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Natural rubber contributions to adaptation to climate change

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Abstract

The purpose of this paper is to present research results relative to impacts of Climate Change on natural rubber production, potential means of adaptation and contribution of rubber to livelihoods resilience to climate change following a recent workshop organized by IRSG in collaboration with

CIFOR/FTA, IRRDB and CIRAD. Climate change already impacts rubber production. In some regions longer dry seasons and more variable precipitations threaten the survival of young plants. Rubber has never been planted in areas with an average temperature higher than 28°C; as latex flow after tapping depends on temperature, higher temperatures may have a severe impact on production. Abnormal rains can also disrupt tapping. These modifications will drive a shift of climatically favourable areas. Most pests and diseases affecting rubber are strongly influenced by climate conditions. Climate change is thus likely to modify their distribution and impacts. Without adaptation natural rubber production is projected to decline, in a context of otherwise increasing rubber demand. Three types of adaptation measures can be mobilized: management, breeding, and medium-term planning of plantation renewals and expansion in marginal areas. Management measures include partially shading young plants, mulching them, partial irrigation and life-saving irrigation to address increased risks of drought as well as adopting measures that reduce runoff. Systematic use of rain guards can address impacts of heavy rains on tapping. Better monitoring, prevention and early intervention can reduce damage by pests and diseases. Genomic assisted selection and collection of wild germplasm can support breeding progress towards high yielding, climate resilient and disease resistant clones. Such measures need to be supported by policies promoting the renewal of plantations and changes of practice. As shown by Sri Lanka the National Adaptation Plan (NAP) can offer opportunities to develop an integrated approach to adaptation of rubber to climate change and to contribute to the adaptation of smallholders.

Keywords: Climate Change, Policies, Economic Development, Knowledge Management, Value Chain.

Introduction

Land-use based activities, such as forestry and agriculture, are central to the achievement of Sustainable Development Goals (SDGs). These sectors are also highly vulnerable to climate changes. About 13 million smallholder families (40 million people) depend on the cultivation of *Hevea* (Pará or rubber tree) across tropical regions. Smallholders produce 90% of natural rubber (NR), a strategic raw material, for which there is currently no sustainable alternative and a greener substitute to petroleum-derived elastomers. A shortage of natural rubber would result in a major freight and transport disruption. As a consequence, adaptation to climate changes is a must. IRSG with FTA/CIFOR, IRRDB and CIRAD have organized a workshop to take stock of research findings and knowledge gaps and to inform climate actions in the rubber sector. This paper presents the main findings resulting from this workshop on impacts of Climate Change on NR production, potential means of adaptation to climate changes and contribution of NR to livelihood resilience.

Impacts of climate change on natural rubber systems

Most of the current rubber plantations are located in areas with a mean annual temperature range of 26°C–28°C and rainfall greater than 1,500 mm, with conditions in marginal areas being either cooler or drier, or both. According to IPCC projections, global temperatures are expected to increase 2°C–3°C by 2050. Climatic margins of rubber cultivation are mainly determined by temperature and rainfall, which in turn will be affected differently by changes in climate in the different areas where rubber is currently cultivated. Some traditional areas will become less favourable because of drought, while some marginal areas will become more favourable due to warming (Gohet *et al.* 2021). Several studies predict shifts in land suitability for *Hevea* in China (Liu *et al.* 2015), India (Debabrata *et al.* 2015), Malaysia (Hafiz *et al.* 2018), and greater Mekong subregion (Golbon et al., 2018). Climate change may benefit future rubber production in the currently cooler, humid marginal growing areas, such as northern Thailand, Laos, Yunnan and Hainan provinces of China, southern Brazil, Gabon and south-eastern Cameroon. Expansion into higher altitude and latitude may also be possible (Blagodatsky *et al.* 2021). Changes may also favour the cultivation of rubber over oil palm (Xu and Yi 2015) — oil palm plantations are restricted to the humid tropics — replacing oil palm in areas that are becoming drier.

