Agroforestry in Southeast Asia's Rubber Sector

Present situation and future perspectives for fairstainable rubber business

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Content

1. Introduction

Southeast Asia is the centre of the worlds rubber production, with Thailand, Indonesia and Malaysia among the top producing countries. 85 % of the rubber area is managed by smallholders (Knoke et al., p. 8). Rubber monocultures (RMC) are dominating the mode of production and are covering millions of hectare in the tropical landscape of the region. The intensification of a single crop has allowed a highly rational work organization and has brought tremendous gains in productivity. However, similar with the controversial oil palm that has experienced much more global public attention in recent years, RMC have been associated with a range of ecological and social problems, such as listed below:

- Deforestation, implying destruction of carbon stocks and loss of biodiversity
- Soil erosion (including risk of landslides and flooding)
- Disturbed water cycle: lower humidity in the fields, but also dropping groundwater levels and water scarcity for human consumption
- Soil acidification through agrochemicals and intensive land use

- Smallholder vulnerability to the highly fluctuating rubber prices on the world market
- High input costs for agrochemicals reduce the revenues for smallholders and can lead into indebtedness
- Issues of food security in regions that rely on a single cash crop replacing traditionally diverse agricultural systems

(Häuser 2015; Jongrungrot et al. 2014)

1Rubber Monoculture Plantation in Kedah, Malaysia

Agroforestry is discussed as a more sustainable option that can be adopted by smallholders to tackle those problems mentioned above. It combines elements of forestry and agriculture. Different trees and crops are grown on the same area. Sometimes livestock is kept as well. There is evidence that Rubber Agroforests (RAF) have a higher biodiversity value and make the land more resilient against soil erosion and water scarcity. Moreover, they can diversify smallholder income and make them more resilient against fluctuating rubber prices and food crisis.

This report will outline the different development trajectories of RAF in the three major rubber producing countries and discuss their ecological and economic performance. From this perspective it aims to examine the potential future role of RAF in a transformation of the rubber sector to more environmental sustainability and livelihood improvements for small scale farmers. The paper is based on a mix of sighted studies, discussions with experts and farmers in Malaysia and Thailand, combined with own observations in the field. It is, therefore, rather the condensation of personal experiences in the context of present research literature than a scientific study.

2. Development and present situation of RAF in the top producing countries

2.1 Indonesia

In the forest frontier regions of Indonesia's outer islands (particularly Sumatra and Kalimantan) RAF have a long tradition. Because of their emergence from and proximity to natural forest vegetation, this type of RAF is often referred to as **jungle rubber**. **Local forest people** have adopted to the global demand for the cash crop rubber by **introducing the rubber tree into their traditional land use systems** once characterized by swidden based shifting cultivation, hunting and gathering (Feintrenie and Levang 2009). During the last century farmers in Indonesia converted vast areas of forest and former swidden plots into extensive RAF, covering up to 4 Million ha on Sumatra's East Coast in the 1990s (ibid.) and – to some accounts – up to 70 % of Indonesia's total rubber area (Joshi et al. 2006, p. 3).

How are jungle rubber agroforests established and look like?

The plots are established by clearing forest, through slash and burn. Then, for the first 2-3 years, rice (ladang) or other upland food crops are sawn out together with the rubber seeds. Due to **constraints in the accessibility to capital, herbicides and hired labour**, **farmers do not stop the spontaneous vegetation** that regrows from stems and the surrounding forest into the plots. They rather keep and **maintain particularly valuable fruit and timber trees** alongside the rubber as an additional source of income. Minor weeding might be conducted to protect the rubber trees from competitive species growing too close to the stem. After the rubber trees are old enough (5 to 10 years) paths are cleared through the area to easily reach the trees for tapping (Feintrenie and Levang 2009; Wibawa and Hendratno undated).

