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Socioeconomic and Ecological Impact Analysis of Rubber Cultivation in Southeast Asia

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Abstract

In this paper, we aimed at examining the role of natural rubber (*Hevea brasiliensis*) cultivation as a source of income for rural communities as well as a potential source of ecological damage. We reviewed existing scientific literature and data sources on natural rubber cultivation particularly in south East Asia. We observed that, the latex from the lower part of the trunk has a high commercial value which can assist rural communities in socioeconomic development; the trunk is a source of timber and wood while its branches are now being used for firewood and pegs. We also found out that, rubber cultivation harms watersheds and destroys tropical forest ecosystems. Nevertheless, the cultivation and establishment of rubber plantations would have a very positive socioecological impact with adequate and effective management and proper sustainable planning as well as an involvement of rural communities in the decision making process.

Keywords

Natural Rubber, Income, Livelihood, Rural Communities, Southeast Asia, *Hevea brasiliensis*

Subject Areas: Agricultural Science, Anthropology, Biodiversity, Biogeography, Conservation Biology, Ecology, Economics, Ecosystem Science, Environmental Sciences, Human Geography, Natural Geography, Plant Science

1. Introduction

Poverty is more than the lack of income and resources to ensure a sustainable livelihood. Its manifestations in-

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clude hunger and malnutrition, limited access to education and other basic services, social discrimination and exclusion as well as the lack of participation in decision-making [1]. Economic growth must be inclusive to provide sustainable jobs and promote equality [2]-[4].

According to [3]-[5], globally, about 836 million people still live in extreme poverty. Though extreme poverty rates have been cut by more than half since 1990, one in five people in developing regions still live on less than $1.25 a day, and there are millions more who make little more than this daily amount, plus many people risk slipping back into poverty [3]-[6]. The overwhelming majority of these people are in South Asia and sub-Saharan Africa especially in small, fragile and conflict-affected countries [3] [6].

In its regional forecasts for 2015, [4] asserted that poverty in East Asia and the Pacific would fall to 4.1 per cent of its population, down from 7.2 per cent in 2012; Latin America and the Caribbean would fall to 5.6 per cent from 6.2 in 2012; South Asia would fall to 13.5 per cent in 2015, compared to 18.8 per cent in 2012; Sub-Saharan Africa declines to 35.2 per cent in 2015, compared to 42.6 per cent in 2012, **Figure 1** [4].

Similarly [7] [8] observed that, poverty alleviation strategies and sustainable development plans especially in rural communities, have become major challenges for many governments worldwide [1]. Hence for many countries especially in Southeast Asia, natural rubber (*Hevea brasiliensis*) cultivation in extensive plantations, has been advocated as a means to alleviate poverty and foster rural development [9] [10]. Studies by [10]-[12] showed that, in Laos for instance, areas planted with rubber will skyrocket from approximately 27,000 ha in 2007 to 195,000 ha in 2010, as a result of foreign direct investments (FDIs) from China and Viet Nam. Additionally, [9] [10] predict that, the area of land dedicated to rubber and other farming systems could more than double or triple by 2050, replacing lands currently occupied by evergreen broadleaf trees and secondary vegetation growing in areas subjected to slash-and-burn farming.

Over the last decade, rubber cultivation has expanded rapidly throughout South-East Asia in order to meet demand for natural rubber, especially in expanding economies such as China and India [12] [13]. And as global

