AN APPROACH FOR ESTIMATING AREA OF RUBBER PLANTATION: INTEGRATING SATELLITE AND PHYSICAL DATA OVER THE NORTHEAST THAILAND

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ABSTRACT: Among the economic crops in Thailand, income from rubber export is highest resulting the expansion of rubber planted areas, formerly in the south to the Northeast Thailand. Spatial information about the planted areas over the Northeast can be incorporated into effective land use planning and decision-making. The study aims to estimate the areas planted to rubber tree, based on an integration of satellite, climate, land form and soil data and to quantify the economic return for the rubber plantation. We used SPOT and THEOS data acquired during the period 2006-2009, covering the entire Northeast which has an area of about 170,000 sq.km. On screen digitization of images was performed, based on visual analysis under the consideration of rainfall, landform and soil data, which simultaneously superimpose on the images. Differentiation and classification of rubber tree was derived from the difference in the cover patterns, resulting 3 classes of the tree age: less than 5, 5-10 and over 10 years. In addition to identifying the planted areas, the main drivers in the rubber plantation were analyzed, based on relevant land qualities and cost-benefit ratio of rubber products. The result indicated that areas planted to rubber tree accounting for about 1,480.19, 384.25, and 379.36 km^2 for <5, 5-10 and > 10 years of plant ages respectively. The ground truth survey was performed and used for Kappa statistic. With this finding, the integration of satellite and physical data offer reliable estimation of rubber plantation areas. We present rubber plantation areas for the Northeast and the main drivers in expanding the rubber planted areas. Moreover, GIS database developed in association with the provincial and watershed boundaries contributes to understand the planted areas in relation to physical and political frameworks, integrating this to other plan for the effective development.

1. INTRODUCTION

Natural rubber (*Hevea brasiliensis* Muell Arg, NR) is one of the most important economic crops in Thailand and its production has been the largest export volume in the world market (Sombatsompop et al, 2009). In 2003, world production of natural rubber reached 7.9 million tons of which Thailand shared about 36% (Prabhakaran, 2010). The rubber plantation covers extensively in southern Thailand where climatic condition and land types are favorable for the rubber tree. The rubber plantation has been extended to Northeast Thailand since the past 15 years when the rubber plant was proved to successfully grow in the Northeast condition. By the past decade, with an attractive price of rubber products, the rubber tree became one of the major economic crops in the Northeast. Recently, the competition for the uplands between rubber tree and the major field crops (cassava and sugar-cane) is strong, they need the same land types. The higher incentives of the rubber product pushed forward the expansion of plantation areas by switching the field crops to rubber tree. The marginal lands have been used for the rubber plantation, resulting degraded land and unproductive yield. Appropriate policy and extension for export require reliable forecast of the plantation areas. To achieve the objectives, effective inventories of the plantation areas in terms of spatial distribution and the tree ages are needed. However it is conceptually a prerequisite in estimating the plantation areas to project the land use changed to the rubber plant, Many studied have elaborated the estimate of the rubber plantation area and age. Suratman et al (2004) applied Landsat TM to develop and evaluate models for estimating area, volume and age of rubber plantations. Meti et al (2008) reported successful use of IRSP6-LISSIII to delineate the rubber areas in southern part of India by using supervised classification. The obtained result provided the plantation areas of plant over 4 years age, excluding the young rubber tree. Pensuk and Shrestha (2008) applied multi-temporal Landsat data (1976, 1990 and 2006) to identify the paddy area conversion rubber plantation in the Phatthalung watershed, southern Thailand. They produced land use maps of the three periods using a supervised maximum likelihood classification. With rapid access of spatial data and higher resolution acquired by satellite, identification and estimate of the rubber plantation area and their ages can be executed as a base for an appropriate strategy in natural rubber plantation planning. This study aims to estimate the areas planted to rubber tree, based on an integration of satellite, climate, land form and soil data and to quantify the economic return for the rubber plantation.

2. MATERIALS AND METHODS

The procedures in this study comprised an estimate of rubber plantation areas in combination of periodically exploring cost-benefit ratio of rubber products. We used multitemporal satellite data with respect to physical data to delineate the planted areas of different plant ages. Details of the procedures of materials and methods are described as follows:

2.1 The study area

The study area, Northeastern Thailand, covers an area of 170,000 sq km with elevation differences between 120-1,700 m, the elevation of 1,700 m found on the North-western portions and 120 m on the low land of the South-eastern portion (Fig 1). Physiographically, the North-East is formed by the strong topography in the North-western portion and flat to gently undulating landscapes in the central portion. The land cover encompasses of dipterocarp and evergreen forests in the upland mountain zone, field crops on the well drained soil of the gently undulating areas and paddy rice on the flat and low lying areas. The soils on the undulating landscapes are mainly derived from alluvium of sandstone origin and are inherently low in fertility. The mean annual rainfall ranges from 1,000-2,500 mm with an average of 1,200 mm and increases from the Southwest to the Northeast portions of the region.

