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Sustainable development of rubber plantations: challenges and opportunities

Vincent Gitz [1] , Alexandre Meybeck [1] , Salvatore Pinizzotto [2] , Lekshmi Nair[2] , Eric Penot[3] , Himlal Baral[4] and Xu Jianchu[5]

[1]Center For International Forestry Research (CIFOR)/Forest Trees and Agroforestry (FTA), v.gitz@cgiar.org a.meybeck@cgiar.org
[2]International Rubber Study Group (IRSG), salvatore@rubberstudy.org; lekshmi@rubberstudy.org
[3]French Agricultural Research Centre for International Development (CIRAD), eric.penot@cirad.fr
[4]Center For International Forestry Research (CIFOR), H.Baral@cgiar.org
[5]The International Council for Research in Agroforestry (ICRAF), j.c.xu@cgiar.org

Abstract

Plantations of all major tropical commodities are expanding quickly, creating opportunities for development and raising concerns about their impacts on the environment, landscapes and livelihoods. Natural rubber is a particularly interesting example with respect to sustainability objectives given it being a strategic commodity to support transportation and new forms of mobility. Furthermore, its world production originates at 90% from millions of smallholders. It is therefore key to the sustainable development of commodity producing countries and the commodity value chains. Global rubber demand has risen rapidly during the last decade, driven by economic development, especially in China. This expansion is expected to continue (albeit at a decelerating rate) and it will continue to be driven by the automotive industry and by the growing importance of natural rubber in the health sector. Various authors have raised concerns on rubber cultivation and expansion and its impact on livelihoods and ecosystems. The purpose of this paper, a collaboration between The Forests, Trees and Agroforestry research program of the CGIAR (FTA) and the International Rubber Study Group (IRSG), is to consider rubber production in relation to its sustainability and challenges in order to identify how it can best contribute to sustainable development in a context of climate change. We first identify some main "sustainability hotspots" that are where the challenges and opportunities are the greatest. We then consider how they can be addressed and propose a way forward to address them in a holistic way.

Keywords: natural rubber, sustainable development, climate change, bioeconomy.

Introduction

The cultivation of *Hevea* (rubber or Pará) tree and processing of natural rubber (NR) is an important economic activity in many countries, sustaining about 40 million people around the world. Natural rubber is a strategic material used in more than 5,000 products (Pinizzotto *et al.* 2021).

The need to replace non-renewable and energy-intensive materials will bring more opportunities for NR use. It is, therefore, important to ensure it is produced in a sustainable way, to fulfil its potential and benefit people who live from its production. Here we discuss NR sustainability challenges, or hotspots, and propose ways to turn these into opportunities towards more sustainable rubber production that could be part of a circular bioeconomy.

Sustainability hotspots

Worldwide, land under rubber cultivation has grown 1.8 times over the past 30 years (IRSG 2020b). Rubber has seen the fastest expansion of all commodities within mainland Southeast Asia (Fox *et al.* 2012) and has increased sharply in less traditional growing countries (Gitz *et al.* 2020). Some authors have expressed concerns about the impacts of rubber cultivation expansion on ecosystems and livelihoods (Warren-Thomas *et al.* 2015; Ziegler *et al*. 2009; Fox and Castella 2013). Most studies refer to impacts compared to previous land cover, often natural forest. Therefore, rather than analysing the impact of *Hevea* plantations *per se*, these studies often largely describe impacts of deforestation. There is a lack of specific studies identifying the impacts of converting diverse land uses other than natural forests to *Hevea* cultivation. Drawing from available studies we consider sustainability hotspots below and discuss how to turn them into opportunities in a later section.

Rubber and natural resources

Warren-Thomas *et al.* (2015) projected that between 4.3 million ha and 8.7 million ha of additional land would be required to meet rubber demand by 2024. The global rubber market has changed since these projections were made, NR demand has slightly declined and it is expected to remain lower than before the COVID-19 crisis until 2024 (IRSG 2020a).