There is knowledge available about water stress thanks to studies on the adaptation to drier conditions in marginal areas, showing that drought can delay growth, increasing the immature period. However, precipitation may increase in some areas, leading to soil runoff and waterlogging (Thaler *et al.* 2021). More frequent rainfall episodes reduce tapping days and thus yield.

To date, little is known about the direct effects of higher temperatures on rubber tree physiology. Even less is known about the impact on yield under different climate change scenarios. Higher temperatures will likely reduce latex flow and therefore latex yield[1]. Latex flow after tapping (duration of flow especially) is linked to internal turgor pressure in the latex vessels. Rubber trees are tapped at night or in the early morning, when the daily temperature is lower and turgor pressure is higher (Ismail and Gohet 2021). In addition to issues linked to irregular rainfall patterns, higher temperatures will likely reduce latex flow and, therefore, yield. Higher predicted night temperatures may be particularly detrimental. This shows the importance of understanding rubber tree hydraulics, water regulation and growth patterns.

Wind damage is also a serious concern, especially with the increased occurrence and strength of typhoons. A high incidence of trunk snaps and broken branches within a short period can cause irreversible damage to a plantation (Chen *et al.* 2021).

Climate change also brings higher risks of pests and diseases caused by more humid conditions — changes in severity and pattern of occurrence have already been observed. A study on the outbreak of Pestalotiopsis (a fungal leaf fall disease) on *Hevea* in South Sumatra showed the role played by recent wetter and more prolonged rainy seasons (Febbiyanti 2021). Pestalotiopsis was first detected in Indonesia in 2016 and has been responsible for reducing latex yield by more than 30%. It has also spread to Malaysia, Thailand and Sri Lanka (Nghia 2021). Treatment for Pestalotiopsis requires the use of fungicides at the early stages of the disease (Fairuzah 2021). In contrast, the long and abnormally dry season caused by El Niño in 2019 significantly reduced the incidence of the disease. However, the prolonged dry season also resulted in stunted growth and reduced latex production.

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[1] Latex is produced when the tree is tapped. It is harvested by slicing a groove into the bark with a hooked knife and peeling back the bark, allowing latex to flow into a container attached to the tree. Trees must be approximately six years old and 150 mm in diameter in order to be tapped. The life cycle of a rubber plantation is divided in two phases: the immature phase — from planting to latex harvesting (after 5 to 7 years) — and the mature phase, which starts with latex harvesting (through tapping) and ends with logging. When latex production declines, old trees are logged and new trees planted. Rotation lengths can vary from 30 to 35 years.

Adaptation of rubber systems

There are a lot of useful results from the research conducted these last 10–15 years with important findings for adaptation. Two types of complementary strategies are available for adaptation of rubber cultivation to climate change: implement climate resilient agronomic practices and develop climate-resilient, high yielding clones through breeding and genomic marker assisted selection. A number of practices have been proposed for the adaptation of rubber systems to climate change. Shading is recommended for nursery plants and for the first two years. This could be achieved by intercropping with banana, for example (Jacob 2021). In drier marginal areas, mulching to conserve soil moisture or irrigation of immature plants has been proposed. Maintaining surface cover by allowing some natural weed flora, intercropping with legumes or leaving part or the entire tree biomass in the inter-rows (Gay *et al.* 2021) can increase soil water infiltration, minimise runoff and soil erosion, increase soil quality and nutrient availability (Blagodatsky *et al.* 2021). Efficient nutrient management, particularly during early stages can have a strong positive effect on the functioning of a rubber plantation. There is a marked difference between the immature and mature stages of rubber, with the soil quality gradually improving during the mature phase (Gay *et al.* 2021).

Increased rainfall can be addressed by adaptive management of tapping and use of rain guards to protect the bark (Singh 2021; Wijaya 2021). Tapping management could include a resting period without tapping and low-intensive tapping, thus reducing days of tapping and associated costs, while preserving annual yield.

