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Expanding Rubber Plantation Degrades Biodiversity and Worsen Local Environment

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ABSTRACT

The rapid growth of rubber plantations in India exacerbates traditional agriculture and degrades biodiversity. Rubber is a cash crop, earns a remarkable income for the farmer and boosts the economy in the world market. The North Eastern states of India produce rubber successfully due to favorable atmosphere and climatic conditions. This region occupies a large area of natural forest and a hotspot of biodiversity. In the recent past, people shifted their occupation to rubber plantations by sacrificing forests and biodiversity. A case study in South Tripura, N-E state of India, highlighted the story behind environmental degradation through rubber plantations. A Likert scale analysis followed by a logistic regression tried to find out the negative impact of rubber plantations.

Keywords Rubber plantation, Deforestation, Environmental degradation, Likert analysis, Logistic regression.

INTRODUCTION

Rubber (*Hevea brasiliensis*, family: *Euphorbiaceae*), a native tree species to Amazon forests, has been successfully introduced as a cash crop in many developing countries, especially in Southeast Asia. Rubber cultivation has been so successful that whereas Southeast Asia produced just 1% of the world's rubber in 1906, it produced more than 75% just 15 years later. India, Thailand, Indonesia, Malaysia, and China are the most rubber-producing countries in South Asia. Apart from the traditional rubber-growing region of India (Kerala), the extension of rubber cultivation to the northeastern region of India was meant to satisfy the ever-growing domestic demand for natural rubber and to rehabilitate the tribal communities practising shifting cultivation. Nonjudicial land-use patterns and extensive rubber cultivation have some adverse effects on the forest ecosystems as well as agroecosystems associated with the cultivation regime.

Rubber is an economic crop and the demand for natural rubber is growing worldwide. It generates income and employment high as compared to other economic crops. The export of natural rubber can boost an economy by earning foreign exchange

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Table 1. Largest rubber producer in the world in 2019-20 (Thousand Tons).

	Production
Thailand	4839.952
Indonesia	3448.782
Vietnam	1185.157
India	1001.405
China	839.909
Cote d'Ivoire	664.695
Malayesia	639.83
Philippines	431.675
Guatemala	350.501
Mayanmar	264.943

Source: FAODATA. (2020).

reserves. Rubber plant needs 8 to 10 years to mature and thereafter the latex can be collected. India is the 4th largest natural rubber producer in the world (Table 1). The state Tripura stands second position in rubber production in India after Kerala (Table 2). The geographical advantages grow rubber plantations rapidly in the state of Tripura. The state has huge biodiversity in flora and fauna. More than 70% of the land was covered by natural forest. People used to cultivate crops in the steps of natural hilly areas. Bamboo and tea were the two indigenous plantations since a long time ago. Once the rubber plantation started, the people suddenly shifted their pattern of cultivation towards rubber and lots of natural forests, bamboo gardens, tea gardens and other cropping land has been converted to rubber plantations. As a result, the economic condition has changed rapidly but the natural environment and biodiversity becomes degraded. Production of each form of natural rubber causes many environmental impacts, including air, water, and soil.

Rubber can grow on many soils, the best options being well drained clayey and deep clay soils. But it can withstand physical conditions ranging from stiff clay with poor drainage to well drained sandy loam. Soil water retention capacity, depth and soil moisture are important factors determining the suitability of a growing site. Ground covering plants can help improving the soil physical properties. An optimal soil pH value for rubber is at 5-6. The performance of the tree can be restricted where there is rocky surface, heavy drainage or soil pH values above 6.5 or below 4. Intensive rubber growing areas can become vulnerable to soil nutrient loss and erosion that result from ground preparation and clear-cutting. Growing rubber together with agricultural crops could be the best way to decrease these environmental impacts.

Table 2. Percentage of rubber production in states of India in 2019-20.

	2010-11	2017-18	2019-20
Kerala	89.4	77.8	74.9
Tripura	4.78	7.27	8.7
Others State	5.82	14.93	16.4

Source: Rubber Board of India. (2023).

In a study by Zhou *et al*. (2016) in Yunnan Province, China, it has been observed that Nitrogen fertilization has a significant influence on N_2O dynamics and contributes to high N_2O fluxes. The results of their study show that the N_2O flux was higher from the fertilized rubber plantation than from the unfertilized rubber plantation. The fertilized trench plot was a hot spot of N_2O emissions from which the emissions were significantly higher than from the slope and terrace plots.