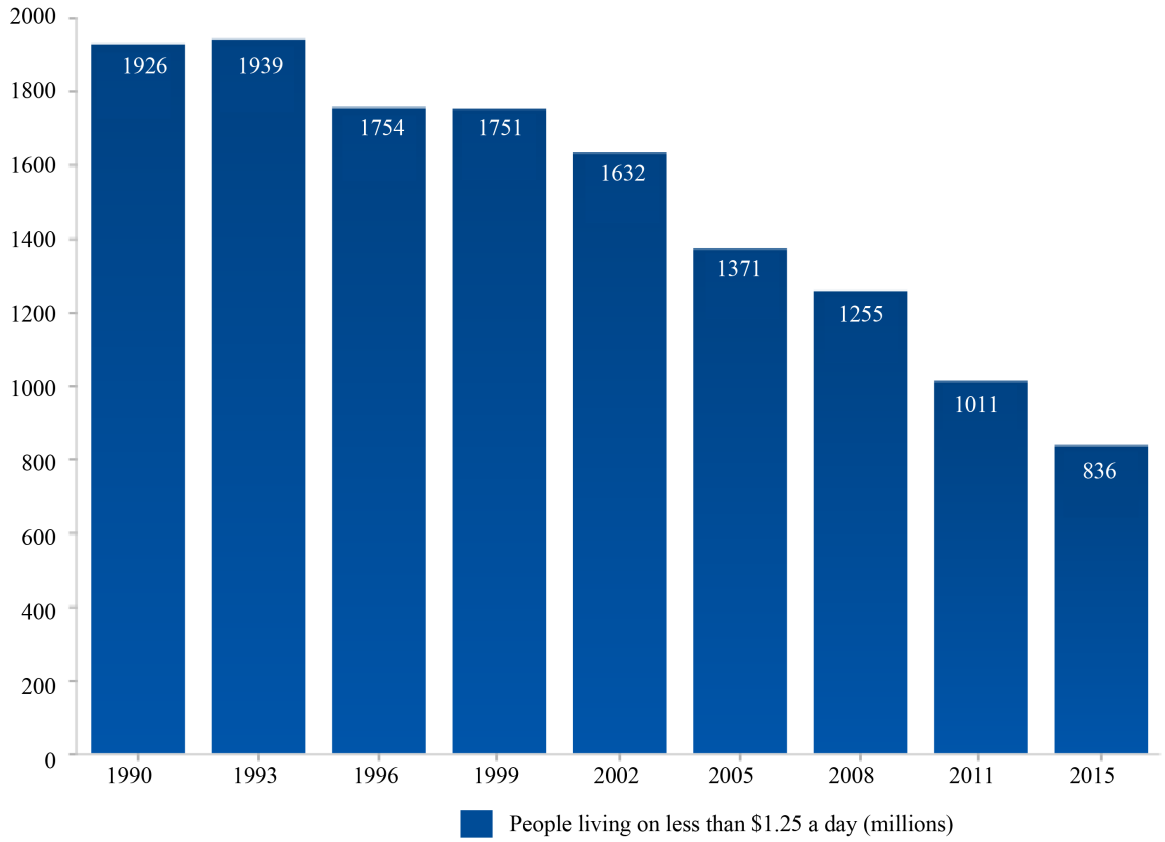

Figure 1. Number of people living on less than $1.25 a day worldwide, 1990-2015 (millions). Source: The millennium development goals report 2015.

natural rubber prices continue to rise, increasing amounts of environmentally valuable and protected lands are being cleared for rubber plantations that are economically unsustainable [14]. This financial incentive, has caused rubber plantations to expand beyond their tropical comfort zone in Indonesia and into the margins of continental Southeast Asia [12] [14] [15]. More than 500,000 hectares, may have already been converted to rubber plantations in the uplands of China, Thailand, Vietnam, Laos, Cambodia and Myanmar [10] [14]. Largely fuelled by increased demand for raw rubber (*Hevea brasiliensis*) latex in India and especially China mainland Southeast Asia has recently experienced a "rubber boom" [16] [17]. While there was a huge expansion of rubber in southern Thailand and Peninsular Malaysia in the 1970s and 1980s, most recently rubber planting has mainly targeted previously peripheral and remote parts of the region, such as rural and upland areas in China, Cambodia, Myanmar, Thailand, Vietnam and Laos [12] [18]-[20]. According to the International Rubber Study Group, the annual production for 2014 in SE Asia stood at 11,183,000 tons for a world average of 12,070,000 tons [21], **Figure 2**. According to this study, world demand for natural rubber is forecast to increase by 3.1% in 2015 under the IMF Scenario and by 4.4% in 2016 [21]. In 2000, a total of around 6.8 million metric tons of natural rubber were produced globally and which increased to more than 12.2 million metric tons in 2013, **Figure 2**.

Asia continues to dominate the world supply of natural rubber, with 93% of total world production in 2013. The three largest countries producing natural rubber in 2013 were Thailand, Indonesia and Vietnam. Thailand has been the world's largest producer of natural rubber since 1993, accounting for 34% of world production in 2013, with Indonesia accounting for 26% while Vietnam is the third-largest producer [22]. Malaysia, which accounted for 32% of world production in 1988, has shifted its emphasis to other crops and nonagricultural investments and produced only 6.9% of the world total by 2013 [22].