Characteristics of Jungle Rubber

- Almost **no input resources** are needed to establish and maintain the plots (no chemicals, no expensive planting materials, no hired labour).
- The **latex output** is **significantly lower** compared with conventional RMC, ranging from 500 to 800 kg/ha/year DRC (dry rubber content) on average in the sited studies (RMC average: 1500 kg/ha/year DRC) (Wulan et al. 2008, p. 438; Wibawa and Hendratno undated; Joshi et al. 2006, p. 3; Feintrenie and Levang 2009).
- Jungle rubber is a **low input system, with significantly lower output**.
- Jungle rubber is known for it's **high biodiversity value and ecosystem services** that can be comparable with those of secondary forest (Tata, Hesti, L. et al. 2008). Researcher in Jambi/Sumatra found 80 different plants on jungle rubber plots, of which 40 create additional value and others are just left to grow if they do not compete with the valuable species (Wibawa and Hendratno undated). Richness of trees and plants can serve as a habitat for birds, mammals and primates. However, diversity of species is highly variable and depends on the maintenance and weeding activity of the farmer.
- **Continuous income flows** through rubber, other fruit crops and wood products complementing each other. Many farmers tend to replant single rubber trees that turned unproductive and do not clear and replant the whole area avoiding years of zero income (Wibawa and Hendratno undated).

Promotion of RAF systems through institutions

Government programs to improve smallholder's situation in Indonesia (such as Perkebunan Inti Rakyat or the Smallholder Rubber Development Project) **solely focus on** the promotion of intensive **monoculture** to increase land productivity. Knowledge of RAF is rather transferred from generation to generation in the family (Wibawa and Hendratno undated).

Nevertheless, some academics have done research in RAF and are highlighting their advantages for smallholder's income and biodiversity conservation if managed well. Those are connected in the Indonesia's branch of **World Agroforestry Center** (ICRAF) and the **Indonesian Rubber Research Institute** both located in Bogor. Both institutions joined to set up a network of improved **RAF system demonstration and research plots** in Jambi, West-Sumatra and West-Kalimantan. The aim is to research the improvement of latex yield and other income sources on the plots by using high quality clonal planting material and testing intercropping with different species and spatial arrangements. I will discuss some of their findings in the sections below.

The present decline of jungle rubber

Jungle rubber has developed under circumstances, where land is abundant and access to capital intensive inputs (herbicides, fertilizers, hired labour) is limited. **Increasing pressure on land** due to agro-industrial expansion (oil palm) alongside infrastructure development and **better access to capital** in rural Indonesia have put jungle rubber under threat. Indonesia's RAF are known for their biodiversity value. However, **farmers do not conserve biodiversity for itself** – it is rather an unintentional side effect of an adaption to constraints and circumstance described above. Where land resources get scarce and agrochemical inputs are available, **farmers tend to intensify their land use system** to reach higher yields on the limited land available. In recent years, this has led to constant transformation of jungle rubber into rubber and oil palm monoculture – a development that caused Feintrenie and Levang (2009) to state the "fall of a sustainable cropping system".

Perspectives for fairstainable[1] business

In principle the preservation of jungle rubber could **contribute to biodiversity conservation** in a surrounding where remaining forests are under constant threat to logging, mining and agro-industrial expansion. But **low productivity questions their future appeal** for small scale farmers. Fairstainable business that aims to partner with jungle rubber farmers needs to focus on improvements in the economic performance of the cropping system (eg. through the introduction of high yielding clonal seedlings). Premium price structures could contribute to allocate an economic value to the biodiversity conservation feature of jungle rubber.

At present, **Indonesia's smallholders produce only dry rubber**. Changing to liquid latex would require large investments in latex processing facilities and distributional infrastructure. As farmers, traders and processors in those areas have never dealt with liquid latex before, the introduction of this feature of commodity management might be challenging.

2.2 Malaysia

Malaysia is underrepresented in the research literature on RAF. **State institutions** like the Malaysian Rubber Board have **focused on the intensification of rubber cultivation** to gain higher latex yields and returns on land. This has led to a widespread promotion of intensive RMC through the Rubber Industry Smallholder Development Agency (RISDA) supplying clonal seedlings, chemical fertilizers and herbicides to farmers.

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[1] *Fairstainable* is a term introduced by *einhorn* to describe a business notion that combines environmental sustainability with social responsibility to create a positive impact on people and environment (see https://einhorn.my/fairstainability/).

