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Natural rubber contributions to mitigation of climate change

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Abstract

The potential of natural rubber to contribute to climate change mitigation is often overlooked. The purpose of this paper is to synthesize available research, mainly from the results of a recent workshop organised by IRSG in collaboration with CIFOR/FTA, IRRDB and CIRAD. Studies have been conducted on the potential contribution of rubber plantations to climate change mitigation in diverse situations, generally focusing on carbon stocked in tree biomass above and below ground.

They show that rubber plantations constitute carbon stocks that can be compared to some agroforestry or forestry systems. However, the global GHG emissions balance needs to take into account the effects of conversion to rubber plantation, which is strictly dependent on the previous land use. Conversion of forests or swidden agriculture can lead to substantial carbon emissions especially if swidden agriculture displaced by rubber in turn translates to an area where it converts natural forest. Such studies show the importance of promoting the renewal of existing plantations and to increase productivity, in rubber and associated crops, to reduce the need for additional land. Rubber plantations can also be an effective mitigation measure on degraded lands. There is a considerable potential in use of rubber wood, largely untapped, that would reduce the need for additional wood collection in forests and for timber plantations. Finally, natural rubber and rubber wood can substitute other products highly dependent of fossil energies and are themselves carbon sinks.

Keywords: natural rubber, climate change mitigation, carbon stocks, degraded land

Introduction

Land-use based activities, including forestry and agriculture have a key role to play in the achievement of the goals of the Paris agreement. Tree commodity plantations, at the interface of agriculture and forestry, are expanding quickly, with significant consequences on land use and associated carbon sinks. *Hevea brasiliensis* (Pará or rubber tree) is cultivated across the world to extract latex and produce natural rubber (NR), a strategic raw material. About 13 million smallholder families (40 million people) depend on its cultivation.

The IRSG, the IRRDB, the FTA research program led by CIFOR and the CIRAD organized an open digital workshop on natural rubber systems and climate change on 23–25 June 2020, to review recent research on impacts of climate change on natural rubber production, potential means of adaptation and contribution to mitigation of climate change. This paper synthesizes knowledge on GHG emissions related to natural rubber systems, including carbon sinks and potential impacts of land use change, in order to show the potential of natural rubber systems to mitigate climate change through improved management, increased used of rubber wood and of natural rubber in substitution to non-renewable materials.

The rubber tree - an efficient carbon stock

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, cutting the bark and letting the latex flow into a container. When latex production declines, old trees are logged and new trees planted. Rotation lengths can vary from 30 to 35 years.

There are several studies on rubber trees carbon stocks. For instance, a study measured total vegetation carbon stocks in *Hevea* plantations of different ages (from 5 to 40 years) and found a maximum of 105.73 Mg C ha^{-1} in plantations of 30–40 years (Brahma *et al.* 2016). Carbon stocks in plantations of 10-20 years were comparable to those of 10-year cocoa based agroforestry (Oke and Olatiilu 2011), while 20–30-year plantations carbon stocks were higher than those of semi-arid, sub-humid, humid and temperate agroforestry systems (Montagnini and Nair 2004). Carbon stocks for

>30-year-old plantations fall within the range of tropical forests of NE India (97–149 Mg C ha^{-1}) (Upadhaya *et al.* 2015) and mango agroforestry systems of Indonesia (121 Mg C ha^{-1}) (Kirsfianti *et al.* 2002). Another study in plantations (age 6 to 35 years) in Xishuangbanna, China, reported the maximum carbon stock in old rubber plantations at 148 Mg C ha^{-1} at elevations below 800 m (Yang *et al.* 2017 and 2019). Kiyono *et al.* (2014) estimated that the average carbon stock in rubber trees (50.0 Mg C ha^{-1})[1] was greater than the average carbon stock in a 5-year fallow period slash-and-burn agricultural system (18.6 Mg C ha^{-1}). An overview of carbon stocks estimates in rubber plantations made in earlier studies can be found in Blagodatsky *et al.* (2016).