Brahma *et al*. (2016) more than 80% of vegetation organic carbon is stored the above-ground and the expansion of Rubber plantations can offer ecological stability over the increasingly practised traditional slash-and-burn agricultural system in NE India, concurrently uplifting the socio-economic conditions of local people through generating income stream from carbon trading.

Sdoodee and Rongsawat (2012) investigated the impact of climate change on smallholders' rubber production in Songkhla province, southern Thailand. They analyzed means of rainfall, rainy days, sunshine, tapping days and latex yield during 2008-2010 and compared using Duncan's multiple range test at the 5% level of significance. They found that temperature and average rainfall has increased during 30 years due to rapid rubber plantation. Golbon *et al*. (2018) applied rule-based classifications to a selection of nine gridded climatic data projections. These projections were used to form an ensemble model set covering the representative concentration pathways (RCPs)

4.5 and 8.5 of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change at three future time sections: 2030, 2050 and 2070. Almost the entire shift projected with high certainty was in the form of expansion, associated with temperature components of climate and temporally limited to the 2030 time window where the total area conducive to rubber cultivation in the GMS is projected to exceed 50% by 2030.

The findings of Ahrends *et al*. (2015) show that rubber is increasingly planted into marginal environments where there is a risk of unsustainability. Given this trend there is an urgent need for systematic and region wide monitoring to quantify plantation losses and impacts on ecosystem services caused by the expansion into marginal environments to underpin the formulation of appropriate policy interventions that limit environmental and societal impacts. Although rubber at current price levels produces lucrative yields in many marginal areas and there is frequently a lack of better alternative crops, policy interventions and greater awareness are needed given that rubber prices are volatile and cash crops such as rubber are currently the main drivers of forest loss in continental SE Asia. Their analysis highlight a clear potential for loss-loss scenarios, such as the clearing of high-biodiversity value land for a crop that is poorly adapted to local conditions and, by altering landscape function whilst not producing long-term sustainable yields, may ultimately also compromise livelihoods.

Bhumiratana *et al.* (2013) discussed apparent issues pertaining to the connections between rubber plantations and the populations at high risk for malaria. They addressed the issues like the current and future consequences of rubber plantations in Thailand and Southeast Asia relative to malaria epidemics or outbreaks of other vector-borne diseases, to what extent is malaria transmission in Thailand related to the forest versus rubber plantations, and what are the vulnerabilities of rubber agricultural workers to malaria, and how contagious is malaria in these areas.

Objectives, Methodology and data source

The main objective of the present work is to analyze the impact of rubber plantations on the local environment. How far the rapid growth of rubber cultivation changes the local climate and degrades the environment? Here deforestation, soil contamination, water pollution, change in animal inhabitants, change in seasonal atmosphere, and biodiversity loss are the basic parameters of environmental degradation.

A primary survey has been conducted on rural households in South Tripura to collect information on rubber production. A five-point Likert scale has been applied to get information on some environmental parameters. One-way ANOVA has been used to find out the reliability of the parameters. 299 people have been asked some important qualitative questions. A composite environmental score has been calculated from the qualitative questions. After that, a normal regression and a logistic regression have been run to test our hypothesis.

Hypothesis 1 : The consequences of environmental changes have not been observed significantly by different age group, education level and gender.

$$(likert\_score)_i = \alpha+\beta_1 (age)_i +\beta_2 (edu)_i + \beta_3 (gender)_i + u_i \;\dots\; \dots\; \dots \quad (1)$$

Hypothesis 2: There is no significant marginal effect on pollution level by age, gender and education level.

$$p_i = \frac{1}{1+e^{-z_i}} \quad \dots \; \dots \quad (2)$$

'p' is the probability of observation of i^{th} individual about pollution level.

$$\text{Where, } Z_i = \alpha + \beta x_i \quad \dots \; \dots \quad (3)$$

$$\frac{p_i}{1-p_i} = e^{z_i}$$

$$log\left(\frac{p_i}{1-p_i}\right) = z_i = \alpha + \beta x_i + u_i \quad \dots \; \dots \quad (4)$$

Where $\left(\frac{p_i}{1-p_i}\right)$ is odds ratio.