Research and trials on RAF

The Rubber Research Institute of Malaysia (RRIM), as well as at least one research group at the Universiti Putra Malaysia[2] (UPM) have conducted trials on RAF as a possible way of increasing smallholder income that has been undermined by low rubber prices (personal discussion, Oct 2018). Trials with intercropping popular fruit trees between the rubber rows have shown that the **fruit trees do not develop and yield properly**, because they **don't get enough sunlight** below the rubber canopy. Therefore, researchers have developed a **new spatial arrangement for intercropping** referred to as **avenue planting**, hedge planting or *sistem berpagar* (fencing system). In this arrangement, two rows of rubber trees are planted more densely while leaving a wider avenue (eg. 22m) for intercropping between the double rows (see chapter 5.1). This system is also mentioned in a guidance book on rubber plantation technologies published by the Malaysian Rubber Board (MRB 2009).

Lack of institutional support

The UPM research group stated that they produced some **good results in trials using the avenue system**, reaching reasonable latex yields, comparable with RMC and good development of intercropped fruit trees. However, their **results have not been recognized** and advanced **by policy makers**. Trial with smallholders have been less successful, because the farmers interest in maintaining the intercropped fruit trees was reported to be low. The researchers concluded that they developed a good system that – unfortunately – has not yet been picked up and disseminated by practitioners outside the university context.

On a field visit to rubber growing communities in Merapoh on the boarders of the Taman Negara (Malaysian National Park), farmers as well as local officials from MRB/RISDA reported that they have been supported to start intercropping with the avenue system (they call it *sistem berpagar*) by those institutions in the past. However, from the 1990s onwards, government policies had changed to a solely support and promotion of RMC. They showed us older RAF plots that had been developed in the 1990s, and were in rather poor condition, while newer plantings had been developed as RMC.

Is there a future perspective for RAF in Malaysia?

From our discussions with state institutions, academics and farmers we got the impression that **agroforestry does not play a significant role in the praxis of Malaysia's rubber sector today**. Institutional support has always focused on monoculture making capital available for farmers to intensify their cropping systems. Farmers themselves seem to be highly accustomed to RMC and rather sceptic to the adaption of RAF Systems. Many are concerned that snakes will hide in the dense vegetation and favour a "clean" plantation (for a detailed survey of the perception of intercropping of institutions and

[2] One of Malaysia's most renowned university located close to the capital Kuala Lumpur

farmers in Malaysia, see Fendel 2017). While, overall, rubber seems to be a sunset business in Malaysia challenged by ongoing industrialization (that shifts institutional focus as well as employment options from the agricultural to the industrial sector) and the proliferation of the much more profitable oil palm, those left counting on rubber have chosen the path of intensification of RMC.

2.3 Thailand

Thailand is the world's number one rubber producer with 95 % of the rubber area managed by small scale farmers (Jongrungrot et al. 2014). As an adaption to several dramatic **drops of the rubber price, smallholders have started to plant fruit and timber trees** into their RMC plots to generate an additional income source.

How are RAF implemented and look like?

In general fruit trees and hardwood species are **planted in the 7 m zone between the rubber rows[3]**. A survey of 19 RAF plots in southern Thailand (Jongrungrot et al. 2014, p. 24) found 21 kinds of timber, 10 kinds of fruit trees and 9 kinds of other plants. Other researchers in the same area found 6-20 different species per rai[4] (Kittitornkool et al. 2018). Some farmers have developed increasingly

2*Diverse Rubber Agroforest in Songkla, Southern Thailand*

[3] See p. 14 for detailed description.