Breeding and selection of high yielding and disease and pest resistant clones

Another approach is to develop climate resilient, high-yielding clones through breeding and genomic marker-assisted selection. The NR industry was founded on a very narrow genetic base, with *Hevea brasiliensis* trees growing in plantations across Asia being mainly from 22 saplings collected by Henry Wickham in the Amazon Basin in Brazil in the 19th century. Seeds from those trees became the progenitors of commercial rubber production, first in Malaysia and then in other rubber growing countries (Othman 2021). Expeditions to the Amazon were subsequently carried out to find new germplasm to broaden the genetic diversity and improve productivity. Broadening the genetic base of cultivated rubber also presents opportunities for adaptation, as wild germplasm constitutes a repository of genes of interest for breeding to resist stress caused by climate change. Recent work in Thailand showed that there is a promising genetic variability among the existing commercial clones for breeding drought tolerant clones (Thaler *et al.* 2021), while research in China showed significant difference between clones in their vulnerability to hurricane damage (Huang et al., 2020).

Research can further develop the possibilities of using rubber germplasm for climate change adaptation, using SNP (single nucleotide polymorphisms) markers for new genetic selection from different *Hevea* species such as *H. Nitida*, *H. Spruceana* and *H. brasiliensis* (Makita *et al.* 2021). The use of modern technologies can fast-forward breeding. International cooperation is key for multinational clone exchanges and for testing.

Diversification of rubber systems

Introducing other crops or trees in rubber production is beneficial, as long as there are no trees above the rubber canopy (Penot *et al.* 2021). When rubber production is not in competition with other crops, intercropping using fruit crops, vegetables, legumes, perennial crops, medicinal and ornamental plants, or even maintaining the natural flora, have beneficial effects on soil quality and fertility (Jessy 2021). Field experiments conducted in Kerala and Tripura states in India showed positive effects of such practices on soil moisture, soil chemistry and reduced erosion. When natural flora is maintained, biological soil properties like soil respiration, as well as earthworm populations, also improve.

Farmers around the world have developed various associations of rubber trees with perennial crops and trees, including cocoa, coffee, tea and fruit trees. In some countries, they have associated rubber trees with fruits that have a local or international market (Colombia, India, Indonesia, Nigeria and Thailand); in Indonesia they use quick growing trees to control, through shade, the invasive *Imperata*; some have combined rubber trees with high value slow growth trees; others with rattan at the end of the production cycle, as its collection destroys the canopy. Some of these combinations are also used in large-scale plantations (e.g., tea plantations in Sri Lanka). In Thailand, rubber agroforestry systems (RAS) have been developed, either for intercropping during immature periods or during mature periods with fruit (durian, rambutan, longkong, etc.), vegetables (pak liang/Gnetum) and timber (teak, mahogany, etc.) (Tongkaemkaew et al 2020, Stroesser et al 2018).

Selected varieties, known as clonal rubber, were introduced in Indonesia in experimental RAS plots. Productivity of rubber and associated trees was good, with no negative impact on rubber growth during the immature period and rubber yield comparable to those from intensive monoculture. In Indonesia, the Smallholder Rubber Agroforestry Project (SRAP) monitored RAS trials from 1994 to 2007 with three main RAS systems based on clonal planting material, with and without intercropping of fruit and timber crops, and the use of fast-growing trees and cover crops for shade (Penot,2001). Examples of jungle rubber systems have also been identified in the Borneo part of Malaysia (Sarawak), Nigeria and Ghana.

Rubber trees contribute to the adaptation of farming systems

Temperature rise and soil moisture deficits are among the environmental changes caused by climate change. Afforestation can improve local climate conditions, namely by evaporative cooling (reduction of surface temperature) due to high actual evapotranspiration (AET), in comparison with grassland cover. A study of rubber tree plantations in Thailand found AET of about 1150 mm yr^{-1} and a mean proportion of net radiation used for evapotranspiration of 0.73. These values are similar to those reported for tropical rainforests, suggesting that well-managed rubber tree plantations might behave similarly to tropical rainforests in terms of evaporative cooling and moisture recycling to the atmosphere (Nouvellon *et al.* 2021).

