Wiebke Niether[1*], Carla Maldonado[2], Erika Silva[2], Monika Schneider[3], Gerhard Gerold[1]
[1]Georg-August-Universität Göttingen, Dept. of Landscape Ecology, Germany; [2]Universidad Mayor de San Andrés La Paz, Institute of Ecology, Bolivia; [3]Research Institute of Organic Agriculture (FiBL), International cooperation, Switzerland

Comparison of Canopy Openness in Different Cocoa *(Theobroma cacao L.)* Production Systems in Alto Beni, Bolivia

Introduction and Hypotheses

Knowledge about canopy openness in cocoa production systems enables the estimation of light penetrating the canopy, and reaching cocoa trees and the soil surface. Hemispherical photography (HP) is an accurate and non-destructive method to determine the canopy openness (Khabba, 2009). Canopy openness influences the micro-climate in the plantation and affects throughfall within the plot. Over time, variations in canopy structure indicate the production of biomass, nutrient enrichment of top-soils by litter fall, and may indicate necessities of shade management of agroforestry stands (Bellow 2003).

Materials and Methods

HP (Fig.1) were taken in 2012 and 2013 with fisheye lenses at 1.30 m above soil upwards along two transects in cocoa production systems and in fallow plots of the same age (Tab.1). All plots were established by the Research Institute of Organic Agriculture (FiBL) and its local partners in 2008 in Alto Beni, Bolivia. Pictures were analyzed for canopy openness using the program Gap Light Analyzer (Simon Fraser University, Institute of Ecosystem Studies, ©1999). Temperature and relative humidity of the air were measured with data loggers (Hobo®, Onset) at 1 m above soil within the plots.

Tab. 1 Cocoa production systems and abbreviations

Production systems	
MONO ORG	Organically managed cocoa monocultures
MONO CONV	Conventionally managed cocoa monocultures
AF ORG	Organically managed cocoa agroforestry systems
AF CONV	Conventionally managed cocoa agroforestry systems
SAFS	Successional cocoa agroforestry systems (organic)
BAR	Fallow plots (secondary forest)

Results and Discussion

Comparison of the HP of the different cocoa production plots show that the canopy of the cocoa monocultures is more open compared to the agroforestry systems due to the difference in tree density (Fig. 2). The reduction of canopy openness from 2012 to 2013 shows the ongoing biomass production of the young production systems. The increase in canopy openness in SAFS from 2012 to 2013 can be explained by a pruning event of the agroforestry trees between the two photo sessions.
Variation in microclimate between the plots might also be explained by canopy openness: the fallow with highest crown cover (Fig.2) keep low maximal temperature and high relative humidity, while temperature and relative humidity in the monocultures are subjected to high fluctuation from day to night (Tab. 2).

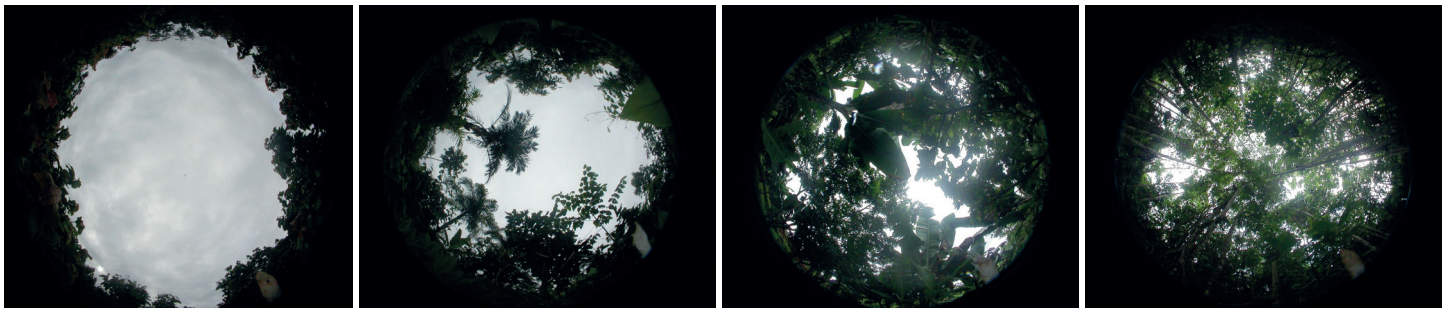

Fig. 1 Hemispherical photography of a conventionally managed cocoa monoculture, a successional agroforestry system with cocoa, an organically managed cocoa agroforestry systems and a fallow plot (from left to right).

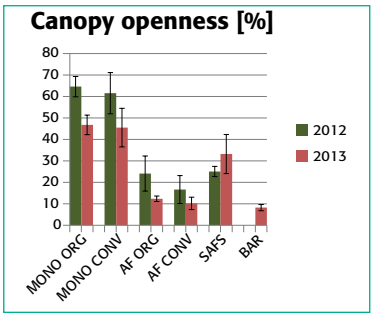

Fig. 2 Canopy openness of the cocoa production systems (n=4) and fallow plots (BAR; n=3) of the years 2012 and 2013. For BAR no data from 2012 are available.

Tab. 2 Minimum and maximum temperatures and relative humidity in the cocoa production systems and the fallow plots (June 2013)

Plot	Maximal temperature [°C]	Minimal temperature [°C]	Minimal relative humidity [%]
MONO ORG	32.7	18.0	52.7
MONO CONV	33.8	19.0	46.3
AF ORG	30.6	19.0	62.5
AF CONV	30.5	19.0	61.1
SAFS	31.9	18.2	65.1
BAR	28.3	19.2	72.9

Conclusions

Hemispherical photography might give indications of microclimatic variation and estimations of tree crown growth in perennial crop stands over time.

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Literature
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More information: http://www.systems-comparison.fibl.org/;
wiebke.niether@geo.uni-goettingen.de

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