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RESEARCH ARTICLE

ECOLOGICAL IMPACT OF RUBBER PLANTATIONS: TRIPURA PERSPECTIVE

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ABSTRACT

Due to agro-climatic suitability of Tripura, a north-eastern state of India, rubber plantation is being promoted. Till 2012, 5.2 per cent of its geographical area has come under rubber monoculture. In spite of socio-economic positive impacts, there are controversies on growing expansion of rubber monoculture among the populace of Tripura, mainly from the perspective of ecology. Based on the available literature of the studies carried out in different places of the globe as well as in Tripura, these aspects have been reviewed in this paper.

INTRODUCTION

Rubber (*Hevea brasiliensis* Mull. Arg., Family: Euphorbiaceae), a native tree species of Amazon forests, has been successfully introduced as a cash crop in many developing countries, especially in Southeast Asia to produce natural rubber (Nath *et al*., 2010). In India, the hinterland of southwest coastal region is recognised as 'traditional rubber belt', but as that area reached the saturation level in area coverage, the non-traditional areas are now in focus (Sinha, 2007). Among non-traditional areas, the north-eastern region of India is emerging as one of the most important rubber growing zones (Sinha, 2007), due to its favourable agro-climatic condition for rubber growing. In the north-eastern region of India, the state of Tripura is the fore runner. As per record of the Rubber Board of India, by 2012, in Tripura 55,415 hectares of land have come under rubber plantation, which is 5.2 per cent of its total geographical area. In India, both in terms of plantation area as well as total production, Tripura stands second, next to Kerala. Though, the rubber plantations in Tripura, as well as in other areas contributed a lot to economy, there are controversies on the ecological impact. Loss of biodiversity is one of the major complaints (Fox *et al*., 2009). There are reports that, its plantation causes local water resource shortage too (Tang *et al*., 2011). Both positive and negative effects on soil fertility, microclimate and carbon sequestration have also been reported (Zhang, 1986; Krishnakumar *et al*., 1991; Kox, 2000; Cheng *et al*., 2006, 2007; Hu *et al*., 2008). In Tripura, it has also made positive contributions in restoring the degraded ecological system (Krishnakumar *et al*., 1991; Krishnakumar and Meenattoor, 2003). In spite of its positive role in restoring degraded land in Tripura, the negative consequences of large scale monoculture cannot be overlooked. On the other hand, there are unscientific arguments against such plantations too. Combating biased arguments is also of immense importance. Hence, promotion of scientific literacy on the issue as well as dissemination of up-to-date research findings need much more attention to make people 'informed decision makers'.

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Natural rubber Vs. Synthetic rubber: importance of rubber plantation

Jones (1994) and Wan and Jones (1996) postulated that, natural rubber is inherently environment-friendly. What for such postulation? Perhaps there is a motivation to draw its green image in comparison to synthetic rubber. Natural rubber is an unusual industrial material, not only of natural origin, but also renewable in nature (Jones, 1997). It also takes less energy (Rahman, 1994). While in the production of 1 ton of synthetic rubber (finite product) energy requirement is between 108 and 174 GJ, the same amount of natural rubber only takes 13 GJ (IRRDB, 1998). Moreover, in contrast to synthetic rubber, which consumes energy and produce CO_2 to convert pure energy (crude oil) into elastomers, the natural rubber plant absorbs CO_2 to meet the need to produce latex inside the tree (Jones, 1997), thereby playing role in minimising global warming.

Synthetic rubber too has got advantages over natural rubber in certain aspects, one of which is related to ecology. It does not cause loss of biodiversity, whereas rubber plantation on commercial scale destroys biodiversity. Perhaps, this is the greatest drawback of the rubber plantations from the point of the environment (Bhowmik, 2006). But, in recent times, on the development of protocols for processing rubber wood, apart from 'latex', when the productive period is over, the tree is being used as 'timber'. In early nineties of last century, International Trade Centre (ITC) estimated that, globally 0.6 million hectares of tropical rain forest can be conserved with the utilisation of economically available rubber wood (ITC, 1993), which indirectly can play a role in conserving biodiversity. The estimates further showed that, if all the available physical potential of rubber wood are in use, an additional 0.3 million hectares of tropical rain forests can be saved. Even India can be able to save 20,000 hectares of rain forests on an annual basis (Dhamodaran, 2008). Hence, considering its natural origin, renewable nature, capability of playing role in minimising global warming and requirement of less energy and potentiality to save huge area of rain forests, it can be concluded that, natural rubber is environment-friendly in comparison to synthetic rubber.