A major concern expressed about the expansion of rubber plantations is the risk of converting highly biodiverse landscapes, such as forest and mosaic landscapes, to monoculture. This concern is not exclusive to rubber — in fact it is the concern with any agricultural monoculture replacing more diverse systems. Some studies have shown that conversion of forests to rubber monoculture decreases species richness and changes species composition (Diaz-Novellon *et al.* 2002; Warren-Thomas *et al.* 2015). Different types of production systems have different impacts, with greater biodiversity in plantations that have greater complexity in habitat structure and agroforestry systems supporting some forest species not found in monocultures. More studies are needed to compare effects on biodiversity of different spatial organizations; to understand interactions between species in complex systems; and to study the effects of plantation management practices (e.g. pest control) on ecosystems.

Some studies have noted negative impacts of rubber monoculture on water and soil resources compared to previous land use (generally in comparison to natural forests). These include:

- Reduction of fog interception compared to more complex forests canopies (Xu *et al.* 2013);
- Decrease of soil organic matter from land preparation (Thoumazeau *et al.* 2019a; 2019b)[1] and erosion from rain events;
- Degradation of aquatic ecosystems from run-off carrying sediments, fertilizers and pesticides (Xu *et al.* 2013; Prasannakumari *et al.* 2019);
- Depletion of deep-soil moisture during the dry season, decline in water discharge at basin level and potential groundwater depletion (Guardiola-Claramonte *et al.* 2008 and 2010; Kobayashi *et al.* 2014).

[1] 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.

Rubber systems and climate change

Natural Rubber Systems and Climate Change interact in multiple ways (Pinizzotto *et al.* 2021). They are already impacted by climate changes and can be either a source or sink of GHG emissions.

Rubber grows in areas with mean annual temperatures of 26°C–28°C and rainfall of 1800–2500 mm (Masson and Monteuuis 2017), with conditions in marginal areas being either cooler or drier, or both. Climate change will make some traditional areas less favourable because of drought or excessive precipitation (Thaler *et al.* 2021), while some colder marginal areas will become more favourable due to warming (Gohet *et al.* 2021). 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) in areas that are becoming drier. Extreme events are also likely to have impacts on rubber production: drought could delay tree maturation and more frequent rainfall could reduce tapping[2] days or increase pests/diseases. Wind damage is also a serious concern, especially with the increased occurrence and strength of typhoons (Chen *et al.* 2021). There are still questions and more research is needed to understand the effects of higher temperatures on rubber tree physiology, as well as impacts on yields and pest and disease distribution on different types of systems.

Two types of complementary strategies are available for adapting rubber cultivation to climate change: implementing climate resilient agronomic practices and developing climate-resilient, high yielding clones through breeding and genomic marker assisted selection (Pinizzotto *et al.* 2021; Masson and Monteuuis 2017). National adaptation plans being prepared by developing countries offer the opportunity to articulate such measures (Meybeck *et al.* 2020).

Social and economic issues

Rubber is produced both in smallholdings (relying on family labour) and in large estates (depending on hired labour). Natural rubber has contributed to increasing the incomes of smallholders in many countries (Liu *et al.* 2006; Fox and Castella 2013). Smallholders sometimes combine rubber with other crops or activities to diversify their income. Their income also depends on their type of operation —independent or linked to companies — and the way trade is organized (whether intermediates are involved).

In Laos, Cambodia, Myanmar and some African countries, expansion of rubber often occurs in larger-scale plantations (normally as monoculture). The main social concerns in large plantations are linked to the types of contracts (often informal or oral contracts), low salaries, poor working conditions, lack of social protection (Bhowmik and Viswanathan 2015) and evictions (OHCHR 2007; Baird 2010; Woods 2011; Global Witness 2013). In addition, relying on monoculture and hired labour, large-scale estates seem to be more susceptible to price fluctuations. When prices are too low, they tend to reduce tapping frequency, affecting the livelihoods of tappers.