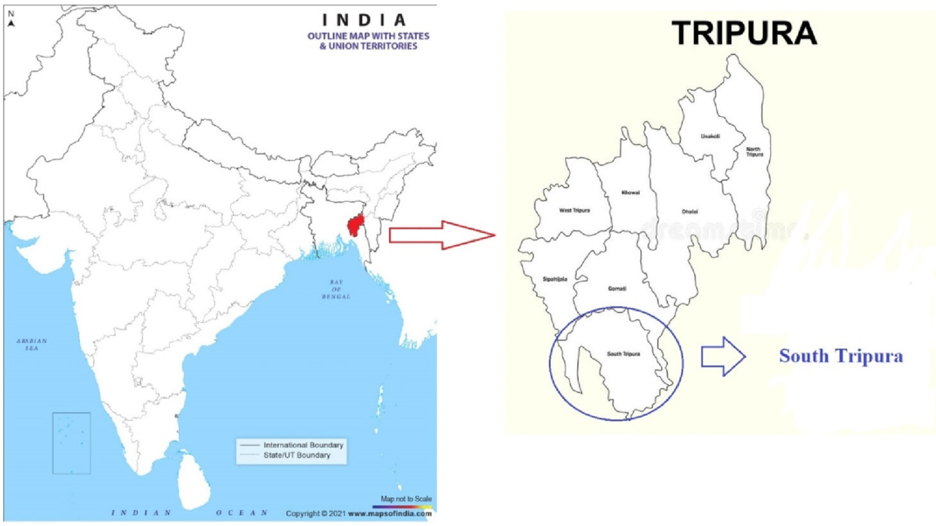

Fig. 1. Map of South Tripura, blue colored circle is survey area.

$$\text{Marginal effect} = \frac{dy}{dx} = \frac{dp_i}{dx_i}\,\hat{\beta}_i \times \hat{p}_i\,(1 - \hat{p}_i)$$

The case study area

South Tripura is a district of Tripura with three subdivisions namely Belonia, Sabroom, and Santirbazar. The total area covered by this district is 2152 sq km. The total population in 2011 (last census) was 875144 and the density of the population was 740 per sq km. The geographical position is 23032/N 91029/E and the average rainfall is 1924.2 mm and the temperature is 35.230C (max) and 7.430C (min). The study area covered 11 villages of South Tripura namely Chatakchari, East Jalefa, East Ludhua, Garifa, Guachand, Magurchara, Purba Harina, Rupaichari, Sabroom, Sonaichari, and V K Pally (Fig. 1).

RESULTS AND DISCUSSION

Rubber tree is originally from the tropical rain forest. It normally grows with the temperature range between 22 -35°C. The Table 3 shows area of total land holding and total land under rubber plantation. The local people measure their land by their own unit named 'Kani' (6 kani = 1 ha approximately). In South Tripura, government itself has vast area under rubber plantation. Government started rubber plantation in this region since 1980s and total area covered by government plantation is 700 ha (4200 kani) approximately. The Table 4 shows the area which are converted into rubber plantation. In the surveyed area 57% of natural forest area has been deforested and 33% area under bamboo garden has been shifted to rubber plantation. Among the total land more than 80% is engaged in rubber plantation. A very few land are used to traditional crop cultivation. The irrigation facility during whole year is very low. Rice is cultivated once in a year during monsoon season and rest of the time the land remains uncultivated due to lack of irrigation. During winter season the villages produces some vegetables, potato and wheat but the intensity is very low.

In Tripura, rubber plants were introduced for soil and moisture conservation by Forest Department in 1963. Rubber is a tropical crop and grows well in Tripura. The following Table 5 shows the total area and production trend of rubber plantations in Tripura from 2004-05 to 2019-20. It is noticeable that during the last 10 years, the total area has increased more than double the rate and the production rate has grown more than 2.5 times during the last few years.

Table 3. Total land holding and total land under rubber plantation.

Village	No. of house-hold	Rubber planted land (acre)	Other crop land (acre)	Total land (acre)
Chatakchari	6	47.77	6.18	53.95
East Jalefa	19	64.66	23.89	88.55
East Ludhua	7	21.42	4.53	25.95
Garifa	14	68.37	21.42	89.78
Guachand	4	10.71	4.12	14.83
Magurchara	10	26.36	11.53	37.89
Purba Harina	6	15.24	7.82	23.06
Rupaichari	6	19.36	4.12	23.47
Sabroom	14	256.99	20.59	277.58
Sonaichari	10	28.83	13.18	42.01
V K pally	10	31.30	6.59	37.89
All village	106	590.99	123.96	714.96
Govt.		1730 acre		

Source: Primary Survey.

Deforestation

In the surveyed area several types of negative impacts of the rubber plantations on forest resources as well as local environment have been identified. All the natural forests, bamboo gardens, *jhum* cultivation and farmland have been converted to rubber plantations. Table 4 shows that the area of forest has been converted into a rubber plantation. The total land under rubber plantation for all villages in the surveyed area is 590.99 acre excluding government plantation. Out of this land 337.71-acre lands (57%) were natural forest and deforested during the last 20 years. Not only that 33% of the land (196.45 acres) was converted from bamboo gardens or fruit gardens to rubber plantations.