Rotation length affects the C stocks of both trees and soils (Blagodatsky et al., 2016). A study modelled the effect of rotation length (25, 30, 35, 40 and 45 years) on the C stocks in rubber plantations in Xishuangbanna, China. The total C stocks (Mg C ha^{-1}) increased with the rotation length, with the maximum (173.60 Mg C ha^{-1}) for the rotation length of 45 years and the lowest (89.86 Mg C ha^{-1}) for the 25-year rotation length (Nizami *et al.* 2014). As the landscape includes plantations of different ages, the time averaged C stock (mean C stock over the whole rotation time from rubber planting to clear-cut) is a useful variable to estimate regional-scale C stocks in rubber plantations (Blagodatsky et al., 2016; Yang et al., 2016). For rotation lengths of 30 years, Blagodatsky et al. (2016) reported time averaged C stocks in above- and below-ground biomass ranging from 38.2 to 46.2 Mg C ha^{-1} depending on the growing conditions. For a given growing condition, the time averaged C stocks increase with rotation lengths.

The impacts of land use change

Large-scale land cover changes are occurring throughout tropical areas driven by the increasing global demand for materials, raising concerns on their impacts on deforestation and associated emissions.

Over the last three decades the area planted to rubber increased by a factor of 1.8 and reached 14.1 million ha (IRSG 2020). Between 2008 and 2018 it increased by 24%. This growth has been most apparent in the Mekong region and Côte d’Ivoire. Expansion is expected to continue, although at lower rates, with projections suggesting a 2.4% per annum increase in the next decade (IRSG 2019), depending on rubber prices (e.g. Grogan et al., 2019), and other factors (e.g. COVID-19 pandemic which may impact the demand in rubber in different sectors).

The shift from tropical forests and swidden agriculture to rubber monoculture has greatly improved the livelihood of many smallholder farmers (Grass et al., 2020; Blagodatsky *et al.* 2021). Concerns have been raised about the impacts of such changes on biodiversity, soil quality, water availability, ecosystem services and livelihoods of local populations (Fox and Castella 2013; Warren-Thomas *et al.* 2015).

Conversion from different land uses to rubber plantation has a significant effect on carbon emissions, which depends on initial land use (Blagodatsky et al., 2016). Conversion from forests or swidden agriculture can lead to substantial carbon emissions from above and below ground carbon pools. However, the losses vary (Gitz *et al.* 2020). For instance, a study in Northern Laos (Kiyono *et al.* 2014) compares carbon stocks generated by rubber plantations to those generated in the swidden system practiced in the area — where the length of fallow has decreased from about 20 to 5 years in the last decades. The study estimated that a rubber plantation standing for 30 years stocks more carbon than a swidden system with a 5-year fallow period. This finding holds even when

[1] After deducting emissions from soil preparation

accounting for emissions generated from soil preparation before rubber planting. However, this benefit is lost if the swidden agriculture displaced by rubber itself moves and replaces natural forests.

The potential contribution of NR to mitigation depends on what *Hevea* cultivation replaces and on how it is conducted:

- Impact is generally negative when it replaces primary or secondary forests
- Impact is positive when it is planted in severely degraded land
- Impact can be neutral or slightly positive when it replaces swidden systems, depending mainly on the length of the fallow period of the system replaced
- Impact is negative when it displaces swidden systems that encroach into forests.
- Systems that are diversified (e.g. jungle rubber) can be as efficient to store carbon as secondary forests
- Improving rubber yields should reduce deforestation by reducing the need for additional land.
- Success may be higher if land-use planning identifies areas with highest environmental and economic returns and includes adaptation concerns

Most land-use change impacts are local-specific. Land-use zoning and planning can go a long way to limit negative impacts. It can preserve areas with high carbon stocks and that are important for biodiversity conservation or other environmental issues by orienting rubber development towards already degraded areas.