[4] Thai measure for land, 1 rai = 0,16 ha.

sophisticated systems of intercropping, **choosing shade-resistant trees, palms and herbal plants** that grow well below the rubber canopy. They aim to create a **multi strata canopy** system resembling natural forest. On a field visit in Songkla province (South Thailand) we saw diverse RAF plots with farmers planting the shade tolerant Salak Palm, Bamboo, local timber species and many other plants that contribute to a **healthy ecosystem and served as additional income sources** (eg. bamboo was used to make charcoal). Many of them have stopped to use herbicides and some even breed bees on their land to produce honey. They were organized in cooperatives and connected with researchers from Prince of Songkla University in Hat Yai. Surveys conducted by those academics underpinned the economic and ecological success of the farmers, showing that they were able to maintain a high latex yield (comparable with RMCs in the same area), while improving several ecological parameters (soil humidity, organic matter etc., for detailed discussion see chapter 3).

Promotion of RAF Systems through institutions

The **Rubber Replanting Aid Fund (RRAF)** is the most important institution supporting smallholders in Thailand by distributing high quality seedlings and conducting training programs to transfer knowledge and agricultural techniques. Until the early 1990s the RRAF solely promoted a monoculture system and prohibited intercropping for smallholders that received aid and support from the fund. Since the late 1990s the RRAF completely changed its policy, first allowing intercropping and later starting to **support smallholders to transform their plots to RAF systems**. In 2013 the RRAF invested 1.5 Million Bath in distributing perennial plants such as Iron Wood, Mahogany etc. to smallholders for planting them between the rubber trees on their plantations (Romyen et al. 2018, p. 141). In 2015 the RRAF has been incorporated into the Rubber Authority of Thailand (RAOT), which is presently promoting agroforestry through the distribution of money and saplings together with the Royal Forest Department.

Openness and intrinsic motivation of Thai farmers to explore RAF

Many of the **farmers** we visited in southern Thailand were **highly aware of the benefits of a functioning ecosystem** and valued biodiversity for itself. They felt strongly connected to their land and were eager to create a diverse planting system that gives home to many plant species and animals, thus moving towards a natural forest ecosystem. Many RAF farmers are organized in cooperatives and groups to share knowledge and experience about intercropping (Jongrungrot et al. 2014, p. 28).

A study conducted by researchers from Songkla University (Romyen et al. 2018) surveyed 400 farmers who grow rubber in conventional monoculture in Songkla and Phatalung on their attitude towards RAF systems. Their perceptions of RAF were overall positive, and they were aware of many favorable impacts they associated with RAF. They valued the potential to gain additional income sources through the selling of timber and fruits as well as the possibility to improve soil quality and resilience against erosion. 86 % of them stated that they want to start intercropping within the next 5 years.

Perspectives for fairstainable business

The interlocking of institutional support, ongoing academic research, a growing group of successful RAF farmers in the field and a generally positive attitude of Thai farmers towards RAF create **highly suitable circumstances for the future development and proliferation of a sustainable rubber sector.** This makes southern Thailand a unique and interesting region for fairstainable businesses who want to engage with RAF farmers.

3. Ecological benefits of RAF

Regions that have faced rapid deforestation and agro-industrial expansion often suffer from land slides and flooding, because the natural forest that has structured the landscape and stabilized the soil has been changed to large monocultures. The loss of biodiversity is another problematic consequence that goes alongside with this trend. RAF could contribute to alleviate those problems, as they can help to restore certain ecosystem services and contribute to biodiversity conservation.

Biodiversity

RAF have – intrinsically – a higher biodiversity value than RMC, because different species are growing together. The diverse flora can attract birds, insects and mammals and can serve as a habitat for them. The actual **biodiversity value strongly depends on the number of different species** that are grown in the plot and the management practices – particularly the undergrowth management (spraying herbicides, manual weeding, etc.) – applied by the farmer. While jungle rubber systems are known for their high biodiversity value that can get close to a secondary forest (Tata, Hesti, L. et al. 2008), it is reasonable to expect much lower biodiversity parameters in Avenue Planting Systems, where farmers combine only two or three species and do not intercrop in between the main rows.

Ecosystem services

The higher planting density and variety produces **more fallen leaves** that cover the soil and will transform into **natural fertilizer increasing soil condition and fertility.** Studies have shown that the topsoil of RAF systems provides a **higher decomposition rate and more organic matter** than RMC. The more diverse and dense the RAF the closer it resembles the nutrition cycle of a natural rainforest (Jongrungrot et al. 2014, p. 30; Kittitornkool et al. 2018).