Table 4. Land used before rubber plantation (Land diversification).

Village	*Jhum* culti-vation	Fallow land (acre)	Natural forest (acre)	Bamboo garden (acre)	Total land (rubber plantation) (acre)
Chatakchari	11.12	0.00	23.47	13.18	47.77
East Jalefa	5.35	2.88	43.24	13.18	64.66
East Ludhua	4.12	0.00	13.18	4.12	21.42
Garifa	8.24	1.24	39.95	18.94	68.37
Guachand	1.24	0.00	7.41	2.06	10.71
Magurchara	4.12	0.00	15.65	6.59	26.36
Purba Harina	0.00	0.82	5.77	8.65	15.24
Rupaichari	0.82	0.00	7.00	11.53	19.36
Sabroom	4.12	4.53	154.44	93.90	256.99
Sonaichari	3.71	1.24	10.71	13.18	28.83
V K pally	0.41	2.88	16.89	11.12	31.30
All village	43.24	13.59	337.71	196.45	590.99

Source: Primary Survey.

Table 5. Total area (in ha) and production (in MT) in Tripura.

Year	Planted area	Cumulative total area	Mature area	Immature area	Production
2004-05	1516	34630	21952	12678	24147
2005-06	2232	36862	23612	13250	25973
2006-07	4758	41620	25469	16151	30563
2007-08	5364	46984	26900	20084	32280
2008-09	7455	54439	28145	26294	33774
2009-10	5103	59542	29507	30035	35408
2010-11	3881	63423	30872	32551	37046
2011-12	4114	67537	31747	35790	38096
2012-13	3228	70765	33114	37651	39737
2013-14	3944	74709	34630	40079	42491
2014-15	3788	78498	36862	41635	46815
2015-16	2482	80980	41620	39359	52025
2016-17	2300	83280	46986	36294	56380
2017-18	1028	84308	54441	29861	65330
2018-19	730	85038	65893	19145	74139
2019-20	416	85454	69837	15617	83701

Source: Rubber Board of India (2023).

Soil degradation

The texture of rubber garden soil is of sandy clay loam type and they are brown to red with low water holding capacity and the sand silt and clay composition is also average type. The chemical character of rubber garden soil says that the pH of the soil varied within the range of 5.42-5.82 and the observation can be correlated with the organic carbon %. It is observed that lower the pH the organic carbon content is also low and this can be attributed to the leaching and rapid decomposition of organic matter as it is found that, acidity increases the decomposition of organic matter.

For microbial biomass in the form of total viable count in the experiment shows that bacterial and actinomycetes count is moderate or low and this might be due to the acidic pH of soils which has restricted the bacterial and actinomycetes population on the other hand fungal population varied greatly. It is observed that, based on the physical, chemical and biological parameters the number and abundance of the faunal groups also varied considerably. It is observed that all faunal groups such as nematodes, earthworms and micro-arthropods were found lower in number and density. Therefore this experiment helps us to understand that the soil of rubber gardens is ecologically degraded land.

Chemical use and contamination

It has been observed that a high level of ammonia is used to process latex to final rubber in different stages of production. The used chemical from rubber processing units are drained into local ponds, grazing land, and river. The drained ammonia easily contaminates water and surrounding land. Due to rapid water pollution, the biodiversity of the local water body becomes degraded. Not only that as a regular use of local water bodies by villagers and their livestock, they suffer several types of diseases. There is no proper drainage system to control or reserve the used ammonia.

Table 6 shows the reliability statistics of six Likert scale questions. The Cronbach's alpha score is 0.773 which indicates the greater internal consistency of the items in the scale. Table 7 represents the regression result between the composite Likert score and other variables. The relation is statistically significant at a 5% level of significance which rejects our hypothesis 1. There is a positive relationship between education level and the composite score. As the level of education increases the consequences of environmental changes have been observed more significantly. A significant negative relationship has been observed between age level and composite score. The younger has more realization of the consequences of change in environmental parameters than the aged one. Students, servicemen and other young generations responded to a positive relationship between rubber plantations and environmental degradation.

Table 6. Likert scale of environmental issues.

Reliability statistics Sample size = 299, Male = 186, Female = 113 Cronbach's alpha	Cronbach's alpha based on standardized items	Number of items
0.773	0.762	6

Table 7. Regression result of composite Likert score and other variables.