The shift toward radial tires, which use a higher percentage of natural rubber than bias-ply tires, has resulted in an increase in natural rubber consumption over the past 35 years. Natural rubber accounted for about 30% of total world consumption of rubber in 1981; the share increased to about 42% in 2013. Increased rubber consumption in the natural rubber-producing countries has also been a factor, as well as the greatly increasing demand for natural rubber in China and India. World consumption of natural rubber declined by 8% in 2009, as a result of the economic downturn, but quickly recovered in 2010. Growth since then has been about 1% - 2% per year, although there has been a slowdown in 2013-2014 [22]. China continues to be the largest consumer of natural rubber in the world, accounting for nearly 37% of world consumption of natural rubber using about 80% of

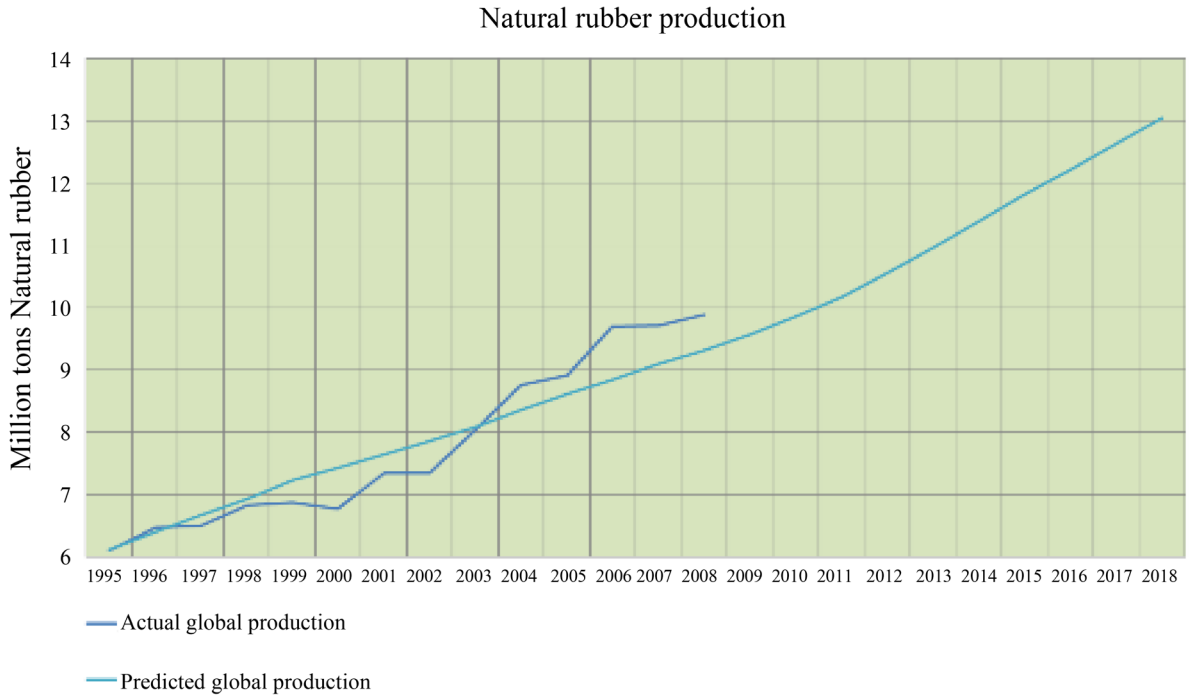

Figure 2. Global and predicted production of natural rubber up to 2018. Sourced from http://2013.igem.org/Team:SDU-Denmark/Tour21.

its natural rubber for tire manufacture. Growth in natural rubber consumption will be highly uneven among the major regions of the world during 2013-2018. Developed regions (the United States, Western Europe and Japan) will grow at less than 1% per year, while developing regions in South America and Asia will grow at 3% - 5% per year. For 2013 through 2018, an average annual increase in global consumption of natural rubber of about 3.7% per year is forecast, **Figures 2-4** [22].

Natural rubber plays an important role in economic growth and sustainable development of a country. The tree also serves as a source of timber, fuel and shade-tree on many farms. It is thus important in farm management