Natural Rubber price fluctuation is complex and depends on many factors: supply and demand, the US dollar value, stock markets and historically presents a positive correlation with the price of oil and synthetic rubber. Price fluctuation of NR is a concern especially for monoculture systems (Gitz *et al.* 2020). Smallholders who depend on monoculture production are very exposed to price fluctuations, especially if they are not supported by public policies or by industry partners. It may seem that the most long-term stable form of NR production is in diversified smallholdings (Ratnasingam *et al.* 2015).

[2] Latex is harvested through tapping, 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.

Turning challenges into opportunities

Looking at the issues discussed above, it appears that potential impacts of rubber expansion and its prospect for sustainable development depend on:

- location of cultivation and what it replaces;
- type of production system and management practices;
- overall efficiency of production (yields and impacts on ecosystems) and potential to contribute to other environmental goals (e.g. replacement of non-renewable materials or contribution to climate change mitigation or adaptation);
- benefits for growers and local communities.

Drawing from country experiences (with rubber and other plantations), we propose a range of measures towards sustainable rubber development that could bring together various actors and public and private partnerships.

Limit negative impacts of land-use change

There are two main complementary approaches: limiting additional land-use change — by reducing the need for new land — and limiting negative impacts of new land-use change

Rubber yields vary, depending on access to high yielding clones and efficient management practices. Reducing this yield gap is the single most efficient way to avoid further land conversion. Using better management practices can also contribute to limit the impacts of rubber cultivation: efficient nutrient and pest management can reduce pollution of ecosystems; integrating rubber into diversified systems can reduce the need for additional land clearance for food production; and changes in management practices can increase biodiversity. Increasing yields can also raise incomes and improve the livelihoods of smallholders (Pinizzotto *et al.* 2021).

Furthermore, renewing plantations, instead of moving them to other areas, also reduces the need for new land, but requires appropriate measures to support farmers until latex can be harvested.

In addition, land-use zoning and planning, as well as environmental and socioeconomic impact assessments, can avoid negative effects for communities and preserve areas that are important for biodiversity conservation or other environmental issues. They can also orient rubber expansion towards degraded land (Gitz *et al.* 2020).

Promote and improve diversified systems

Several crops and trees can be interspaced at different stages in a rubber plantation, providing food or fibre and an additional source of income (Jessy *et al.* 2017; Déo-Gratias *et al.* 2018), including cocoa, coffee, tea, sesame, fruit trees, rice, tubers, as well as livestock (Fox and Castella 2013; Langenberger *et al.* 2016; Penot *et al.* 2017; Penot and Ollivier 2009). Some of these combinations are also used in large-scale plantations (e.g. tea plantations in Sri Lanka).

While rubber production may be lower per hectare in diversified systems than in monoculture, total productivity and other environmental benefits must be considered, especially given the fluctuations in rubber price. Another way to improve the profitability of rubber production systems is to increase the use of rubber wood.

Role of rubber in climate change mitigation

Various studies have been conducted on the potential contribution of rubber to mitigate climate change (Kyono *et al.* 2014; Nizami *et al.* 2014; Brahma *et al.* 2016). These show that rubber plantations constitute carbon stocks that can be compared to cocoa plantations, or to some agroforestry or forestry systems (depending on the age of the plantation). Some propose that longer rotations stock higher amounts of carbon (Nizami *et al.* 2014). The impact of NR needs to be considered in a wider greenhouse gas emissions balance. If planted in degraded areas, rubber is an effective carbon sink, whereas replacing forests or swidden agriculture can lead to carbon emissions; these, however, are variable (Li *et al.* 2008). For example, Kiyono *et al.* 2014 calculated carbon stocks from rubber cultivation and swidden agriculture in Northern Laos. They showed that a rubber plantation standing for 30 years can result in a greater carbon stock than that of the 5-year fallow swidden system (considering emissions generated from soil preparation before rubber planting). However, this benefit is lost if swidden agriculture displaced by rubber in turn replaces natural forests.