Advantage of '*Hevea*' as a species as/over other trees

Hevea brasiliensis is deciduous and indigenous to the tropical rain forests of Amazon basin (Thomas and Panikkar, 2000). Due to its robust nature and economic importance, its cultivation has been extended away from the equator to latitudes as far as 29^0 N in India and China, down to 23^o S in Sao Paulo state, Brazil (Rahman, 1994). As it is deciduous, its wintering causes decrease in photosynthesis (falling nearly to zero because of annual leaf exchange) for short spell of time, say for little more than one month (Moreira *et al*., 2009). But, due to its heavy canopy owing to large leaf area index (LAI), often 6 or more, particularly beyond a certain age of growth (Devakumar *et.al*., 1998), it shows better photosynthesis in overall. According to Rahman (1994), beyond a certain age of growth, the rate of photosynthesis is even comparable to that of forest ecosystems. According to Jones (1997), it is probably at least equal to that of virgin forest and may even exceed it. The photosynthesis rate of a mature rubber leaf is 10 to 15 *u*mol CO_2 per m^2 per second as compared to 5 to 13 umol CO_2 per m^2 per second in many other trees (Sethuraj and Jacob, 1997; Nataraj and Jacob, 1999). Thus, due to large LAI, high rate of photosynthesis, it is reported to be relatively efficient converter of solar energy into dry matter production, even comparable with virgin jungle, especially once the tree reaches maturity (Rahman, 1994) and in that way plays a positive role as carbon sink in assimilating carbon from atmosphere. Physiological studies have shown that *Hevea* is more effective than teak in taking up CO_2 (Sethuraj and Jacob, 1996). Hence, it can be inferred that, the *Hevea brasiliensis* occupies an advantageous place as a forest species or even serves better in purifying atmosphere by assimilation of CO_2 in photosynthesis and releasing O_2 as the by-product of photosynthesis.

Carbon sequestration

With the recognition of increasing green house gases (GSHs) in atmosphere due to human intervention resulting in global warming, attention has been drawn to the attempt of minimising carbon from the atmosphere by adopting appropriate actions. The plants can play a decisive role in this respect. However, there is an argument that, the old-growth forests store carbon for centuries, whereas plantations and young forests are actually net emitters of carbon due to disturbance in the soil and the degradation of the previous ecosystem. But, when there comes the question of choice regarding plantations with an equitable view of economical and environmental causes, as in Tripura, where even forests too consist mainly of plantations, the rubber plantations have glittering opportunities. Review of several studies have indubitably indicated that, natural rubber plants are good sink for atmospheric CO_2 (Jacob, 2003). The amount of carbon fixed in the rubber tree has been assessed in different genotypes and geographic locations (Sivakumaran *et al*., 2000; Wauters *et al*., 2008; Annamalainathan *et al*., 2010). On an average, a rubber tree is capable of fixing approximately one MT of CO_2 during its 30-year economic life cycle and therefore, within a hectare of rubber having over 300 trees, a minimum of 300 MT of CO_2 is fixed. Cheng *et al*. (2007) compared the carbon sequestration of *Hevea brasiliensis* with rain forest and secondary rain forest in Hainan Island of China. The carbon sequestration of rubber trees per hectare amounts upto 272.08 tonnes within 30-year life period (57.91 per cent was fixed in litters), whereas in case of rain forest and in secondary rain forest, those are 234.305 tonnes and 150.203 tonnes respectively.

Loss of Biodiversity

Loss of biodiversity is one of the potential dangers associated with sprawling rubber plantation (Li *et al*., 2007). Its unrestricted expansion has devastating environmental effects (Ziegler *et al.,* 2009). But, the question is, what are the reasons? Is the species '*per se'* is responsible? Or, is it antagonistic to other forms of life in ecosystem? According to Kox (2000), the leaf coverage and the root system of rubber trees regulate the microclimate allowing a range of secondary plants to flourish, provides protection of soil against dehydration and the erosive influence of rain. Kox (2000) further mentioned that, the trees also offer a habitat for a great variety of fauna. In spite of that, we cannot deny the fact that, almost in all rubber plantations in Tripura, there are only upright rubber trees on clear ground with dry leaves. It is due to monoculture, not due to the *Hevea* '*per se'*, which changes the landscapes. It has also been reported that, biodiversity remains remarkably high in rubber plantation, in marked contrast to most other forms of monoculture (Jones, 1997). By inherent nature it does not possess the characteristics which result in almost clear ground devoid of flora and fauna. The rubber plantations are being raised as 'monoculture plantations', because human beings are doing it such way, whereas, naturally, in its indigenous place in tropical rain forests, it co-exists with different forms of life. In a comparative study of the plantations of *Hevea brasiliensis*, *Tictona grandis* and natural forest in north Bengal in India, where for considerable years there were no anthropogenic interferences/disturbances, it was found that in terms of total number as well diversity of living organisms, the rubber plantation is rich and almost nearer to natural forest (Krishnakumar *et al.,* 1991). Number of plants, herbs and shrubs were more in rubber plantation in comparison to *Tictona* plantation. In natural forest, monocot plants were recorded 20,000 numbers per hectare and diocot plants 60,000 numbers per hectare, whereas in rubber plantation, these were recorded 18,000 and 80,000 numbers respectively. In Tripura too, from rubber plantations 50 species of plants (Krishnakumar *et al*., 1991), 11 species of earthworms have been recorded (Nath and Chowdhury, 2010).