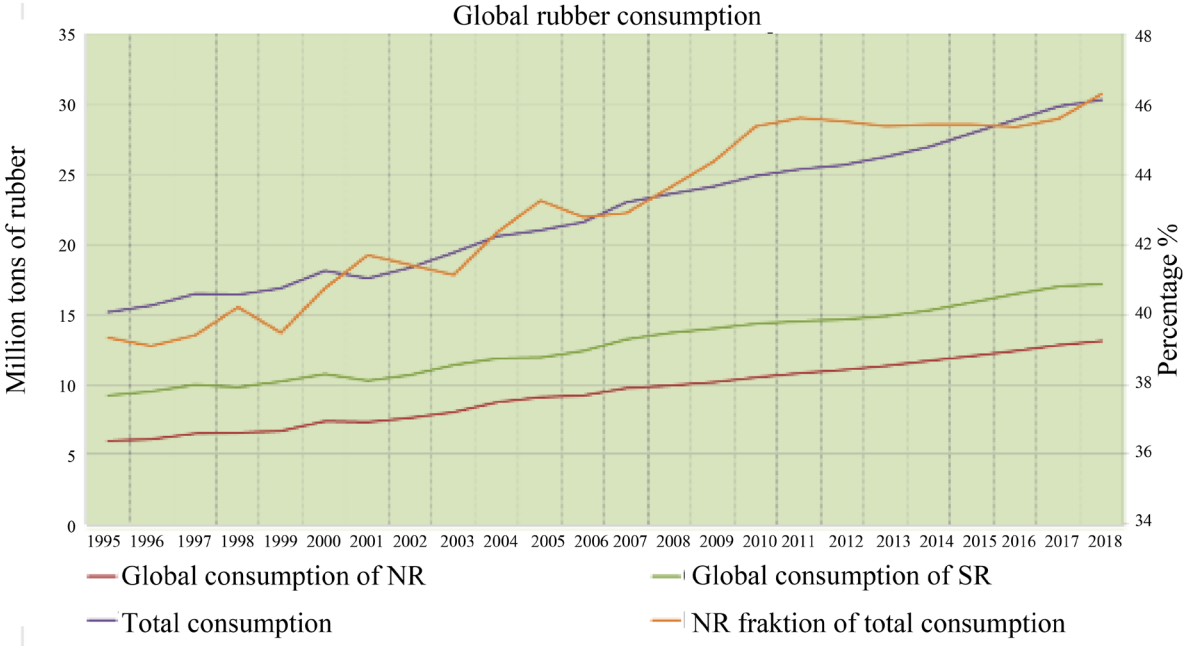

Figure 3. Global and predicted consumption of natural rubber (NR) and sustainable rubber (SR) up to 2018. Sourced from http://2013.igem.org/Team:SDU-Denmark/Tour21.

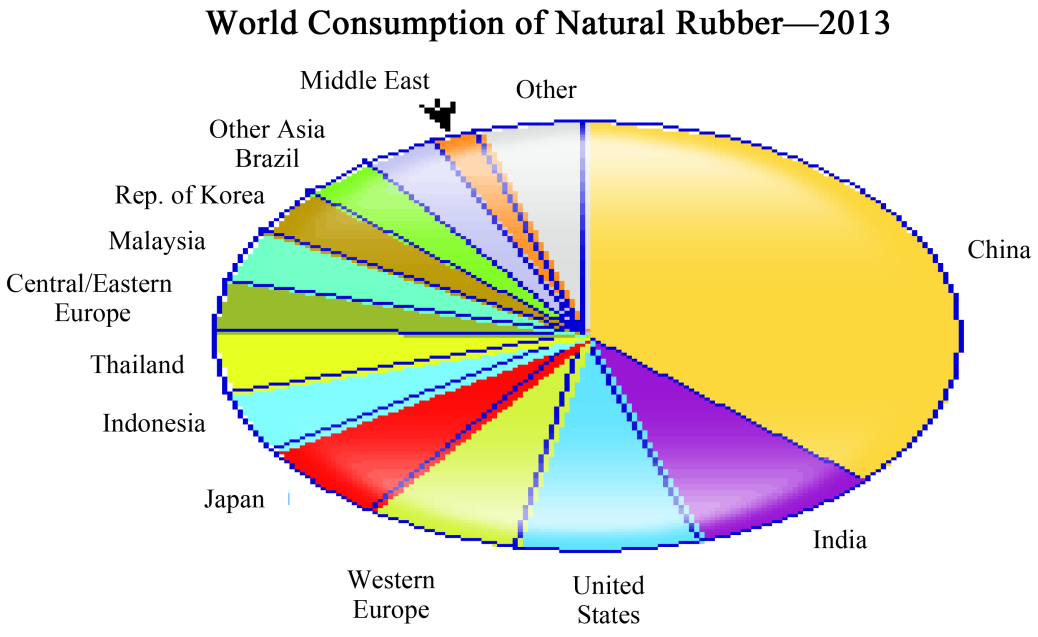

Figure 4. World consumption of natural rubber, 2013. Sourced from IHS, 2014.

and poverty alleviation for rural communities [12] [23]. Indigenous peoples living at low population densities in and around many tropical forests especially in the Brazilian Amazon, are known to have been using rubber for centuries, practicing sustainable harvesting and utilization of this resources compatible with conservation [24]. However, with recent boom in prices and increase in both local and international demand, establishment of massive rubber plantations have been undertaken globally. This has exerted more pressure on available forests, contaminated lands and water resources as well as disrupted biological cycles [14].

