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Can intercropping with the cash crop help improve the soil physico-chemical properties of rubber plantations?

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ABSTRACT

Although rubber-based (*Hevea brasiliensis*) agroforestry systems are regarded as the best approach to improving the sustainability of rubber agriculture and environmental conservation, soil physico-chemical properties and their related interactions have rarely been examined in such systems. The objective of this study was to examine the management and landscape effects on soil structure, soil moisture and soil nutrients in the Xishuangbanna region. The treatments were tropical rain forest (TRF), rubber monoculture (Rm), and two rubber-based agroforestry systems: *H. brasiliensis–T. cacao* (HTAs) and *H. brasiliensis–F. macrophylla* (HFAs). The results showed that after approximately three decades of the conversion from tropical rain forest to rubber monoculture, soils in the rubber plantations suffered serious degradation (poor soil physical properties, poor soil structure, limited soil moisture, unstable aggregates, depleted nutrients and serious soil erosion). However, the rubber-based agroforestry systems (both HTAs and HFAs) evidently improved the soil physical properties and enriched the soil nutrients in the rubber plantations. Compared to the corresponding values in rubber monoculture, the total soil porosity, initial soil moisture, soil mean weight diameter (MWD) and soil hydraulic conductivity (K_s) in rubber-based agroforestry systems increased, on average, by 13.3%, 54.7%, 31.5%, and 246.4%, respectively. In addition, the nutrients of C, N, P, Ca and Mg increased, on average, by 38.8%, 38.5%, 48.2%, 47.9% and 31.4%, respectively, after the transformation from rubber monoculture to agroforestry systems. Our results clearly indicated that the soil physico-chemical properties of rubber plantations were improved by interplanting, and the patterns of the intercropping system could play key roles in promoting the sustainable development of agriculture and the environment.

1. Introduction

Land degradation, characterized by erosion, deforestation and excessive cultivation, is a serious problem that will continue during the 21st century, especially in the developing countries of the tropics and subtropics. In Xishuangbanna, China, land degradation has become a social, environmental, ecological, and human health-related issue due to the habitat or territorial competition between natural vegetation and industrial tree plantations (Mann, 2009; Ziegler et al., 2009). Natural vegetation, which is a major component of forest ecological systems, plays a significant and irreplaceable role in preserving ecosystem health and regional ecological security. Specifically, the tropical rainforest, which is described as a “greenhouse”, once dominated the areas and had high levels of biodiversity and valuable ecological services. However, global population growth and increasing demand for agricultural products, particularly rubber plantations (*Hevea brasiliensis*), led to the development of a series of sustainability labels to reduce negative biodiversity, ecosystem services and social outcomes (Edwards and Laurance, 2012; Edwards et al., 2012).

Natural rubber trees are a perennial crop that is widely distributed within the tropical rainforest of the Amazon Basin, but large-scale rubber trees are planted in monoculture (Davis, 1997). Rubber is the main crop replacing natural vegetation and traditional agriculture in southeast Asia due to the increasing demand for and high price of natural rubber (Li et al., 2008). In Yunnan Province of China, rubber monoculture covered 424,000 ha in 2010, or 22.1% of the landscape, and the spread continues in Xishuangbanna prefecture (Xu et al., 2014), leaving barely 3.6% of this area occupied by important tropical seasonal rainforest (Li et al., 2007). The conversion of natural forests to rubber plantations and its continued expansion may result in a myriad