The dense canopy of an agroforest can provide a shady environment reducing the day time temperatures on the plantation which is related to **higher humidity** that can positively effect plant development and latex yield. Moreover, it **protects the soil from extreme heat and draught as well as heavy rainfall**. The roots of the rubber trees can intervene with the roots of other plants and hardwood species making the plantation more **resistant against heavy storms**. The combination of a dense canopy that tempers heavy rainfall, a healthy soil that can absorb and store more water and a complex root system that stabilizes the top soil **protects the plot against surface runoff, soil erosion and water overflow**. The environmental benefits are not exclusively bounded to a single plot. The introduction of RAF into a landscape that has been shaped by deforestation and monocultures can help to **prevent landslides, flooding and severe droughts** protecting the surrounding population that is living in that area. RAF can serve as buffer zones against heavy rain and waterflow as well as a below surface water storage (Jongrungrot 2018; Kittitornkool et al. 2018).

4. Economic performance of RAF

Economic viability is crucial for farmers if they consider adapting a new agricultural system. If biodiversity improvements and ecosystem services will not correlate with economic benefits, only a few environmentalists will introduce intercropping to their rubber plantations. Langenberger et al. (2017) who have conducted a comprehensive review of available literature on rubber intercropping remark that "**where intercropping is practiced, it is basically economy driven**." They conclude that RAF "needs either to be highly profitable or at least be labor extensive to be adopted on a considerable scale."

Does intercropping reduce the latex yield?

A common assumption that occurs in discussions on RAF is that intercropping does reduce the latex yield due to **high competition for nutrition, water and sunlight** between the different trees and plants. It is one of the main concerns that discourages farmers to adapt a RAF system. It is well known that the **output for jungle rubber does not even reach 50 % of RMC yields**. However, this might be due to low quality seedlings, zero fertilizer application and poor tree maintenance. Objective data on the latex yield of improved intercropping systems is scarce. A **study published by ICRAF** (International Center for Research on Agroforestry, Wulan et al. 2008) conducted forecasts over a whole productive cycle of different RAF-Systems based on trial plantings with clonal seedlings, different spatial arrangements and weeding intensities in Kalimantan (Indonesia). Depending on the system, the **estimated latex yield ranges from 865 – 1,131 kg/year/DRC.** This outcome is significantly **higher than the yield of jungle rubber** but still **lower than that of RMC plantations** (1500 kg/year/DRC).

Unpublished data from the **Prince of Songkla University in Hat Yai** (Thailand), based on a **survey of 3 cooperatives** comprising 172 households practicing RAF, shows that **the RAF farmers produced up to 1500 kg/ha/year/DRC**. Their latex yields were comparable with those of RMC famers (Kittitornkool et al. 2018). Farmers we spoke with were convinced that rubber trees benefit from a healthy ecosystem resulting in high dry rubber content parameters and excellent latex yields. In their view, intercropping rather positively effects the latex yield than reducing it. A **favorable microclimate** with lower temperatures, higher humidity and decomposition rate **might have a positive effect on tree healthiness** and **stimulate the latex flow** inside the bark. This effect might outnumber losses due to competition with other trees and plants. Researchers at the *Universiti Putra Malaysia* noted regarding to their planting trials with an avenue RAF-System that they achieved reasonable latex yields that where comparable with RMC, too.

While there is still a lack of larger studies that deliver scientific evidence on the latex yield of RAF, the available references suggest that it is possible to gain a high latex output if the RAF-System is managed and maintained well.

Labor requirements

Do RAF require more labor than RMC? This question is crucial as many smallholders don't have the capital to hire labor or combine their agricultural work with other off-farm activities. Thus**, farmers might be reluctant to change to a new planting system if that means too much work.** The required labor for implementing, maintaining and harvesting a RAF strongly depends on the type of system that is used – more precisely the level of sophistication, the choice of intercrops and the practiced undergrowth management. **Jungle rubber** is known for its **low labor requirements** as farmers do not actively choose and plant perennial intercrops, but rather keep the spontaneous vegetation and often reduce weeding to a minimum. However, low labor input is reflected by low latex output. **More sophisticated systems** like the avenue planting or the Thai rubber forest gardens have better yields but can **require more labor than RMCs.** Alongside the rubber trees, intercrops must be chosen and planted, maintained and harvested.