In this study, we carry-out a literature survey to assess how the establishment and cultivation of rubber plantations, could help improve on the livelihoods of rural communities while assessing its ecological impacts. We assume that, with adequate and effective management and proper sustainable planning, rubber cultivation would be a way of breaking the poverty nexus and ecological impacts that arise. The paper has been divided into four sections, with the first looking at the biophysical characteristics of rubber, here we describe the rubber tree and give its natural potentials. The second section looks at the social and economic advantages/potentials of rubber cultivation. In the third section, we explore the probable ecological potentials of rubber cultivation and in the fourth section, we analyze the probable socioeconomic and ecological impacts that arise from the cultivation and establishment of natural rubber plantations. We then conclude that, the cultivation and establishment of rubber plantations would have a very positive socioecological impact with adequate and effective management and proper sustainable planning as well as an involvement of rural communities in the decision making process.

2. Biophysical Characteristics of Rubber

Many plant species are known to produce natural rubber but due to quality and economic considerations, the source of natural rubber is limited to *Hevea brasiliensis* [25]. *Hevea brasiliensis*, is a tropical plant species native of the Amazon basin and introduced from there to countries in the tropical belts of Asia and Africa during late 19th century [24] [25]. This is often referred to as the most far reaching and successful of introductions in plant history resulting in plantations over 9.3 million hectares, 95% of it across the globe in Asia [25]. The rubber tree, has a straight trunk and thick, somewhat soft, light brownish gray bark and belongs to the family Euphorbiaceae. It can sometimes attain a height of about 30 m especially when in the wild [26] [27].

The young plant shows characteristic growth pattern of alternating period of rapid elongation and consolidated development with trifoliate leaves and long stalks. The tree is deciduous in habit and winters from December to February with quick refoliation and copious flowering there after [25]. The economic life period of rubber trees in plantations is around 32 years; up to 7 years of immature phase and about 25 years of productive phase. Optimal growth conditions include an annual rainfall of about 2500mm, monthly mean temperature range of 25 to 28˚C, well-drained laterite, sedimentary and non-lateritic red or alluvial soils [26] [27]. However, some Chinese clones have excellent drought-resistance and can be grown successfully even where the rainfall is below 1000 mm [28]. Though recently many high-yielding clones have been developed for commercial planting, natural rubber still remains the most economically important member of the genus *Hevea*. This is due to the fact that, the extracted milky latex, is the primary source of natural rubber [20] [22]. Moreso, the tree grows well under cultivation and a properly managed tree responds to wounding by producing more latex for several years [20] [29].

Latex is a gummy white liquid full of minute globules occurring in special cells or in a series of special vessels, which permeate the bark, leaves, and other soft parts of the tree. It consists of a mixture of water, hydrocarbons, resins, oils, proteins, acids, salts, sugar and caoutchouc, the substance used as the source of rubber [28]. The significance of latex to the plant is obscure, but it is known to be of some value in the healing of wounds, and it may serve for protection, nutrition, and the transport of materials or as a fluid reservoir. Usually only the latex from the lower part of the trunk is of importance commercially, although trunks and branches are now being used for firewood and pegs [24] [27].

3. Social, Economic and Ecological Impacts of Rubber Cultivation

3.1. Social and Economic Impacts

This agricultural transition from subsistence production based on shifting cultivation to commercial production based on tree crops, are typically smallholder schemes, covering a few hectares per family, and combine private investments, government issued economic land concessions, sharecropping, and contract farming in various

ways [20] [29].

Laos for instance, has seen a dramatic increase in rubber cultivation and tapping beginning from the mid-1990s and especially since the mid-2000s, as hundreds of thousands of hectares of mainly forest lands and former swidden fields have been converted into monoculture rubber plantations [17] [30] [31]. However, the development of rubber in Laos, when considered at the national scale is very complex, with many different small farmer initiatives, aid agency supported development projects, and especially Foreign Direct Investment (FDI) arrangements being initiated [9] [32]. For example, in Hat Nyao Village in Luang Nam Tha Province, small holder farming families have the potential to benefit economically from the development of small-scale rubber plantations [16] [20]. It is therefore seen as a tool for eradicating opium production in northern Laos, and more generally for decreasing swidden agriculture throughout hilly and mountainous parts of the country [17] [19].

The bulk of dry natural rubber produced in the world is used in tyres, especially those which call for high performance notably tyres for aircraft and for trucks. It is the ability of natural rubber to dissipate heat that makes tyres containing it so much safer than tyres made entirely with synthetic rubber. Between 60% and 70% of natural rubber used in the United States is used in this way [30]. In addition to tyres, a modern car has more than 300 components in which natural rubber is incorporated and the weight of rubber in a modern car is over 100 kg in tyres, mountings, seals, carpets, hoses, fan belts, grommets, adhesives and coatings. In industry, rubber is used in conveyor and drive belts, hoses, lining for tanks, for insulation and for shock absorption [30].

