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

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Abstract

Cocoa (*Theobroma cacao* L.) grows naturally as an understory tree in tropical forests and produces well under shaded and non-shaded conditions. It is cultivated by small scale farmers in South America under various conditions, ranging from monocultures to different kinds of agroforestry systems. While in monocultures it is exposed to direct sunlight, one or various tree species shade the cocoa in agroforestry systems. Also organic cocoa cultivation is becoming more and more popular due to premium prices and increasing ecological consciousness. In Alto Beni, Bolivia, the Research Institute of Organic Agriculture (FiBL) and local partners have established a long-term field trial to compare cocoa production systems. The bi-factorial randomised block design includes management and biodiversity factors combined to the following five cocoa treatments: monoculture and agroforestry systems both under organic and conventional management, and successional agroforestry system (high plant species diversity) under organic management and for further comparison fallow plots of same age as the cocoa plots. Research is done in all fields of agronomic, economic and environmental interest.

This study focuses on the comparison of the canopy openness of the different cocoa production systems and fallow plots. Knowledge about the canopy openness enables the estimation of light entering the production system, especially on the cocoa layer (photosynthesis relevant) and also on the soil as canopy openness influences the microclimate in the plantation. Another aspect of the canopy is the impact on the throughfall within the plot. Over the time, variations in the canopy structure indicate the production of biomass, of nutrient enrichment by throughfall (rain-wash and nutrient leaf leaching in the canopy) and may indicate pruning necessities when the plant cover above the cocoa exceeds critical values.

To estimate the canopy openness, in the years 2012 and 2013 hemispherical photography was taken with fisheye lenses in the different cocoa production systems and in the fallow plots. The photos were analysed with the programme Gap Light Analyser. First results of canopy openness between the cocoa systems will be shown and discussed for leave area index and potential microclimate differences.

Keywords: Agroforestry, canopy openness, cocoa, system comparison

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FiBL Forschungsinstitut für biologischen Landbau
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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).

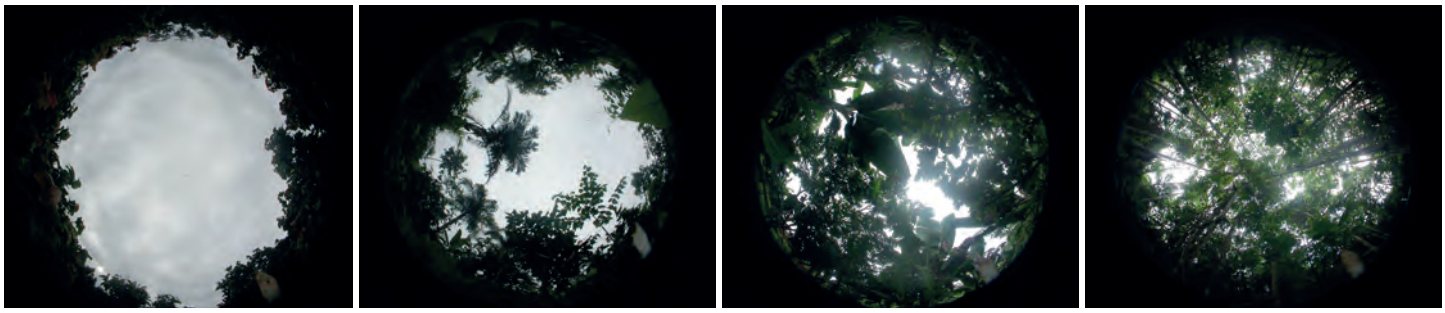

Fig. 1 Hemispherical photography of a conventionally managed cocoa monoculture, a successional agroforestry system with cocoa, an organically managed cocoa agroforestry systems and a fallow plot (from left to right).

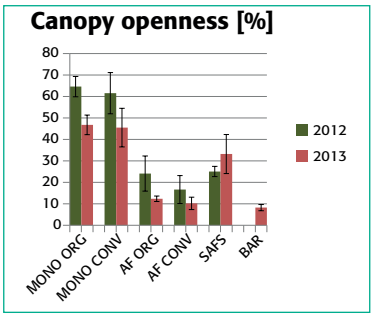

Fig. 2 Canopy openness of the cocoa production systems (n=4) and fallow plots (BAR; n=3) of the years 2012 and 2013. For BAR no data from 2012 are available.

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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