Nevertheless, our experience from field visits in Thailand as well as the sighted literature shows that farmers are able to handle the additional work load. As tapping is only a half day job, the afternoon can be used for other tasks (pruning, weeding, fertilizer application, fruit harvesting etc.). The same accounts for rainy days where no tapping can be done. Tapping frequency can be adjusted to the changing requirement of other duties or external tappers can be hired on a fifty-fifty share basis[5]. **Additional income** through the **selling of other products from the RAF** can **compensate farmers for the additional work.** In this context the **intercropping of timber trees** seems to be most attractive as it **does not require any labor inputs** after the saplings are planted. When timber trees are harvested and sold after 10 to 20 years, the farmer does not need to do this himself, but calls a trader who will cut and cart away the trees (Jongrungrot and Thungwa 2013). Consequently, it is important to **adjust the RAF-System to the available labor resources**. If labor is limited due to off-farm activities, farmers can restrict the choice of intercrops to timber trees or deploy an avenue system (see section 5.).

[5] In this arrangement, tappers get payed by a fifty percent share of the harvested rubber.

Farmers benefit from diversified income sources

If the latex yield of RAF turns out to be slightly lower and the labor cost higher than in RMC plantations, non-rubber products, such as food crops, fruits, timber, fuel wood, herbal teas and powders or honey might compensate or even outnumber this tendency. Moreover, it has been repeatedly mentioned that **intercropping reduces farmers dependency from a single cash crop**, as they can sell non-rubber products if the rubber price is dropping to the bottom.

Researchers from ICRAF compared the net present value – the income from one-hectare land after subtracting all costs and expenses – of different RAF-Systems with that of conventional RMC over a period of 20 years, based on the mentioned trial plantings in Kalimantan. They found that **improved RAF-Systems can achieve high returns comparable with RMC plantations.** The lower latex yield was compensated by the selling of fruits and timber (Wulan et al. 2008). After that, they calculate the margins against a simulated drop of the rubber price by 50 %. In this model, the returns of the RAF-Systems exceed those of the RMC plantations. Another study in Thailand showed that particularly the intercropping with timber trees can generate high additional income that makes farmers resilient against fluctuating rubber prices. Farmers who have planted **timber trees** into their rubber plots perceived them as a kind of pension stock or insurance that **can be sold in times of low rubber prices or high age retirement** (Jongrungrot and Thungwa 2013).

5. The praxis of growing RAF – suitable plant species and spatial arrangements

The main challenge of rubber intercropping is to find a spatial arrangement and selection of species that **minimize competition for sunlight**. In a mature RMC plantation with a common planting density of 7 m between the rubber rows and 3 m between the trees inside the row (3 x 7 m), **up to 90 % of the ground area is shaded by the canopy of the rubber trees** (Langenberger et al. 2017). This explains why Researchers in Indonesia (Joshi et al. 2006, p. 8) and Malaysia[6] repeatedly reported that fruit trees did not yield in RAF trial plantings if they were planted between the rubber rows in a normal 3 x 7 m spacing. This problem can be met by either **changing the spatial arrangement of the rubber trees** to **allow more sunlight infiltration** or **by focusing on shade tolerable plants** and timber trees instead of light demanding fruit trees. Those two strategies are reflected in the development of two divergent RAF-Systems which I will outline in the following sections.