Rubber cultivation has been proposed as an alternative to traditional short-term rainfed crops in response to climate change in Sri Lanka (Rodrigo and Munasinghe 2021). Potential benefits include reduction of mid-day air temperatures by up to 6°C within the rubber plantation, with an average decrease of 3.7°C during the day, and the retention of up to twice the surface soil moisture. This also provides a more comfortable working environment for the farmers.

Livelihood resilience is of particular importance in environments that are highly vulnerable to climate impacts. Rubber farmers in Sri Lanka have higher levels of social capital and greater capacities to access other livelihood capital assets than non-rubber growers. However, smallholders that are purely engaged in rubber are very exposed to fluctuations in the price of rubber, especially if they are not supported by public policies or by industry partners as part of their corporate social responsibility programmes. Smallholders with diversified production may experience more stable conditions. Income diversification provides better economic resilience and sustainability. This was found to be a potential benefit of RAS in trials in Indonesia (Penot *et al.* 2021).

Mobilizing climate action to create an enabling environment

National Adaptation Plans (NAPs) were established to a) reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience; b) facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate. Rubber could be better integrated in these plans and resulting national policies. There are already some examples. In Sri Lanka's NAP rubber is part of the agriculture export sector along with other commodities for which the following adaptation options have been identified: germplasm improvement, improvement of farm and nursery management practices, initiate research studies to assess climate impacts, monitoring and surveillance of pests and diseases, sectoral capacity development (Meybeck and Gitz 2021). Cameroon's NAP contains a measure for strengthening rubber production capacity in a context of climate change. Other measures can be deployed. For instance, in Chile's NAP there is a specific adaptation plan for plantations, with some measures common to agriculture (monitoring of pests and diseases). Some countries (Uruguay, Uganda) have conducted multistakeholder dialogues that can inspire a similar national process for rubber.

Conclusions

Climate change already impacts rubber production. In some regions longer dry seasons and more variable precipitations threaten the survival of young plants as well as the level of production of mature plantations. In other regions increased rains disrupt tapping. Most pests and diseases affecting rubber are strongly influenced by climate conditions. Without adaptation rubber production is projected to decline while consumption will increase.

Adaptation measures include improved management, breeding, and medium-term planning of plantation renewals and expansion. Drought can be addressed by partially shading young plants, mulching, partial irrigation and life-saving irrigation. Impacts of heavy rains on tapping can be reduced by the systematic use of rain guards and by adapting tapping schedules. Better monitoring, prevention and early intervention can reduce damage by pests and diseases. Collection of wild germplasm and genomic assisted selection can support breeding progress towards high yielding, climate resilient and disease resistant clones. Climate change will drive a shift of climatically favourable areas. High resolution climate projections are needed to assess climate suitability for rubber in traditional and marginal areas in the future. Observed climatic data could be analysed and used for plantation management, such as calculation of the need for irrigation water and estimation of disease risks. More research is required on the impacts of climate change on plant physiology, the effects of rubber plantations on microclimate, new genomic selection methods (looking also to other *Hevea* species) for increasing yield and resistance to drought and diseases, as well as on the potential of RAS for adaptation.

Adaptation of natural rubber to climate change calls for concerted action of all relevant actors: governments, research organizations, producers, and industry at both national and international levels. The preparation and implementation of the National Adaptation Plan (NAP), as well as the implantation of national determined contributions (NDC) offer opportunities to develop an integrated plan for adaptation of rubber to climate change and to support adaptation of small holders. Such national plans need to be supported by a coordinated international research strategy by the integration of rubber in climate financial mechanisms, building upon co-benefits with mitigation action, as well as by coordinated action between producing countries and consuming industries and their supply chain.

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