The potential of rubber to contribute to mitigation, therefore, depends on what it replaces and how. In general:

- Carbon is generally lost when rubber replaces natural forests.
- Carbon stocks are increased when rubber is planted on severely degraded land.
- Contribution can be neutral or slightly positive when rubber replaces swidden systems, depending on the length of the fallow period of the system replaced.
- Carbon is lost when rubber displaces swidden systems that then encroach on forests.
- When combined with other trees, NR systems can store carbon as efficiently as secondary forests.

Another way in which natural rubber systems could contribute to mitigation is by using wood from rubber plantations instead of fossil fuels (Nouvellon *et al.* 2021; Fallot *et al.* 2009; Waewsak *et al.* 2020; Gitz *et al.* 2020). There is also scope for using more rubber wood in furniture production, which would reduce the need for additional wood collection in forests and for timber plantations. For instance, in Malaysia, rubber wood has replaced the dwindling supply from natural forests (Ratnasingam *et al.* 2015) and is the main material for its furniture industry (Gitz *et al.* 2020).

Contribution to adaptation to climate change

Introducing rubber trees contributes to adapting other agroecosystems, as well-managed rubber tree plantations might behave similarly to tropical rainforests in terms of evaporative cooling and recycling moisture 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. It is also a source of diversification of income.

Improving sustainability in large-scale plantations

There are three main points to be considered to improve the sustainability of large-scale plantations:

- Where and how they are established: ideally, operating permissions or land concessions should be granted following established land-zoning/land-use planning/impact assessment exercises. Even in the absence of these, the decision to provide permissions or grant concessions should consider local environmental and socioeconomic conditions.

- Worker remuneration and safety: appropriate recruitment and training, as well as fair wages and safe working conditions are a key component of the sustainability of plantations. They can be complemented by social protection schemes (Bhowmik and Viswanathan 2015).
- Practices to conserve or restore ecosystem services: permissions to operate or concessions should also include provisions related to the conservation of a certain amount of forest or the establishment of biodiversity corridors. They should also consider appropriate practices to reduce pollution from agrochemicals. Large-scale plantations can also experiment with and develop innovative mixed systems that improve ecosystem health.

Support for smallholders

Examples of policies that support smallholders are available in several countries, including China (Fox and Castella 2013; Xu and Yi 2015), Malaysia and Thailand (Fox *et al.* 2014). Smallholders cultivating rubber in more sustainable ways will need different types of support:

- Access to high quality genetic material. This can be provided by government agencies or by private companies.
- Technical support through research, extension, information exchange networks and collective organisation.
- Financial support to invest in new production, renewing plantations and diversifying income.
- Access to markets.

Considering Natural rubber as a strategic material for a sustainable world

Low-emissions development pathways require innovative thinking on how we manage our limited resources, how we further replace energy-intensive non-renewable materials and how we redesign production cycles to reduce waste (Martius *et al.* 2021). In this context, NR is one of the products that could become a centrepiece of a forest-based circular bioeconomy. Natural rubber is renewable. Further work is needed on comparing the environmental and social sustainability of natural rubber with synthetic rubbers. To realise its full potential of substitution as a green material, research is seeking to improve NR attributes, while foam and adhesive applications have been explored in pre-commercial settings (Fatimah Rubaizah *et al.* 2021). Importantly, diversification of uses for natural rubber will develop new markets, making it less dependent on the tire market which is likely to reduce price volatility. Considerable progress is also being made in reuse and recycling for enhanced raw material efficiency embracing circular economy, especially for tires, creating long term carbon sinks (Nair *et al.* 2021).

Conclusions

The development of rubber production brings sustainability challenges and a range of opportunities for sustainable development. There is a wealth of knowledge and evidence to make this transition to sustainability effective, in a pro-active way. Experience shows that coordinated action between actors is key to success. With adequate support, smallholders and large-scale producers can make a shift towards more sustainable production. Governments, research and industry need to support these efforts while further developing new uses and markets for natural rubber as part of a circular, forest-products-based bioeconomy. The implementation of the Paris agreement and of the SDGs offers opportunities to support and coordinate actions of various categories of actors, to integrate them in broader national efforts and organize international coordination both on research and for the recognition in producing and consuming countries of the contribution of natural rubber to climate action and sustainable development.

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