[6] Personal discussion with the Rubber Research Institute and a research group from the Universiti Putra Malysia

The avenue/double row planting system

Malaysian and Indonesian researchers have developed a planting system in which **wide avenues between the rubber rows** give **sufficient space and more sunlight for intercropping**. To achieve a with RMC comparable number of rubber trees per hectare (400 – 500 / ha), narrow **rubber double rows** are planted with trees set up more densely inside the rows. A book published by the Malaysian Rubber Board (MRB 2009) recommends a system were rubber double rows are planted with a distance of 2 x 3 m (2 m inside and 3 m inter row distance). In between two double rows an avenue of 22 meters is spaced for intercropping. This arrangement fits 400 rubber trees/ha. Due to the wide avenues it **can** be combined with almost any large fruit or timber tree (e.g. Durian, Mango, Teak or Mahogany) as well as cash and food crops like cocoa, coffee, tea, maize or dry rice. If combined with tree crops, those are normally planted in one row in the middle of the avenue. In a trial planting conducted by ICRAF Indonesia a spacing of 2 x 6 x 14 m (2 m inside, 6 m inter row and 14 m avenue distance) has proven successful in the combination with timber trees (Mahogany, Teak and Eucalyptus). Only Acacia was unsuitable as it was growing too fast, heavily overshading the rubber trees. The researchers recommend to start with the planting of the timber trees 2-3 years after the rubber to avoid severe competition for sunlight (Joshi et al. 2006).

From an economic perspective, avenue systems allow the **intensification of a single fruit crop alongside rubber** and are, therefore, also suitable for larger plantations based on hired labor. It represents a compromise between monoculture oriented intensive agriculture and more diverse, organic style systems that focus more on ecosystem services. However, while giving a lot of space for intercropping, **latex yield can drop if the rubber trees are planted too dense.** A trial planting in Sri Lanka showed that rubber trees planted 2,4 x 2,4 x 14 m achieved a yield of only 1200 kg/ha/year DRC compared to 1500 kg/ha/year in a common 3 x 8 m monoculture spacing (Rodrigo et al. 2004).

From an ecological perspective, compared with monocultures, the system provides already reasonable improvements. Nevertheless, its biodiversity benefits are rather small if only two or three species are combined. Because different trees are planted rather separated from each other (in exclusive rows) their interaction and, thus, the **restoration of ecosystem services** (nutrition cycle, protection against erosion, attraction of animals) **might be limited.** However, smallholders who apply this system could, in principle, increase the number of intercropped species in the avenue and mix trees and other plants more randomly to achieve higher ecological improvements.

The Thai System: Rubber Forest Gardens

Farmers in Thailand developed this system, when they spontaneously started to intercrop valuable plants into their rubber plots to create an additional income source as a reaction to the falling rubber price. Rubber trees are arranged in the **common 3 x 7 m pattern** while **intercrops are planted in the inter-row space. Species for intercropping** are **chosen by their ability to grow in a shady environment.** Only the rubber is arranged in exclusive rows, while the up to 20 different additional trees are rather distributed, mixed and clustered according to the experience and knowledge of the farmer. In this way the RAF comprises **three canopy levels**: rubber trees at the top level, a middle level consisting of local timber trees, Bamboo and Palms and a lower level of herbal plants and shrubs that naturally grow in the understory of a rainforest (Kittitornkool et al. 2018). The **integration of fruit trees is limited**, due to the **lack of sunlight**. Most suitable fruit plant is the shade tolerable Salak Palm that grows and yields well below the dense canopy. Other species like Mangostane, Santol, Champedak and Longkong can be planted as well but their yields will be lower. The intercrops are normally not planted in a row, but rather a cluster of assorted species arranged with each other following the experience and knowledge of the farmer.

The following plants have been mentioned by farmers and academics to grow well in the System:

Timber trees:
- Hopea odorata
- Shorea roxburghi
- Dipterocarpus alatus
- Eagle wood (Agarwood)
- Mesua ferea

Other trees and palms:
- Gnetum (seeds, rope and paper production, food and juice)
- Caryota urens (palm whine and palm sugar)
- Syzygium grande
- Bamboo (used for charcoal production),
- Hookers Fishtail Palm
- Garcinia merguensis
- Michelia champaca

Herbs and Shrubs:
- Tongat Ali/Long Jack (Eurocoma longifolia Jack) (powder for traditional medicine)
- Misai Kucing (Orthosipon aristatus)
- Hempedu Bumi (Adrographis paniculate)
- Kacip Fatimah (Labisia pumila)

A big advantage of this system is that it does not have to be set out from the beginning but can be **gradually adopted into already existing monoculture plots**, setting the threshold for small farmers quite low. Farmers can try to integrate new plants by trial and error and benefit from exchange with other colleagues about their experiences and knowledge. The appearance of the RAF-System depends on the individual choice and practice of the farmer and can highly vary between different plots. It is rather a model for smallholders than for large plantations. The economic benefits for smaller farmers can be promising, if low rubber prices can be compensated by the selling of timber and other non-rubber products.