Latex is used in thousands of products, from gloves to condoms, it is indispensable in transportation, in communication, in furnishing us with power and light, in cushioning our bodies and protecting our senses from the jars and jolts, the noise and tumult of modern life [11] [32] [33]. Latex from natural rubber provides essential parts of garden products, sports equipment and the ball in many games, and in weatherproofing garments. In the home, latex from natural rubber exists in flooring and underlay for carpets, for suspension in chairs, in foam mattresses and in cushions. Industry today makes countless different articles that incorporate rubber and the number is increasing every day. Natural rubber is also widely used in soil stabilization, in vibration absorption and in road surfacing [30].

Rubber wood, particularly branches and damaged trunks, is often used as fuel in wood-burning dryers and smokehouses. A hectare of cleared plantation will provide about 300 m^3 of wood from felled seedling trees and about 150 m^3 from felled bud-grafted trees [30]. For a 100 ha rubber plantation yielding 100 tons of rubber *per annum*, the expected fuelwood requirement to make Ribbed Smoked Sheets (RSS; *are coagulated rubber sheets processed from fresh field latex sourced from well managed rubber plantations adopting modern processing methods*), would be 150 - 200 m^3 *per annum*. This can be obtained from 50 - 75 ha of felled seedling trees or 100 - 150 ha of felled bud-grafted trees. Where progressive and continuous replanting is carried out, it should be possible to meet fuelwood requirements from felled trees. Some estates allocate an easily-accessible area as a fuelwood reserve, so that when no wood is available from felled trees, this area can be harvested rather than incurring the cost of collecting sufficient fuelwood from scattered trees [30] [34]. Malaysia has been promoting the development of its downstream rubber wood industry, and has the most diversified rubber wood industry, with various types of wood-based panel plants and furniture mills.

In India for instance, a rubber tree from small holdings will have about 0.57 m^3 of timber and per hectare yield is about 150 m^3. At present, the total availability of rubber wood is estimated as 0.94 million·m^3/yr and it is estimated to be 1.5 m^3/year by 2020 [34]. The wood from a rubber tree is moderately hard with an insignificant amount of heartwood, and it can be used either directly as timber, useful for making furniture or to make plywood. Thus rubber wood helps to reduce the pressure on forests for timber and firewood and thus leads to "indirect sequestration of carbon" [11] [32] [33].

In Thailand, rubber has been exploited since the 1990s as a source of timber and fuel wood. Here, potential saw log and sawn wood availability increased from 2.8 million·m^3 to 4.18 million·m^3 and 0.84 million·m^3 to 1.25 million·m^3 from 1997 to 2012, respectively [23] [35]. The Thai government posits that the cultivation of rubber, which is a perennial plant, would help revive the degraded environment of the region due to the massive cultivation of short-lived cash crops for over 50 years [23] [35]. Hence, government supported research, has generated new rubber varieties which are suitable for the climate and land of the country. This plus the decrease of cassava price has pushed many farmers in the region to start growing rubber and making Thailand, the world's largest producer and exporter of natural rubber [23] [35]. In India, rubber plantations have been identified as a source of honey since 1920's though organised commercial exploitation is relatively recent [36]. The rubber tree is a prolific source of honey obtained from the extra floral nectaries at the tip of the petiole. The ho-

ney flow period is usually between the months of January and March [36]. Experimental trials have reported up to 19 kg of honey per hive per year for the popular Indian honey bee, *Apis cerana indica* compared to the reported average yield of 60 kg per hive per year for *Apis mellifera*. The estimated net income per hive per year during 1996-1998 was 15 USD (1000Rs) and 5 USD (350Rs) for *Apis mellifera* and *Apis cerana indica* respectively [36].

An estimated 10 million people regularly collect rubber, either as a full time job or as a major sideline to farming. The vast majority of these people live in south and Southeast Asia; Thailand, Indonesia, India, Malaysia and Sri Lanka, where most of the rubber produced in the world comes from [28]. In India, over a million households directly depend on natural rubber plantations for their livelihood with a greater number depending on natural rubber processing and product making sectors in the country. In many cases, smallholder families tap rubber as a sideline, tapping trees on their way to tilling their paddy fields and collecting the latex on their way home after a day working on food crops [11] [28] [32] [33].

3.2. Ecological Potentials of Rubber Cultivation

The honey bee species *Apis mellifera* is the most common species in the world while *Apis cerana indica* is an indigenous variety which is the most common species in the rubber plantations of India's Kerala and Tamil Nadu States [36]. *Apis mellifera* was introduced in India in the 1960's and was successfully reared in Himachal Pradesh, Haryana and Punjab States. In the rubber plantations, this species was introduced as a rehabilitation measure after the outbreak of Thai sacbrood disease in the early 1990's which almost completely destroyed the hives of *Apis cerana indica* [36].

