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The climatic-environmental significance, status and socio-economic perspective of the grown-shade coffee agroecosystems in the central mountain region of Veracruz, Mexico

La importancia climático-ambiental, el estatus y la perspectiva socioeconómica de los agroecosistemas de cafetales cultivados en la región montañosa central de Veracruz, México

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Abstract. Climate and vegetation coexist in a dynamic equilibrium. However, lack of vegetation can cause local and regional climate changes. Grown-shade coffee agroecosystem provides resources, environmental services and socio-economic benefits. We found that coffee production has decreased but its economical value has increased; however, the socio-economic indicators decreased. High deforestation rate is causing changes in the precipitation patterns and fog frequency, contributing to an environmental and socio-economical crisis in the region. This work presents an analysis of the influence of local and regional climate on the grown-shade coffee in central Veracruz, and the factors involved in land-use change with the respective consequences for the coffee producers.

Key words: Agroecosystems, *Coffea arabica*, cherry coffee, grown-shade coffee, production units, income and producers welfare

Resumen. El clima y la vegetación coexisten en un equilibrio dinámico. Sin embargo, la falta de vegetación puede causar cambios climáticos locales y regionales. Los agroecosistemas del café de sombra proveen recursos, servicios ambientales y beneficios socio-económicos. Se encontró que la producción de café ha disminuido pero su valor económico ha incrementado; sin embargo, los indicadores socio-económicos han disminuido. La alta tasa de deforestación está causando cambios en los patrones de precipitación y en la frecuencia de niebla, lo que contribuye a la crisis ambiental y socioeconómica de la región. Este trabajo presenta un análisis de la influencia del clima local y regional en el café cultivado a sombra en el área central de Veracruz, así como los factores que intervienen en el cambio de uso de suelo con las respectivas consecuencias para los productores de café.

Palabras clave: Agro-ecosistemas, *Coffea arabica*, café cereza, café cultivado a la sombra, unidades de producción, ingresos y bienestar de los productores.

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INTRODUCTION

Mexico occupies the twelfth place among the countries with the highest deforestation rate, spanning from 2,600 to 3,480 km^2/year in the period 1990-2005 (CONAFOR, 2006; FAO, 2007), and the annual rate of deforestation of primary forests for the period 2010-2015 was 0.1% (FAO, 2015), despite the forest's environmental significance. Tropical forests provide resources and environmental services, regulate the water cycle, conserve biodiversity, provide soil stabilization (Daily *et al.* 2000; Bruijnzeel, 2004; Ruiz Pérez *et al.* 2007), and through carbon sequestration they help to mitigate global climate change (Chazdon *et al.*, 2016).

It is expected th at global climate change will impact severely Mexico and Central America, where temperature change will have the most severe effects (IPCC, 2014). Climate change will affect all ecosystems, including those manage by humans, and assessing the impacts of climate change on crop productivity is nowadays a priority (Challinor *et al.*, 2009). For instance, in the state of Veracruz in Mexico, by the next mid-century it is expected to have a reduction of 22-27% of the coffee productivity due to climatic changes, including increment of temperature and decrement of precipitation (Gay *et al.*, 2004). And this scenario does not consider the effect of deforestation.

Since the late nineteenth century, Veracruz has been subject to an extensive and systematic change of land-use. Currently, these changes include natural ecosystems being replaced by forest systems, extensive animal husbandry and farming, and agricultural systems (García-Romero *et al.*, 2010). The highest deforestation rate was reported for the period 1984-2000, where 40% of the territory had an advanced erosion level, representing and important soil loss (García-López, 2009). In the central mountain region of the state, in Cofre de Perote, deforestation rates are ca. 2 km^2/year, with a drastic forest reduction up to 56.8% of the original area. Natural ecosystems in the region have been replaced mainly by agriculture lands, and improved and cultivated pasture, covering 27 and 15% of the total area respectively (Garcia-Romero *et al.*, 2010). Further, within the region, at La Antigua River, the land use and cover changed dramatically for the period 1990-2003 mainly caused by deforestation of natural and fragmented forest due to the advance of agricultural and animal husbandry practices (Muñoz-Villers and López-Blanco, 2008).

The coffee production in Veracruz has a long history, dating back to the late 18th century in Córdoba. Small farmers (landholdings between 2 and 3 ha) have traditionally represented over 80% of the coffee producers in the region. In the 1980s, coffee was one of Mexico's principal agricultural exports; representing ca. 35% of the total agricultural export value (Fox Quesada, 2004). And because of its importance, grown-shade coffee has been extensively studied demonstrating its environmental importance (Castillo-Campos *et al.*, 2011; Olguin *et al.*, 2011; Ruelas-Monjardín *et al.*, 2014). For instance, the shade trees associated to coffee plantations play an important role in carbon sequestration (Pineda-Lopez *et al.*, 2005; Tscharntke *et al.*, 2011), and these coffee systems act as reservoirs of biodiversity (Contreras Hernandez, 2010; González Zamora et al., 2016; Mayoral *et al.*, 2016). Plant composition in these "agroecosystems" is mostly comprised by trees (e.g. *Inga jinicuil* and/or *I. leptoloba*) and shrubs (orange, guava, banana) that maintain soil fertility by reducing soil erosion, providing organic matter (Jimenez-Avila, 1982), and fixing atmospheric nitrogen (Roskoski, 1982).

Unfortunately, currently the main vegetation characteristic in the region is the large surface area of seasonal agriculture and grown- and induced-pasture (grassland) with 4,708.4 km^2, 61% of the total area (7,693.8 km^2). Tropical forest covers an area of 109.13 km^2 (1.4%), similar to urban areas (101.13 km^2), whereas fir, pine and pine-oak temperate forests occupy an area of *ca.* 1,009.3 km^2 with a proportion forest/grassland of 21%. Mixed forest represents only the 10% of the total area (770.72 km^2). As for the grown-shade coffee plantations and the cloud forest relicts, these have an area of ca. 975.84 km^2 (Figure 1).

This work presents an analysis of the economical importance and current situation of grown-shade