In spite of the presence of different forms of life in rubber plantations as mentioned above, it is a fact that, globally, destruction of biodiversity is taking place for promotion of monoculture of rubber to meet the industrial need with a resultant loss of biodiversity. Therefore, recently this phenomenon is being termed as 'green desert' by the environmental activists. It is now recognised that, land-cover transitions to rubber monoculture has resulted significant loss of both above ground and belowground biodiversity (Li *et al*., 2008; Ziegler *et al.,* 2009, 2009a). Assessing the scenario of large scale and rapid land-cover conversion to rubber monoculture in Motane Mainland Southeast Asia (land between 300-3000 m. above sea level of China, Laos, Thailand, Vietnam, Cambodia and Myanmar), where more than 500,000 hectares of land have already been converted to rubber plantations, Ziegler *et al*. (2009a) predicted that, by 2050, the area under rubber and other monoculture would be double or triple replacing lands currently occupied by evergreen broadleaf trees and secondary vegetation.

Reviewing the transition from subsistence-production based shifting cultivation to small-scale rubber cultivation in three South Asian countries, *viz*., Srilanka, Bangladesh and India including the state of Tripura, Nath *et al*. (2010) opined that, no doubt the rubber plantations increased forest coverage in planted areas, but at the cost of local biodiversity. In Tripura, the rubber plantation not only destroyed natural homestead forests, agro-forestry lands (occupied by horticultural plants), but also in some places even forests (both planted and natural). According to them (Nath *et al*. 2010), only standing trees and clean ground with dry leaves cannot create the sense of a forest that does not virtually have any wildlife and other vegetations.

In Tripura, it is yet to be unearthed, to what extent the biodiversity have disappeared for rubber and to what extent loss is likely to be incurred in future to reach to the target level (100,000 hectares). In initial years, in Tripura, rubber plantation were in degraded land, but, in recent years there has been encroachment of land demarcated for horticulture and of even in forest land including the land which have been distributed under Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act., 2006 (FRA). There are also attempts to convert tea gardens to rubber plantations. What is the prime force? Obviously economic profitability is the dictate of market force. As a corrective measure, we need enforcement of the restriction provisions of laws. If we fail to make profitable production and value addition in private lands under cultivation, it will be difficult to restrain the owner from conversion to rubber monoculture, which is a challenging task. We cannot ignore that, ecologically, in comparison to 'natural forest', the 'man made forest' is fragile as it possesses less biodiversity as well as less number of living organisms. Again, among man made forests /plantations, monoculture is more fragile. Further, monoculture is better than no plantation or barren field.

Effect on microclimate

Nowadays, the people of Tripura have a general feeling that the local climate is changing. It is becoming hotter and drier. There is a lack of adequate rainfall. Even in the middle of monsoon the riverbeds are dry. There is a tendency to blame the expanding cultivation of rubber for changes. Is it scientifically correct? Whether as a plant species '*Hevea'* can be made responsible or not, is a question of paramount importance.

Rainfall : If the perception that rain fall is decreasing is found to be correct, is not it ironical that, *Hevea brasiliensis* is the native plant of Amazon forest, which is a biggest rain forest of the world? Is not it ironical that, mighty Amazon River, the basin of which is its homeland, carries the most amount of water of all the rivers in the world? Hence, it is clear, as a species *Hevea brasiliensis* '*per se'* cannot be blamed for, even if at all there are changes in rainfall. Further, in Tripura, whether there is any significant trend of annual decline of rain fall at all? Though changes of seasonal distribution are being experienced, the trend analysis of 20^{th} century indicates no significant changes in annual rainfall (Bhattacharjee, 2002). Analysing the database corresponding to the period 1984-2008 of Agartala, the state capital of Tripura, it has also been found that, annual rainfall did not show trend of decline (Sailajadevi, 2010). Analysis of moisture regime reveals that, monthly distribution of rainfall during two halves indicates a shift in the distribution. Observed rainfall peak was May-June during the first half (1984-1995) and June-July during the second half (1996-2008). Two rainfall peaks (May-June and Sept-Oct) were observed during first half which was changed once during the latter half.