Improving management and yields contributes to increase carbon stocks and reduce deforestation

It is possible to reduce land-use change and deforestation through more intensive systems (Warren-Thomas et al., 2015) by increasing the yield of latex with improved genetic material, managing organic residues, improving tapping practices (Singh 2020) and by diversifying production systems (Gitz *et al.* 2020).

The genetic material is important to achieve higher and stable yields. Plant breeders are trying to produce vigorous clones, high-yielding in both latex and timber, resistant to the major diseases, and with a shorter immaturity period (Gitz *et al.* 2020; Makita *et al*. 2021).

Soil quality is also important to maintain and increase yields. After conversion from arable land or renewal of the plantation, soil quality may decrease during the immature phase (Thoumazeau *et al.* 2019). It improves during the maturity phase, getting closer to the soil quality of local forests, as shown in plantations in Thailand (Gay *et al*. 2021), where soil organic matter losses occurred mainly during renewal of the plantation. In Thailand, as 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, but in others residues are simply burnt. The preliminary results from a project in Côte d'Ivoire have shown that leaving part of or the entire tree biomass in the inter-rows has a positive effect on soil quality and tree growth only 18 months after the logging of the old plantation (Gay *et al*. 2021). Such improved practices that increase soil organic matter also rise carbon stocks in the soil, contributing to mitigation.

Soil erosion driven by rain events is common in rubber plantations, resulting in decrease of soil organic carbon. A study in Southwest China showed that mid-age rubber plantations had the highest erosion rate (3.5 and 5 times higher than young and old plantations, respectively) (Blagodatsky *et al.*

2021). The Land Use Change Impact Assessment (LUCIA) model was applied to scale plot-level results up to watershed level to study the impact of weed management on soil erosion. It was concluded that weeding once a year and no-weeding minimized soil loss during a 20-year rotation. Once-weeding was suggested as the best practice, as it controlled overgrowth of understory vegetation by keeping weed cover below 50% (Liu *et al.* 2019). Other studies have shown that retaining natural flora in rubber plantations reduced soil acidity and improved soil health, carbons stocks and soil nutrient status (Abraham and Joseph 2015; Jessy 2021).

Trees grow rapidly during the immature phase, with a high demand for nutrients and a 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 requirements are low (Chotiphan *et al.* 2019). Rubber trees do not require high quantities of fertilizers during the mature phase and almost no pesticides (Penot *et al.* 2021), comparing favourably with GHG emission balances of many other crops.

Judicious crop mixing in rubber plantations (also applicable in large scale plantations) can increase carbon stocks and either improve or not reduce growth and yield of rubber, sustain, or improve soil fertility status and reduce costs of cultivation (Jessy 2021). Low light availability within the plantation after canopy closure limits the choice of crops during the mature phase to shade-tolerant crops like coffee, cocoa, vanilla and certain medicinal and ornamental plants (Jessy *et al.* 2015 and 2017; George and Met 2018). Extending rotation lengths in plantations to 40 years, for SW China, Nizami *et al.* (2014) favours introducing economically and ecologically important species (e.g. *Coffea arabica*, *Theobroma cacao*, *Myristica yunnanensis*, *Bennettiodendron leprosipes*, *Gmelina arborea*, *Mesua ferrea*, *Erythrophleum fordii*, *Podocarpus fleuryi*, *Shorea chinensis*, *Dipterocarpus tubinatus*) between the rubber trees when trees are about 35 years old, to avoid erosion when replanting *Hevea* trees.

Increasing the use of rubber wood

Natural rubber systems can contribute to overall emissions reduction when the wood from plantations is used as a substitute for fossil fuel (Nouvellon *et al.* 2021) as in the case of coke replaced with charcoal from *Eucalyptus* in the steel industry (Fallot *et al.* 2009) or using rubber biomass for power plants in Thailand (Waewsak *et al.* 2020). The government of Thailand also promotes the production of rubber wood pellets both for domestic use and export (Gitz *et al.* 2020). The nationally determined contribution of Indonesia promotes the use of rubber wood for energy production.