According to [36], the carbon sequestration potential of natural rubber trees (of 7-9t C per ha per year or more) is much greater than most tree species commonly used in afforestation/reforestation programmes. Studies at the Rubber Research Institute of India (RRII) show that, a total area of about 0.5 m ha of natural rubber in India, will have about 3.5 to 4 mt C for sale in the Kyoto market every year which is 7% to 8% of the combined demand for carbon credit by Japan and the European Union (50 mt C per year) [36]. Considering that, the cost of sequestering C in developing countries is about 15USD per ton C (which will vary depending on the demand in the carbon market), therefore the rubber plantations in India alone have a potential market value of 105 to 120 USD per ha per year in the Kyoto carbon market. But this market can be tapped only if natural rubber plantation is explicitly included for carbon crediting under the Kyoto Protocol [25].

In the North Eastern States of India for example, natural rubber cultivation has greatly helped to reclaim ecosystems that were severely degraded due to intensive shifting cultivation practiced by the native tribes. Also, community-based natural rubber cultivation has helped these people to improve their standard of living and integrate with the main stream society [36]. Moreso, effluents produced during natural rubber processing, are now used to generate biogas which is used for domestic cooking purposes as well as for drying rubber. Use of biomass gasifiers and the possible use of solar thermal systems for drying rubber are examples of the use of non-conventional energy in the natural rubber processing sector. The use of non-conventional energy in the natural rubber processing sector, helps in "displacing" fossil based fuels which amounts to "indirect sequestration of carbon" and therefore qualify for CDM funding hence increase rural income.

It is absolutely clear from available data that, the carbon assimilation or sequestration capacity of natural rubber plantations, is much higher than most other similar terrestrial eco-systems. It is even more than that of most evergreen forests, mainly because of the fact that, considerable vegetative growth takes place in the case of rubber compared with virgin forests that are several decades or even centuries old and are not growing at a fast rate. The data provided in the **Table 1** substantiate this [36].

4. Socioeconomic and Ecological Impacts of Rubber Cultivation

According to [17], complete land disenfranchisement arise when foreign investors acquire land with rich soils for low state rents, often without having to appropriately compensate local people, let alone ensure that they significantly benefit from the investments. These plantations strip local resources away, leaving local people, most of who are ethnic minorities poorer and with fewer livelihood options than they had before. Agriculture chemicals negatively affect livestock consequently and dramatically reducing or diminishing village savings and safety nets. This is because rural people often rely on selling livestock during financial emergencies [17] [37]. According to [38], in Southeast Asia, livestock are the most important source of wealth identified by villagers. The

Table 1. Comparing carbon sequestration (tC/hectare/year) of various terrestrial ecosystems. Sourced from Rubber Board 2015. Higher carbon sequestration capacity in natural rubber.

Ecosystem	t/C/hectare/year
Tundra	0.1 - 0.3
European forests	0.4 - 0.6
Tropical South American Rainforest	0.71 ± 0.3
Amazon	1.02 ± 0.24
USA forest woodlands	1.4
Various temperate forests	2.5
Successional temperate deciduous forests of the USA	3.7 ± 0.3
Pine forests of USA	3.78 ± 0.16
Natural rubber plantations	7.82

reduction of livestock as a result of land concessions pressures has, thus, significantly contributed to increasing poverty amongst villagers. Many water bodies are being poisoned by herbicides (used against "weeds") and pesticides (used against termites) applied to plantations. Vegetation directly adjacent to water bodies has also been cleared and planted with rubber, with no buffer zones being established as required by the most environmental law. Spraying equipment has frequently been washed in the streams and nearby rivers [17] [37].

[37] [39] posit that, in northern Laos, environmental impacts associated with large-scale plantation development, including serious erosion, were already evident in areas affected by the Viet-Lao Rubber Company in late 2006. Overall, habitat and stream hydrology had been badly affected, resulting in dramatic declines in fish, crabs, shrimp, shellfish and turtles, and edible stream bank vegetation, thus negatively affecting local livelihoods and food security. Furthermore, [37] also observed that, erosion was damaging aquatic habitats and reducing villager fish catches. Villagers are also afraid to consume water from the streams, believing that doing so might negatively impact their health. Those who have stood in the water for long periods while fishing have experienced burning and severe peeling on their lower legs. [37] carried-out an assessment of the environmental and social impacts created by the VLRC Industrial Rubber Plantation which had no existing environmental and social plans. The study observed that, the 33 villages, populated by 12,644 people, affected by the Viet-Lao Rubber Company plantations had lost 83% of their agricultural land to rubber by the end of 2006. Of those, 18 villages were left with 10% or less of their agricultural lands, and of these villages, four had no agriculture land at all. Meanwhile, [24] found that, large rubber concessions have contributed to increasing poverty amongst poor groups living within the cultivated areas. The natural rubber tapper for example is very often at the bottom of the educational scale and many are women with high illiteracy as well as very low pay. Also, [24] observed that, child care and education are at their rudimentary best, living conditions are quite primitive and latex allergy awareness is extremely low or inexistent.

