAS Kg/ha	S&M Kg/ha
Nitrogen yield	7.49	6.64

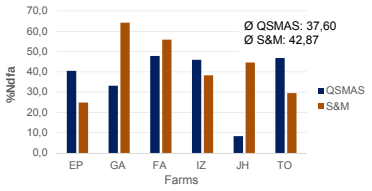


Figure 3: N_2 fixed in beans on six farms [%]

No significant differences between the systems in nitrogen fixation (p: 0.61, SED: 9.84) and nitrogen yield (p: 0.64, SED: 1.70) were measured. SED value of nitrogen fixation was high and indicated big differences in yield among the farms.

Discussion and Conclusion

The results showed that in the growing conditions of average weather conditions in La Danta, bean plants had lower water stress in the S&M System. However, in dry conditions in La Danta neither of the systems had a superior effect on water stress. Results also showed that trees represent a direct competitor for water supply and therefore planting design (tree density) is determining.
There was no significant difference in nitrogen fixation and fixed nitrogen yield found between the systems. Nitrogen fixation capacity was in the expected range calculated and no clear evidence was found of a specific limitation. Fixed nitrogen yield was found in a smaller amount than expected. Presumably plant growth was limited by water supply.
In the context of the predicted climate conditions (which occur 2015) with dry periods none of the systems is superior in terms of the determined parameters, but design of the systems is more influential to increase yields.

References

Calero Calderón, A. 2008. Bachelor Thesis, UNA de Managua, Somotillo-Chinandega.
CIAT 2009. CPWF Project Report. Cali, Colombia
Gangloff, G., 2015. MSc thesis Institute for Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim.
Hellin, J., Wélchez, LA. & Cherrett, I. 1999. Agroforestry Systems 46:229-237.
Holdridge, LR. 1947. Science 105:367–368.
Pavon Tijerino, JD. 2008. MSc thesis Universidad Nacional de Colombia, Sede Palmira, Fac. de Ciencias Agropecuarias.
Pohl, A. 2016. MSc thesis. Institut of Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim.
Rivera, M., O. Ferreira, E. Amezquita, A. Castro, I. Rao. 2010. 19th World Congress of Soil Science, Soil Solutions for a Changing World 75, 1 -6 August 2010, Brisbane, Australia.
Warth, B. 2015. MSc thesis Institute for Plant Production and Agroecology in the Tropics and Subtropics, University of Hohenheim.
Wélchez, L.A. & I. Cherrett, 2002. LEISA Magazine, Conservati, pp.10–11.

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.

Contact: ivonne-kampermann@web.de, carsten.marohn@uni-hohenheim.de