Managing soil quality to improve sustainability of rubber plantations, what do we know?

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Extended abstract

Understanding the relationships between the functioning of rubber plantations and the functioning of soils is integral to the issue of the sustainability of natural rubber systems in the context of climate change. Soils play a major role in mitigating and adapting cropping systems to climate change. On the one hand, soils contribute to carbon sequestration in ecosystems through their capacity to store organic carbon. They are also important in the regulation of emissions of other greenhouse gases like methane and nitrous oxide. On the other hand, soils support the productivity of agricultural lands through the regulation of nutrient and water cycles that depend a lot on the activity of the organisms living at the soil surface or in the soil layers.

Most of the recent scientific literature about rubber plantations and soils mainly deals with the negative effects on soils of the land use change related to the conversion of natural forests to rubber plantations. For instance, de Blecourt et al. (2013) showed a strong decrease in soil carbon stocks in the Xishuangbanna Dai Autonomous Prefecture of China, while Guillaume et al. (2016a, 2016b) provided a broader view of soil degradation after conversion of forests to plantation systems in Indonesia. Deforestation is indeed an important issue but our objective in this presentation is to consider the role of soils in the sustainability of rubber plantations after the deforestation had happened. We have identified several issues that must be addressed. Rubber plantations are perennial systems with a lifespan of 25 years or more and a forest-like functioning (i.e. annual production of above and belowground litter). Therefore, we can wonder i) if rubber plantations can improve the soil quality after intensive annual crops known to deplete soil resources (e.g. cassava in Thailand), ii) if soil keeps degrading after forest conversion or if there is any room for soil function improvement. From the point of view of an agronomist, the main questions are iii) about the sensitivity of the performances of a rubber plantation, in particular yield, to soil quality and iv) about the good agricultural practices that can help to improve soil quality.

In the following, we are bringing some answers to these questions based on the works CIRAD and its partners have carried out over the last years. Part of these works is based on the use of the Biofunctool method

(Thoumazeau et al. 2019a, 2019b), which is a new methodology for assessing soil quality. According to Karlen et al. (1997), this method has been developed on the premise that soil quality is the capacity of soils to function and to deliver ecosystem services. Concretely, it means that we cannot assess soil quality only through the measurement of nutrient stocks or basic physical parameters such as soil texture. We need indicators of the main functions of soils. In this respect, the Biofunctool method assesses three main soil functions following the conceptual framework proposed by Kibblewhite et al. (2008): carbon transformation, nutrient cycling and maintenance of soil structure. For each function, we selected low cost in field indicators, with the idea of building an affordable and user-friendly tool for assessing soil quality. The current version of the Biofunctool method includes nine indicators which are aggregated in one soil quality index.

The life cycle of a rubber plantation is commonly divided into two phases of unequal duration. The immature phase spans from the set-up of the plantation to the beginning of latex harvesting that occurs between five and seven years old after the planting of the trees. The mature phase that follows can last up to 30 years and corresponds to the period of tree tapping for latex. Our recent works highlighted the specificities of these two phases with respect to response to fertilization, nutrition of the trees and soil quality. The immature phase is characterized by a rapid growth of the trees, high nutrient requirement and a significant and positive response to fertilization or soil fertility (Vrignon-Brenas et al. 2019; Perron et al. 2021). During the mature phase, growth of the trees and nutrient export are low, and response of yield to fertilization is unclear (Chotiphan et al. 2019). Regarding the soil quality, Thoumazeau et al. (2019a) showed that the Biofunctool soil quality index (SQI) is low during the immature phase and did not improve much after the conversion of cassava fields to rubber plantation in Thailand. During the mature phase, the SQI improved significantly and was getting closer to the SQI of local forests.

Further works showed how some agricultural practices could protect or improve soil quality. The studies carried out in Thailand by Clermont-Dauphin el al. (2016), Thoumazeau et al. (2019b) and Neyret et al. (2020) illustrated the importance of soil cover management. Neyret et al. (2020) compared runoff and soil detachment between maize fields, mature rubber plantations with intercrops between the tree lines and mature rubber plantations in which herbicides were used to eliminate the natural vegetation cover growing between trees. The results clearly showed that the risk of soil erosion increased when the soil was bare even in mature plantation with a dense tree canopy. The two other works highlighted the benefits of cover cropping with legumes. First, Clermon-Dauphtin et al. (2016) showed the strong influence of growing *Pueraria* on the growth of the trees. In this study the nitrogen fixation by the leguminous crops was estimated to more than 200 kg of nitrogen per hectare. In the second study in the same region, Thoumazeau el al. (2019b) looked at the effect of *Mucuna* cover on the soil quality assessed with the Biofunctool method. The results show that the soil quality of a four-year-old plantation with *Mucuna* cover was significantly higher than a four-year-old plantation with cassava intercropping, and was similar to the soil quality in a nine-year-old plantation.

Most recently, we studied the impact of the long-term cultivation of rubber tree on soil quality. In southern Thailand, we showed a continuous loss of soil organic matter (SOM) in a chronosequence of forest and rubber plots set up to mimic a 75-year sequence equivalent to three successive rubber plantations after deforestation (Paklang et al., *in prep.)*. From this study, it appears that SOM losses occurred mainly at the renewal of the plantation, between the logging of the old plantation and the planting of the new trees. In Thailand, like in most rubber-producing countries, part or all of the tree biomass of the old plantation is exported before setting up a new one. In some countries, trunks and bigger branches are used as timber representing an alternative source of revenues for farmers, but in other countries, residues are simply burnt. In an experiment in

Ivory Coast, we are testing another option, which is to leave part or the entire tree biomass in the inter-rows. First results from this experiment showed the positive effect of this practice on the Biofunctool SQI and tree growth 18 months only after the logging of the old plantation.

The objective of this communication was to put forward the role of soils for the sustainability of rubber plantations. First, we saw that soil quality can have strong positive effect on the functioning of the rubber plantation. Therefore, managing soil quality must be taken into account in strategies for the adaptation of rubber plantations to CC. In this respect, it is important to keep in mind that soil quality naturally improves in mature plantations. In the meantime, good agricultural practices can be adopted to avoid soil degradation or further improve its quality. Soil cover and logging residues management are examples of the importance of adding organic matter, alive or dead, to the soil. Lastly, besides experimental works to enrich our knowledge of the relationship between practices, soil quality and plantation performances, it is also important to work on the factors that can contribute to the adoption of these practices by smallholders. That is certainly the main bottleneck to address in the future.

Key words: Rubber plantation, soil sustainability, soil quality index, Biofunctool, good agricultural practices.

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