Similarly, [14] espoused that, rubber plantations establishment could result in a significant reduction in carbon biomass, desiccate the region's water systems, and increase the risk of landslides through erosion. Moreso, as marginal lands are often too dry, too slanted, too high, too wet, too cold and too windy, rubber plantations require increasing amounts of input in the form of fertilizer, pesticides, and labour in order to maintain yield levels. The research also suggests that climate change will render 70% of current and another 55% of future plantation areas environmentally poorly suited for rubber. Smallholder farmers' livelihoods face additional threat from price fluctuations, loss of food security, and the narrowing of income sources [40]. There is therefore a clear potential for loss-loss scenarios when forest is being cleared for rubber plantations that are not economically sustainable, and that have negative impacts on soils and water balance.

In Xishuangbanna Prefecture of China's Yunnan Province, each hectare of rubber plantation, loses an estimated 22.5 tons of soil per year to erosion, and a further 136.5 tons of water through shrinking groundwater tables [40]. Consequently, if there is no consideration of forest protection, then in the next 25 years Xishuangbanna is going to be much drier in the lowlands [40].

[38] studied poverty issues in the ethnic Ngkriang village of Ban Don in Bachiang District, Laos. He determined that, the village had become very poor as a result of losing almost all of their agricultural land to Viet-

namese rubber plantations. He also found that, there were apparently no compensations being provided, at least at the time of the study, in 2006. This he concluded, are clearly having a massive and rapid impact on landscapes and livelihoods in Laos. In the same trend, [41] observed that most of the conflicts in Northern Laos, have emerged between rubber plantation development and biodiversity protection inside Lao National Protected Areas.

[42], examined and emphasized the serious problems related to unequal sharing and distribution of revenue from rubber plantations in Sri Lanka as well as the non-handling of labour issues. The study observed that, rubber plantation did not give a reasonable production to be economically viable for tapping. Moreso, the production cost of crape rubber was very high, leaving only one third of the income as a profit which was unable to cover even the interest of the bank loan used in purchasing the land. The study further posits that, environmental problems stemming from intensive cultivation of rubber and other cash crops also affect other regions in Southeast Asia. This is because, farmers are transitioning into plantation monocultures and away from swidden, or slash-and-burn, agriculture. The problems linked to that shift include erosion, increased stream sedimentation, accelerated pesticide use, and declining water quality [40] [42].

Similarly, a study on rubber and oil palm expansion in Thailand found that, rubber plantations reduced biodiversity by at least 60 percent with insectivores and frugivores suffering greater losses than more omnivorous species [40] [43]. According to the study, of the 128 species recorded across all habitats, 84% were recorded in forest, and 60% were recorded only in that habitat. Of the 16 Globally Threatened or Near-Threatened species recorded in the study, 15 were recorded only in forest. Species occurring in plantations were significantly more widespread in Thailand than species recorded only in forests and had a tendency towards smaller body size. Species richness in plantations was unaffected by plantation age or distance from nearest forest edge, but was significantly greater where undergrowth was allowed to regenerate beneath the crop trees [43].

5. Conclusions

The cultivation and establishment of natural rubber plantations, is an income generating activity and good for the development of rural communities. Nonetheless, the spread of rubber plantations to supply global burgeoning demand, is destabilizing rural livelihoods, reinforcing the poverty nexus, harming watersheds, and destroying tropical forest ecosystems. Therefore, as many countries continue to encourage the development and establishment of rubber plantations, widespread monitoring of rubber expansion and its economic sustainability will prove vital for land-use planning and policy interventions. A carefully formulated payment for ecosystem services programmes, and a certification scheme for "environmentally friendly rubber" have potential to reduce the environmental impact of rubber expansion while ensuring the supply. Finally, though the current understanding of the social, economic and ecological impacts are still limited and certain gaps of information still exist in many countries, a wider involvement of stakeholders, governments and rural communities in the decision making process, would help bridge these knowledge gaps.

We also believe that, many countries should encourage more research into the ecological benefits and damages of rubber cultivation such as to better analyze its impact of rural communities. Moreso, the area of rubber cultivation and rural community conflicts, is a potential source of further research that can be explored by researchers.

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