The **ecological benefits** from this system are **tremendous**. A **favorable micro climate** and high decomposition rates resemble the nutrition cycle of a natural forest and create a lot of organic matter and a **healthy soil** that is **protected against erosion** through a dense canopy and complex route system. Moreover, Rubber Forest Gardens have a **high biodiversity value** as many different trees, palms, plants and shrubs create a complex ecosystem and habitat for insects, birds and other small animals (Kittitornkool et al. 2018).

Planting, maintenance an undergrowth management

It is generally recommended to **start with the planting of fruit and timber trees 2 to 5 years after the rubber** to avoid that they overgrow and shade the rubber trees. Smaller shade tolerable plants and herbs such as Salak, Cacao or Tongkat Ali should be planted after the larger trees have developed a canopy.

From an ecological perspective the natural undergrowth is beneficial as it increases biodiversity and creates a favorable environment for animals, especially for insects. However, particularly in the first years after planting, **fast growing vegetation can disturb and overgrow the rubber saplings**, hampering them from developing properly. A study conducted in Indonesia shows that a higher weeding intensity inside the rubber rows (two meter strip) had a positive effect on tree growth (Joshi et al. 2006). Therefore, for the first years it is **recommended to keep a two-meter strip** alongside the rubber rows **free from spontaneous vegetation**, while **the interrow space can be used to plant annual food crops,** as it is already practiced by many smallholders. Legumes can be a good alternative, but their maintenance requires a lot of labor and is more suitable for plantations than for smallholders. **After the canopy** of the rubber, fruit and timber trees **has closed**, **weeding intensity can be reduced to a minimum** as most of the aggressive spontaneous vegetation is prevented by the lack of sunlight. This is particularly the case for Rubber Forest Gardens with a dense multi-level canopy. In avenue systems manual weeding with a string trimmer can help to reduce the undergrowth to an acceptable height.

6. Conclusion

RAF can play an **important role** in a **fairstainable transformation of the rubber sector** providing several environmental and economic advantages over monoculture. From an ecological perspective RAF offer the unique possibility to overcome the dichotomy between conservation zones and intensive agriculture **combining conservation aspects with economic viability on the same piece of land.** In regions where the transformation of forests into agricultural land is more the less inevitable or has already taken place, the introduction of RAF-Systems could **help to diversify the landscape, restore ecosystem services** and help to **prevent soil erosion, landslides and flooding**. In a context where remaining forests become rare, RAF could – at least to a certain degree – help to **conserve biodiversity**. Particularly jungle rubber and rubber forest gardens can serve as habitats for birds, insects, reptiles and small mammals and function as **wildlife corridors** that connect remaining patches of forest.

Smallholders could profit from **diversified income sources** through timber and other non-rubber products and make themselves more resilient against fluctuating rubber prices. Trial plantings have shown that RAF can have a **good economic performance** if farmers use high quality clonal seedlings, combine the right species and are able to maintain and manage the plot well.

Economic viability is crucial for the future dissemination of RAF. Fairstainable business that seeks to promote RAF should:

- **Support local academic research and collaboration between peasant cooperatives, universities, state institutions and businesses to foster knowledge generation and transmission among all stakeholders**
- **Provide high yielding rubber clones and quality timber tree seedlings/saplings to farmers**
- **Implement a premium price structure that allocates an additional value to rubber that is produced in RAF-Systems that provide ecosystem recovery**
- **Built up new supply chains/help to increase market access for certified rubber and non-rubber products such as charcoal maid from bamboo, honey or herbal products.**

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