Number of obs = 299; Prob > F = .0002
F(3, 295) = 6.86; Adjusted R2 = 0.0557

Likert_score	Coef (SE)	P>|t|
edu	.1028998 (.0522064)	0.050
age	-.0391002 (.0188036)	0.038
gen	.018302 (.4399076)	0.967
_cons	17.56096 (.9798013)	0.000

Values of SE are within first bracket.

The marginal effect of all variables on pollution has been derived after logistic regression (Tables 8–9). The logistic regression result is significant at a 5% level of significance. This result indicates that there is significant environmental degradation due to the rapid growth of rubber plantations. The marginal effect of the probability of pollution is 0.633. The marginal effect of one year increase in education changes positively the level of pollution by the amount of 0.028 for an average individual. Whereas, the marginal effect for an actual individual is 0.022. The marginal effect of one year increase in age has a negative impact on pollution levels. This result clearly rejects the hypothesis 2 and establishes that there is a significant marginal effect on pollution level by age, gender and education level.

From the Likert scale analysis, it has been observed that 43% of people agreed and 10% of people strongly agreed that due to rubber plantation local temperature, average rainfall, soil quality and biodiversity have changed drastically during the last 15 years. The state of Tripura is mainly a hilly area covered by natural forests. The average temperature lies between 24 – 32°C during the summer season. But recently it has been observed that during May-June

Table 8. Logistic regression over pollution and other variables.

Log likelihood = -160.57596; Number of obs = 299; Prob > chi2 = .0000; LR chi2(3) = 82.42; Pseudo R2 = 0.2042

Pollution	Odds ratio (SE)	P>|z|
edu	1.132678 (.0413114)	0.001
age	.9822504 (.0123567)	0.155
gen	.0781034 (.029329)	0.000
_cons	6.197389 (4.120179)	0.006

Values of SE are within first bracket.

Table 9. Marginal effects of all variables on pollution.

Marginal effects after logit y = Pr(pollution) (predict) = .63383968		Average partial effects after logit y = Pr(pollution)
Variable	dy/dx (SE)	Coef. (SE)
edu	0289144 (.00844)	.0225162 (.0061235)
age	-.0041565 (.00292)	-.0032386 (.0022476)
gen*	-.4965015 (.05133)	-.4589973 (.0708119)

(*) dy/dx is for discrete change of dummy variable from 0 to 1. Values of SE are within first bracket. Pr is probability.

the average temperature has increased to 34-38°C. One of the main reasons behind this is the continuous deforestation of large natural forest areas.

The counterpart of deforestation is rainfall. Rainfall is the most variable element of climate which has a relationship with surface temperature. More than 50% of people believe that the average rainfall has decreased due to rubber plantations. The average rainfall in Tripura is 1922 – 2855 mm. But during the last few years, it has been observed that the average rainfall has decreased and become irregular during the year. Daily uses of rubber latex and processing chemicals of ammonia people to suffer several types of skin problems. Not only that people observed that it also affects the respiratory system of those who are working in the rubber garden for a long period. More than 60% of male respondents who are working in rubber gardens are suffering skin problems and respiratory problems.

CONCLUSION

Rubber (*Hevea brasiliensis*), is a well-known cash crop and certainly, it helped to stimulate economic growth and social life rapidly. However, from the findings of the case study area, it is obvious that rubber plantation has significant environmental impacts. India has a significant contribution to world rubber production and in India; Tripura is the second largest producer of rubber in the global market. Therefore rubber production plays a very significant and crucial role in the economy. In Tripura, the livelihood condition has changed remarkably during the last three decades. The average annual income of rural people has increased and other associated parameters of the standard of living have also changed. Now if we concentrate on the negative side of rubber plantation then it can be easily concluded that Tripura is losing its sustainability in traditional agriculture, bamboo and other fruit cultivation and finally biodiversity. Deforestation of natural forests, biodiversity loss, natural water pollution, soil quality degradation, and human health problems are increasing day by day. The diversity of cropping patterns has changed abruptly during the last two decades. Villagers will no longer be able to intercrop food crops with rubber trees resulting in major changes to traditional livelihoods. This poses a major threat to the villagers' food security. Consequently, this study cannot say that the benefits of rubber are sufficient to cover the costs. They have lost their traditional wild animals and other inhabitants. Indigenous product like fruit, vegetables, and bamboo crafts becomes scarce day by day. The people of the state become less interested to cultivate and continue their heritage and own culture.

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