Seasonal trends in rainfall indicate a decline during post monsoon and winter season, though not significant. Rainy days during South-West (SW) monsoon declined at a rate of 0.4 days per year. Extreme rainfall events during the season increased at a rate of 0.15 days per year over a span of 25 years. Decline of rainy days during summer is notable. Extreme rainfall events during summer indicate a decline of 0.03 days per year. 0nset and withdrawal of SW monsoon as an index of climate change was also studied (Sailajadevi, 2010). Pented rainfall of fourth spell (May 30 to June 3) was the onset during the first half (1984-1995) and pented rainfall of third spell (May 25 to 29) was the onset during the second half. When, the two periods were joined together pented rainfall of 3rd spell was found to be the onset. Withdrawal of the monsoon has been extended to 46th week (Nov. 12-18) during the latter half instead of 45th week (Nov. 5-11) during the first half. Do the changes in distribution pattern mentioned above have any relation with rubber plantation? Till date, there is no such study in or for Tripura. However, a study has been conducted by Research Centre for Eco-environment Sciences of Chinese Academy of Sciences, Beijing, for Hainan Island which may enlighten us to get an idea for Tripura too. Based on 40 years' (1951-1990) climatic data, analysing the hydrological dynamic characteristics of rubber plantation and estimation of the water balance in the rubber plantation , the researchers concluded that, in the 19 counties of Hainan Island , the large-scale substitution of the natural vegetation with the rubber plantations had no significant effect on local rainfall (Jiang, J. and Wang, R., 2003).

According to them, main reasons are : (1) 80 per cent of the rainfall in Hainan Island is brought by typhoons ; (2) the proportion of 11.6 per cent rubber plantations in total forest coverage in Hainan Island is not enough to influence the local rainfall ; and (3) although, the rubber plantation is artificial vegetation, it has the similar function to the tropical rain forest. The rainfall of Tripura is mainly influenced by Bay of Bengal and the climate of wider geographical areas even beyond the boundary of Tripura. Moreover, the proportion of rubber plantation in the state is only 5.2 per cent (55,415 hectares in 2012, as per information from Rubber Board of India) of its geographical area, whereas, forest cover together with tree cover is 78.3 per cent (anonymous, 2011). In this context, is there any remote possibility of influence of the rubber plantations on local rainfall? Analogy of drying up of riverbeds with inadequate rainfall and linking it up with rubber plantation also appears to be not scientific. Riverbeds may dry up for variety of reasons, which demand proper study.

Temperature: With regard to temperature, increase in mean annual minimum temperature has been observed at a rate of 0.05^0C per year over a span of 25 years (Sailajadevi, 2010). No change has been noticed in mean annual maximum temperature. Trend analysis on seasonal basis reveals that, the minimum temperature increased at a rate of 0.04^0C during SW monsoon, while the trend for 2000-2009 showed an increase for minimum temperature except during post monsoon. Cusum plot for seasonal minimum temperature indicates 1994-95 as the year in which the shift to warming occurred. It is of interest to note though not significant, that maximum temperature shows an upward trend only during SW monsoon. A downward trend is observed in the winter and post monsoon maximum temperature during the decade 2000-2009. Cusum plot for maximum temperature during SW monsoon indicates that, the change to the warming phase occurred during 1990 and continued up to 1998. It is also interesting to note that, there was increase in T_{max} during SW monsoon. Cold nights decreased at a faster rate (-1.7 days per year) than the increase of hot days (0.9 days per year), which is in concordance with the result obtained for minimum temperature. The cusum chart for cold nights indicates a sudden change in direction towards warming, which reconfirms the year 1994 as the major point for T_{min}. Seasonal trends for hot days did not increase during summer. All the other seasons depicted an increase of hot days though not significant. Decrease of cold nights during SW monsoon at a rate of 0.8 days per year is in agreement with the earlier results obtained for the season. The number of days where T_{max} exceeded the thresholds was observed to be increasing over the years during SW monsoon. Number of days with $T_{max} > 33^0$C increased at a rate of 0.16 spells per year. Evaluation of T_{min} during winter indicates the difference between the first and second halves widens during December. An increase of more than 2^0C observed for the second half, compared to the first half indicates that December is becoming warmer over the years. The observed decline in the T_{min} of second half during the beginning of February revealed a shift in the winter that extended up to the middle of the month. From analytical findings of Sailajadevi (2010), it can be inferred that, increase of minimum temperature in all seasons and of maximum temperature during SW monsoon has taken place. The trends in the hot days and cold nights, consistency in the non increase of hot days during summer, identification of the 1994 as the major direction of change to warming are some interesting observations. The question remains whether the changes in thermal climate as mentioned are due to rubber plantations or not? As mostly the plantations are in barren field or in denuded forests (that too mostly plantations) or on the lands affected by shifting cultivation and increased green covers (Nath *et al*., 2010), cannot be made responsible. Rather, as due to rubber plantation green cover increased, there is the possibility that it has played a role in minimising temperature though an overall increase of minimum temperature in all seasons and maximum temperature during SW monsoon has taken place. It may be due to other reasons including global warming.