There is also scope for using more rubber wood in furniture production. Rubber wood is the main material for the furniture industry in Malaysia, where it is also used in medium density fibreboard and other panel products (Gitz *et al.* 2020). In Malaysia the rubber wood has replaced the dwindling supply from natural forests (Ratnasingam *et al.* 2015) and its use has been possible thanks to the partnership between public and private actors.

Increasing the use of rubber wood would also reduce the need for additional wood collection in forests and for timber plantations and reduce accordingly pressure on natural forests. These positive effects of the use of rubber wood should be factored in any global analysis of rubber production in relation to climate change.

Substituting synthetic materials with natural rubber

Natural rubber has diverse applications in the tyre, anti-vibration, anti-seismic and medical equipment industries (Gohet 2021). It is a greener substitute to petroleum derived elastomers, representing about 47% of the global elastomer market in 2020. Natural rubber has many attributes that makes it ideal for plastic substitution in textiles, footwear and construction (Pinizzotto *et al*. 2021).

Research is underway to improve NR attributes related to damping, oil resistance, gas permeability, wet grip and rolling resistance. Other product applications have been explored in pre-commercial settings, including foam and adhesives. A specialty latex foam shows excellent sound-absorbing and vibration-damping properties, and a water-based adhesive gives an alternative for non-toxic, environmentally-friendly and less odorous adhesive (Fatimah Rubaizah *et al.* 2021).

Considerable progress is also being made in reuse and recycling, particularly for tires that can be recycled for roads and buildings creating long term carbon sinks.

Natural rubber and climate action

Natural rubber production has a considerable potential for climate action and sustainable development, which needs to be recognised by national and international mechanisms and plans. (Gitz and Meybeck 2021; Brady 2021; Omokhafe 2021; Rodrigo and Munasinghe 2021; Meybeck and Gitz 2021). With the Paris agreement and the Nationally Determined Commitments (NDCs) there is better recognition of synergies and trade-offs between mitigation and adaptation as well as of synergies with sustainable development, opening up additional ways to better integrate land use, and in particular rubber production.

Most countries have integrated in their National Determined Contributions (NDCs) objectives and measures related to land use, land-use change and forestry (LULUCF) including reduced deforestation, afforestation and sustainable forest management. Some of them also have targets regarding development of bioenergy. For instance, Indonesia explicitly aims to increase the use of rubber wood for bioenergy. The implementation of broad LULUCF objectives can include measures related to rubber, including for instance renewal of plantations. Moreover, the periodic revision of the NDCs offer opportunities to explicitly integrate rubber related objectives.

The implementation of NDCs in consuming countries could include measures promoting the use of natural rubber to substitute non-renewable products or increasing the lifespan of carbon stocked in rubber products — for instance blending ground tyre rubber with asphalt to produce longer lasting road surfaces.

At international level there also opportunities for the potential of natural rubber for mitigation to be better recognised and valued, for instance to extend to rubber and bamboo products the accounting of carbon in harvested products as is the case for harvested wood products (HWP).

Conclusions

Natural rubber systems have a considerable potential to increase their contribution to mitigation of climate change. It includes Hevea trees themselves as carbon sinks, better management of land use and land use change and improved management practices to increase soil carbon and yield, as well as increased use of rubber wood and of natural rubber in substitution to non-renewable materials. The realization of this potential requires research and development, coordinated action in landscapes and along the value chain, enabling policies as well as appropriate recognition and support at international level.

The Paris Agreement has profoundly changed the way climate action is determined, putting the focus on the NDCs, on national actions, priorities and specificities. This gives additional opportunities for sectors that are important nationally to have a broader influence in the determination, implementation and revision of the NDCs. It is obviously the case for rubber within the set of producing countries, in traditional and non-traditional areas. In addition, recent years have seen a growing emphasis on the role of the private sector in climate action, with more importance given to initiatives of actors other than governments. This creates new opportunities to increase the visibility and integration of rubber in international negotiations and financial mechanisms. The sector can mobilize for action its well-organized mechanisms of collaboration between countries and with the private sector through the IRSG and between research organizations through the IRRDB.

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