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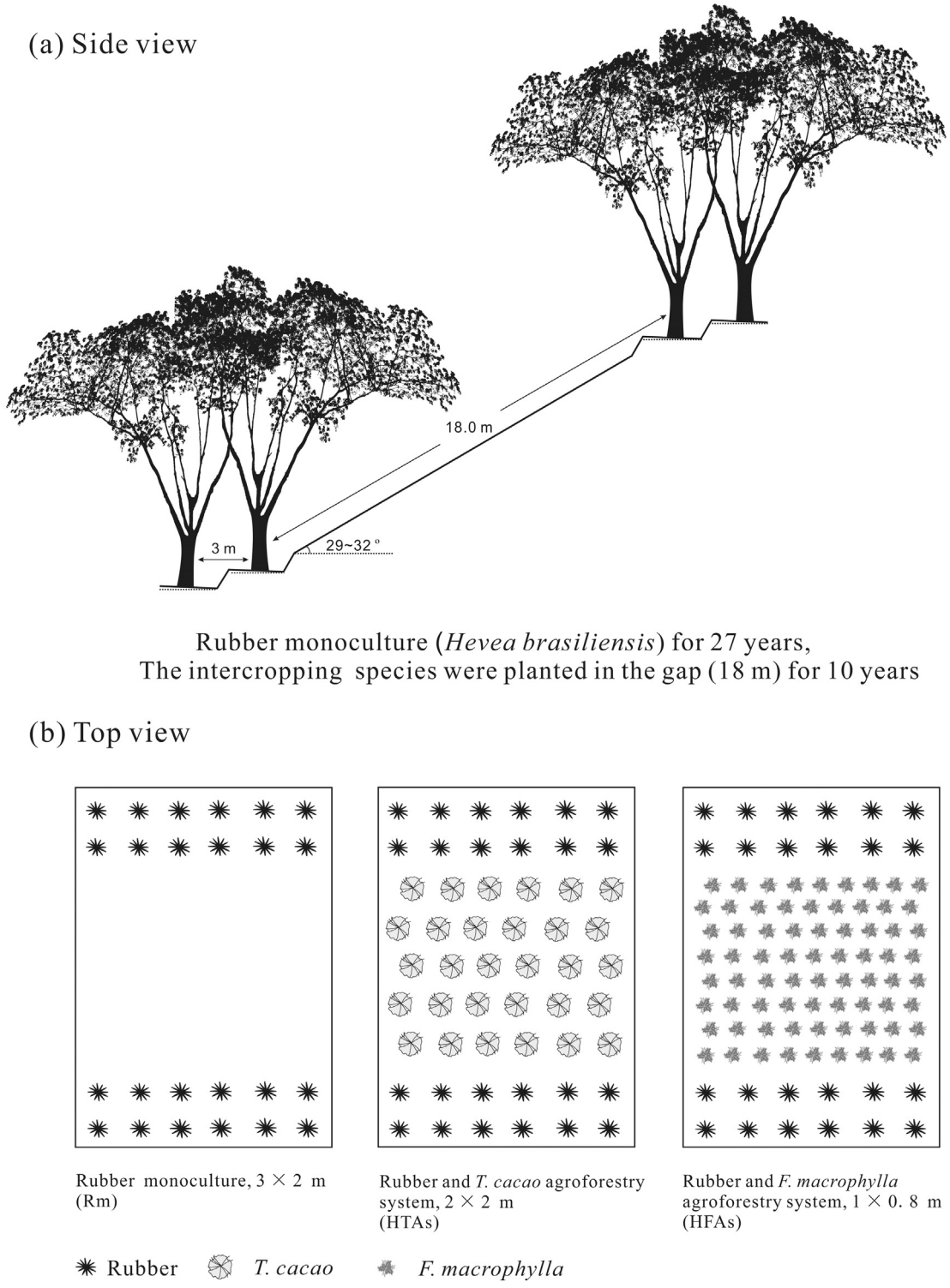

Fig. 1. Planting patterns of the rubber plantation and intercropping species: (a) side view, (b) top view.

of negative environmental consequences. Compared to natural tropical forest, rubber monoculture is associated with significantly lower biodiversity (H.F. Xiao et al., 2014; Z.W. Xiao et al., 2014; Krashevska et al., 2015), pollution by pesticides, chemical fertilizers, herbicides and increased greenhouse gas emissions (Hassler et al., 2015). Additionally, current planting patterns influence soil physico-chemical properties, such as excessive water loss, increased soil erosion (Mann, 2009), reduced water infiltration (Ziegler et al., 2009), soil hardening crusting (Liu et al., 2015), depletion of soil nutrition and environmental degradation (Chaudhary et al., 2009; Qiu, 2009).

Therefore, a combined planting pattern of rubber and interplanting or rubber-based agroforestry system could provide an important method to promote the sustainable development of agriculture and the environment in rubber plantations (Viswanathan and Shivakoti, 2008; van Noordwijk et al., 2012). In the agroforestry system, rubber plantations are commonly intercropped with other cash crops, such as fruits, traditional Chinese medicinal plants and beverage crops. The rubber-based agroforestry system combines agricultural, ecological and