Sucking of sub-surface water: There is also a saying that, the rubber plant is sucking the ground water and making the land dry. Is there any study or any scientific explanation available? According to Krishnakumar and Rajeswari Meenattoor (2003), rubber trees utilize much less water than many forest species for a comparable biomass production. Further, Bhowmik (2006), based on an interview with residents of the locality of 8 rubber growing villages (5 villages under Belonia Subdivision and 3 villages under Udaipur Subdivisions of earlier South District) of Tripura, came to the conclusion that , the ground water levels in the villages do not show any sign of depletion. Respondents believe that the levels have remained the same even after introduction of rubber plantation in the area though utilization of water from the wells has increased during the past several years. According to him, this indicates that, the rubber plantation is rather helping conservation of water and recharge of aquifers. Though the promoter of rubber cultivation are of the view that, rubber plantations exhibit similar hydrology to rain forests and will not cause water shortage (Zhang *et al.,* 2011), in contrast, local belief/perception of high water use of *Hevea brasilielsis* have been reported from China (Guardiola-Claramonte *et al*., 2010). In China, the observations of researchers were different (Guardiola-Clarmonte *et al.,* 2008, 2010; Qui, 2009; Zhang *et al.*, 2011). Extensive field observations in Xishuangbanna of China suggest that, rubber is depleting the subsurface water resources, as significant deep root water uptake occurs during leave flushing coinciding with the driest and hottest period (Guardiola-Clarmonte *et al.,* 2008). Qui (2009) and Zhang *et* *al.* (2011) even referred rubber as 'water pump', as according to them, the rubber plants are associated with water depletion in the basins where they are grown. Guardiola-Claramonte *et al.* (2010) also suggested greater annual catchment water losses through ET (Evapo-transpiration) from rubber dominated landscapes compared to the traditional vegetation cover. However, Dr. A.D. Ziegler of the National University of Singapore is cautious in using the term 'water pump'. According to him, sufficient research has not yet been done to evaluate the extent of the hydrological threat (Anonymous, 2012). Data are also too sparse to quantify the extent of the impacts (Ziegler *et al.,* 2009). With this background, observation and conclusion of Bhowmik (2006) based on the perception of local residents and that too of only 26 respondents, appears to be over simplistic and hence, need scientifically valid evaluation.

Effect on soil health

From reviewing the literature, it appears that, number of researchers have reported the impact of rubber plantations on soil health (Aweto, A.O., 1987; Krishnakumar *et al*., 1990, 1991,1991a; Joshep,1991; Krishnakumar and Potty, 1992; Rahaman,1994; Cheng *et al*., 2007; Mandol and Pal, 2010).

Restoring soil erosion: Soil erosion is a problem everywhere, which decreases the nutrient of soil, as we know that nutrients are naturally available in top soil. From analysing of different observations (Philip *et al*., 1996; Sethuraj, 1996; Jacob, 2000), it appears that, 'as plant', the rubber can play a role in restoring soil erosion. The root concentration in rubber plantations occurs in the top 18 cm of the soil and horizontally they spread up to 2 meters from the plant base (Philip *et al*., 1996). Being a surface feeder, rubber tree affords good soil binding and reduces erodibility of soil considerably (Sethuraj, 1996). The thick canopy helps to cut down direct radiation and intercepts rain. According to Rahman (1994), once the trees have established a complete canopy, the rate of run-off generally differs little from that in similar areas with natural forest. Thus, soil moisture status is improved and soil erosion is prevented. The reduced soil temperature leads to reduced oxidation of soil organic matter and favour its built up (Jacob, 2000).

Physical and nutrients status: Krishnakumar *et al.* (1991a) examined soil properties, nutritional enrichment, under storey vegetation and biomass recycling under rubber and natural forest. Based on the study, they opined that, rubber plantations present almost a closed ecosystem in a near steady state during their life span. In Tripura, it has been found that, its plantations enrich organic matter which consequently improves physical properties such as bulk density, soil porosity, moisture retention and infiltration (Krishnakumar *et al*., 1990). Joshep (1991) also reported that, the nutrient recycling through litter decomposition is very rich; as a result significant accumulation of organic matter to the soil takes place, which helps to improve soil organic matter and water content. Eappen *et al.* (2005) also conducted a comparative study on the influence of different forest species, *viz*., Sal (*Shorea robusta*), Acacia (*Acacia auriculiformis*), Cashew (*Anacardium occidentale*), Teak (*Tectona grandis*) with rubber (*Hevea brasilensis*) in Tripura and found that, the influence of the rubber plantations on soil properties is comparable to other tree plantations particularly Sal and Teak. Improvement of the bare soil, soil of denuded forests as well as areas subjected to continuous shifting cultivation is a challenging task in different areas including those in Tripura. Exposure of the bare soil to the sun and the impact of rainfall can lead to accelerated decomposition of the organic matter, leaching of nutrients, breakdown of the aggregate structure of the surface soil, diminished infiltration and increased run-off and erosion of soil (Rahaman, 1994). A team of ICAR Research Complex for NE Region, Tripura, also reported decline in soil pH, organic carbon, available nitrogen, available phosphorus, available potassium (Datta *et al*., 2001). Shifting cultivation usually proceeds by clearing of vegetation and burning the organic debris, which lead to destruction of organic matter, soil structure, thereby decrease the soil fertility and soil microbial population as well as reduce water intake capacity of soil due to deposition of hydrophobic aliphatic hydrocarbons (Mandol and Pal, 2010). In Tripura, the rubber plantation has shown credibility in such situations to improve the physical (bulk density, porosity), chemical (nutrient availability), and biological (soil microbe) properties of the soil (Krishnakumar *et al*., 1991a; Krishnakumar and Potty, 1992).

Conclusion

In modern time, we cannot think of society without rubber. For that, in respect of environmental consideration, dependence on natural rubber is better, for which we need rubber plantation. Tripura, a north eastern state is fortunate enough that it has been gifted by nature an agro-climatic condition which is suitable for *Hevea brasiliensis* to grow. Hence, this opportunity needs to be utilised for socio-economic development of the state. It has also shown its credibility to improve the soil health, especially of the bare land or denuded forest land or the land degraded by shifting cultivation. But, unrestricted expansion of the monoculture may pose a threat on the ecology of the state, especially with regard to the destruction of biodiversity.

Though initially, its plantations were confined to bare land or denuded forest land or the land degraded by shifting cultivation, recent attempt of transition of lands covered by different vegetations including horticultural orchards, and attempts to convert tea gardens, are serious problems. Even, there are cases of encroaching reserve forest and/or the land distributed under the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006 in certain pockets. For the purpose, enforcement of restriction provisions of laws as well as interventions are urgently needed to make present or other eco-friendly uses of land more profitable. In rubber plantation too, intercropping is desirable. A more realistic approach may be to promote diversified agro-forestry systems in which cash crops such as rubber can play an important role, but not be planted as monoculture (Ziegler *et al*., 2009). From the available literature on the impact of rubber monoculture on microclimate (Jing and Wang, 2003) and analysis of data on rainfall and climate of the state (Bhattacharjee, 2002; Sailajadevi, 2010), it can be concluded that, till date it has not made significant impact on rainfall and temperature and even if the plantation is expanded upto target level (1 lac hectares), there will not be significant changes. However, its impact on ground water needs valid evaluation.

REFERENCES

Annamalainathan, K. Satheesh, P.R. and Jacob, J. 2010. Rubber plantation as a potential sink for atmospheric carbon dioxide: an ecosystem flux approach. In *: IRRDB Workshop on Climate Change and Rubber*, Rubber Research Institute of India and IRRDB, Kottayam, India.

Anonymous 2011. State action plan on climate change. Department of Science, Technology and Environment, Government of Tripura.

Anonymous 2012. Quantifying the environmental consequences of the spread of rubber in Southeast Asia. National University of Singapore. Retrieved from: http://www.nus.edu.sg/research/rg168.php.

Aweto, A.O. 1987. Physical and nutrient status of soils under rubber (*Hevea brasiliensis*) of different ages in south-western Nigeria. *Agricultural Systems*, 23(1) : 63-72.

Bhattacharjee, B. 2002. *Tripurar Jalbayu O Prakriti* (In Bengali). Agartala, Tripura, India.

Bhowmik, I. 2006. Impact of rubber plantations on the environment of Tripura. In : *Natural Rubber in Tripura – Baseline Data and Future Planning*, Tripura Rubber Mission, India, pp. 82-88.

Cheng, C., Wang, R. and Jiang, J. 2007. Variation of soil fertility and carbon sequestration by planting *Hevea brasilience* in Hainan Island, China. *J.Environmenttal Sciences*, 19(3) : 348-352.

Datta, M., Bhattacharya, B.K. and Saikia, H. 2001. Soil fertility – a case study of shifting cultivation sites in Tripura. *J. Indian Soc. Soil Sciences*, 49(1) : 104-109.

Devakumar, A.S., Sathik, M.B.M., Jacob, J., Annamalainathan, K., Prakash, P.G. and Vijaykumar, K.R. 1998. Effect of atmospheric and soil drought on growth and development of *Hevea brasiliensis. J. Rubb. Res*., 1(3): 190-198.

Dhamodaran, T.K. 2008. Status of rubber wood processing and utilisation in India : a country report. In : *Workshop on Promotion of Rubber Wood Processing in the Asia Specific Region*, Sanya, Hainan, China.

Eappen, T., Rao, D. V. K. N., Karthikakullyamma, M., Sarma, A. C., Dey, S. K., Varghese, Y. A. and Krishnakumar, A. K. 2005. Influence of plantation crops on soil properties in Tripura. *Natural Rubber Research*, 18(1) : 67-80.

Fox, J., Castella, J., Ziegler, A.D. 2009. Swidden, rubber and carbon can REDD+ work for people and the environment in montone mainland southeast Asia ? In : *Working paper No. 9, CGIAR Res. Programme on Climate Change*, Agriculture and Food Security, Copenhagen, Denmark.

Guardiola-Claramonte, M., Troch, P.A., Ziegler, A.D., Gimbelluca, T.W., Vogler, J.B. and Nullet, M.A. 2008. Local hydrologic effects of introducing non-native vegetation in a tropical catchment. *Ecohydrology,* 1 : 13-22. DOI :10-1002/eco.3.

Guardiola-Claramonte, M., Troch, P.A., Ziegler, A.D., Gimbelluca, T.W., Vogler, J.B. and Nullet, M.A. 2010. Hydrologic effects of the expansion of rubber (*Hevea brasiliensis*) in a tropical catchment. *Ecohydrology*, 3 : 306-314. DOI : 10.1002/eco.110.

Hu, H., Liu, W. And Cao, M. 2008. Impact of land use and land cover changes on ecosystem services in Menglun, Xishuangbanna, Southeast China. *Environ. Monit. Assess*, 146 : 147-156.

IRRDB 1998. Annual Report, International Rubber Research and Development Board, Helford. Pp.24.

ITC 1993. Marked study on rubber wood—a study of the world development potential. International Trade Centre (ITC). UNCTAD/GATT,Geneva. Pp. 99.

Jacob, J. 2000. Rubber tree, man and environment. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. George, P.L. and Jacob, C.K.), Rubber Reasearch Institute of India, Kottayam. pp. 509-610.

Jacob, J. 2003. Carbon sequestration capacity of natural rubber plantations. In : *IRRDB Symposium on Challenges for National Rubber in Globalisation*, Chiang Mai, Thailand.

Jiang, J. and Wang, R. 2003. Hydrological eco-service of rubber plantations in Hainan Island and its effect on economic development. *J. Environmental Sciences*, 15(5) : 701-709.

Jones, K.P. 1994. Natural rubber as a green commodity : part . II. *Rubber Development*, 47(3) : 37-41.

Jones, K.P. 1997. Rubber and the environment. In : *Joint Workshop of the International Rubber Study Group (IRSG) and secretariat of the United Nations Conference on Trade and Development (UNCTAD) on oppurtunities and constraints for the internalization of environmental costs and benefits into the price of rubber.* IRSG and UNCTAD.

Joseph, K.T. 1991. Soil conservation. In : *The State of Natural Conservation in Malaysia* (Ed. Kiew, R.). Malayan Nature Society, Kuala Lampur, pp. 209-221.

Kox, H.L. 2000. Ecological advantages of NR latex production. Nature Rubber, 17(1) : 4

Krishnakumar, A.K., Eappen, T., Rao, N., Potty, S.N., Sethuraj, M.R. 1990. Ecological impact of rubber (*Hevea brasiliensis*) plantation in North East India. 1. Influence on soil physical properties with special reference to moisture retention. *Indian J. Nat. Rubb*. Res. 3 : 53-63.

Krishnakumar, A.K., Gupta, C., Choudhury, D. and Meenattoor, R.J. 1991. Rubber (*Hevea brasiliensis*) plantation in Tripura : some ecological considerations with reference to microclimate. In : *National Seminar on Resource Management*, Agartala, Tripura.

Krishnakumar, A.K., Gupta, C.,Sinha, R.R., Sethuraj, M.R. , Potty, S.N., Eappen, T. and Das, K. 1991a. Ecological impact of rubber (*Hevea brasiliensis*) plantations in North East India.2. Soil properties and biomass recycling. *Indian J. Nat. Rubb. Res*., 4(2) : 134-141.

Krishnakumar, A.K.and Potty, S.N. 1992. Nutrition of *Hevea* . In : *Natural Rubber : Biology, Cultivation and Technology* (Eds. Sethuraj, M.R. and Mathew, N.M.). Elsvier, Amsterdam, pp. 239-262.

Krishnakumar, A.K and Meenattoor, R. J. 2003. Restoration of denuded lands in the north eastern India through rubber plantations. *Leisa India*, December. Pp. 23-24.

Li, H., Aide, T.M., Ma, Y., Liu, W. and Cao, M. 2007. Demand for rubber is causing the loss of high diversity rain forest in SW China. *Biodivers. Conserv*., 16(6) : 1731-1745. DOI : 10.1007/s10531-006-9052-7.

Li, H., Ma, Y., Aide, T.M. and Liu, W. 2008. Past, present and future land use in Xishuangbanna, China and the implications for carbon dynamics. *Forest Ecol. Management*, 255(1) : 16-24.DOI :10.1016/j.foreco.2007-06-051.

Mandal, D. and Pal, T.K. 2010. Rubber plantation in North East India and its influence on soil properties and ecosystem--an appraisal. In : *State level seminar on frointier areas of Chemistry to commemorate 150th birth anniversary of acharya P.C. Roy*. Department of Chemistry, Tripura University and Tripura Stae Council for Science and Technology.

Mongia, A.D. and Bandyapadhyay, A. 1994. Soil nutrition under natural and planted forest in island ecosystem. *J. I. Soc. Soil Sci*., 42(1) ; 43-46.

Moreira, A., Moraes, L.A.C. and Fageria, N. K. 2009. Potential of rubber plantations for environmental conservations in Amazon region. *Bioremidiation, Biodiversitity and Bioavilability,* 3(1) : 1-5.

Nataraj, K.N. and Jacob, J. 1999. Clonal differences in photosynthesis in *Hevea brasiliensis* Mull. Arg. *Photosynthetica*, 36 (1-2) : 89-98.

Nath, S. and Chaudhuri, P.S. 2010. Human-induced biological invasions in rubber (*Hevea brasiliensis)* plantations of Tripura (India) – *Pontoscolex corthrurus* as a case study. *Asian J. Exp. Biol. Sci*., 1(2) : 360-369.

Nath, T.K., Inoue, M. and De Zoysa, M. 2010. Rubber planting for forest rehabilitation and enhancement of commercial livelihood : a comparative study in three south asian countries. In: *18th Commonwealth Forestry Conference*, Edinburgh.

Philip, V., Rao, D.V.K.N., Varghese, M., Vinod, K.K., Pothen, J. and Krishnakumar, A.K. 1996. Spatial distribution of roots and nutrients in soil under rubber plantations in Tripura. *Indian J. Natural Rubber Research,* 9(2) : 106-111.

Qui, L. 2009. Where the rubber meets the garden. *Nature*, 457 : 246-247.DOI : 10-1038/457246a.

Rahaman, W.A. 1994. Natural rubber as a green commodity – Part.1.*Rubber Developments*, 47 : 13-16.

Sailajadevi, T. 2010. Has the climate changed in NE India ? In *: International Workshop on Climate Change and Rubber Cultivation : R & D priorities*, Rubber Reasearch Institute of India, Kottayam, India.

Sethuraj, M.R. 1996. Impact of natural rubber plantations on environment. In : *Natural Rubber : An Eco- friendly Material*, Rubber Board, Kottayam,pp. 55-59.

Sethuraj, M.R. and Jacob, J. 1997. Rubber and the Environment. In : *Second meeting of the Expert Group, Project on Promotion of Natural Rubber as an Environment Friendly Raw-materials and a Renewable Resource*, Cochin, India.

Sinha, A. 2007. Prospect of rubber plantation in NE region with special reference to the state of Tripura. In : *Seminar-cum-workshop on 'saving soil and croplands*', Soil Conservation Development, Assam, Guwahati.

Sivkumaran, S., Kheong, Y.F., Hassan, J. and Rahman, A. 2000. Carbon sequestration in rubber : implication and economic models to fund continued cultivation. In : *Proceeding of Indonesian Rubber Cnference and IRRD Symposium.* pp. 79-102

Tang, Z., Zhang, Y., Sony, Q., Liu, W., Deng, X., Tang, J., Deng, Y., Zhou, W., Yang, L., Yu, G., Sun, X. and Liang, N. 2011. Rubber Plantations act as water pumps in tropical China. *Geophys. Res. Lett*., 38: L24406, doi : 10. 1029/2011/GL050006.

Thomas, K.A. and Panikkar, A.O.N. 2000. Indian rubber plantation industry : genesis and development. In : *Natural Rubber : Agromanagement and Crop Processing* (Eds. George, P.J. and Kuruvilla, C.), Rubber Research Institution of India, Kottayam, pp.1-9.

Wan, A.R. and Jones, K.P. 1996. Natural rubber as a green commodity. In : *Natural Rubber : An Ecofriendly Material*, Rubber Board, Kottayam, India, pp. 1-17.

Wauters, J.B., Coudert, S., Grallien, E., Jonard, M. and Ponette, Q. 2008. Carbon stock in rubber tree plantations in Western Ghana and Mato Grosso (Brazil). *Forest Ecology and Management,* 255 : 2347-2361.

Ziegler, A.D., Fox, J.M. and Xu, J. 2009. The Rubber Juggernaut. *Science,* 324(5930) : 1024-1025.

Ziegler, A.D., Bruun, T.B., Guardiola-Claramonte, M., Giambelluca, T.W., Lawrence, D., Nguyen, T. 2009a. Environmental consequences of the demise in swidden agriculture in SE Asia : geomorphological process. *Human Ecol.,* 37(3): 361-373. DOI: 10.1007/s10745-009-9258-x.

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