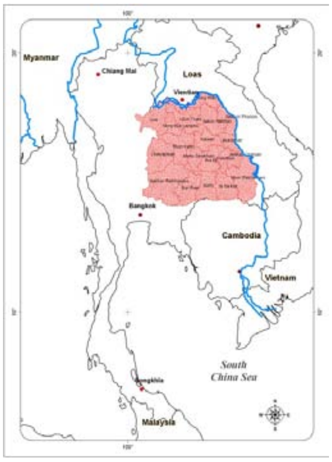

Figure 1 Study Area

2.2 Data sources

- Multitemporal satellite data used in this study consisted of 99 scenes of the year 2005-2009 (Table 1)
- Topographic maps (1:50,000) of the Royal Thai Survey Department
- Digital map of soil series group available from Land Development Department
- Digital maps of landform compiled by Geoinformatics Centre for Development of NE Thailand Khon Kaen university
- Spatial annual rainfall kriged interpolation from over 200 stations across Northeast Thailand covering at least 15 year of record.

2.3 Preprocessing of satellite data

Analysis of the satellite data was performed, including geometric correction, transforming the images coordinates to the ground control point selected from the corresponding point of the topographic maps and then performing a resampling of the pixel with nearest neighbor algorithm. A process of histogram equalization and matching was performed for better discrimination. The RGB colour composite images were produced on screen and used for digitization.

2.4 Image analysis

Rubber tree is a perennial crop that requires upland, well drained and deep soils under high rainfall (Department of Agriculture, 2005; Land Development Department, 2005; Watson, 1989) As a result, emphasis was placed on the areas of annual rainfall over 1,200 m.m, under which the plantation areas are predominantly restricted to the middle and high terraces, piedments and hills. An extensive exploration of other areas was also carried out.

On screen digitization of the false composite color (RGB) image overlaid by landform and soil maps was performed. Classification of the rubber trees was derived from the difference in the cover color and pattern, resulting 3 classes of the tree ages : <5, 5-10 and over 10 years. The young rubber plantation could be delineated by identifying the planting spacing of 5x7 m. which is predominantly practiced in the region with support of Google maps, Point Asia map and available aerial photo. With THEOS panchromatic images available, young rubber plantation can be resolved with a higher accuracy.

Table 1 Satellite data used for the study

Satellite/Sensor	Acquisition date	Num. of scene
SPOT2/HRV	Jan 2006	4
	Dec 2005	2
SPOT4/HRV	Jan 2005	1
	Nov 2005	1
	Jan 2006	2
	Feb 2006	4
	Dec 2006	2
	Jan 2007	2
	Feb 2007	4
	Mar 2007	2
SPOT5/HRV	Apr 2005	1
	Dec 2005	5
	Jan 2006	5
	Feb 2006	3
	Mar 2006	1
	Nov 2006	5
	Dec 2006	7
	Jan 2007	9
	Feb 2007	5
	Mar 2007	8
	Apr 2007	5
THEOS/ Multispectral	Dec 2008	2
	Jan 2009	3
	Feb 2009	3
	Oct 2009	1
THEOS/ Panchromatic	Dec 2008	3
	Jan 2009	2
	Feb 2009	3
	Apr 2009	4
Total		**99**

2.5 Validation and field investigation

The ground survey provides details of establishing the relationship between image feature and rubber covers as well as site characteristics. To achieve the objective this approach used a number of replications for each class and allocated the sampling site by GPS. Over 88 ground sites of the different plant ages with various landforms and soil types were investigated. Observation records at each site included cover types and their composition, landform, topography, soil and other land characteristics. Estimate and measurement of rubber stands and the land characteristics was carried out to ensure the observation together with information on land use, landform and soil maps. The obtained map was checked against the ground truth. Kappa coefficient was applied to validate the obtained results.

2.6 Analysis of main driving forces

The development of scenarios of rubber plantation requires an understanding of physical data in together with human needs. Criteria for a driver should be physically possible, economically viable, socially acceptable and technically feasible. We analyzed the main driving forces in shaping land use for rubber, based on the previous study on land suitability for rubber tree (Paiboonsak et al, 2006) and the trend of economic return for rubber products. A cost-benefit ratio (C-B ratio) was applied to quantify the economic return for rubber product which affected incentive for expansion of the planted lands. We used the agricultural statistics collected by Office of Agricultural Economics (OAE) (OAE 1990-2003, OAE 2004, OAE 2005, OAE 2006, OAE 2007 and OAE 2009) to calculate the C-B ratio. The C-B ratios for cassava, sugar-cane and rice cultivation were also studied from the same sources of information, to compare with those of the rubber plantation.

3. RESULTS AND DISCUSSION

3.1 Rubber plantation areas over the Northeast

The plantation areas and its distribution, based on the multi-temporal data of the diverse satellite platforms, are shown in Table 2 and Figure 2. The total areas accounted for 2,243.80 sqkm., representing 1.37% of the entire Northeast. Of the total plantation areas, the young rubbers (<5 years old) occupied about 50%, some of which have been intercropped with annual crops (cassava, pineapple). It was noted that the age of rubber plantation could yield significantly in variation of spectral reflectance. The younger rubber plantation found in the Northeast resulted from one or mixed surface covers of rubber canopy, inter-croppings, weed and sparse native trees. The accuracy in identification of the young rubber plantation was reliable in some portions of the areas when using THEOS panchromatic data. The THEOS panchromatic data could resolve the pattern of the young rubber plantation which has mostly the planted spacing of 5x7 m. The mature rubber plantation could be resolved or identified by the color composite images of multispectral data.

Table 2 Rubber plantation area

Year	Plantation areas	
	Area (sq.km)	Percent (%)
< 5	1,480.19	0.88
5 10	384.25	0.23
> 10	379.36	0.22
Other	166,581.54	98.67
Total	**168,825.34**	**100.00**

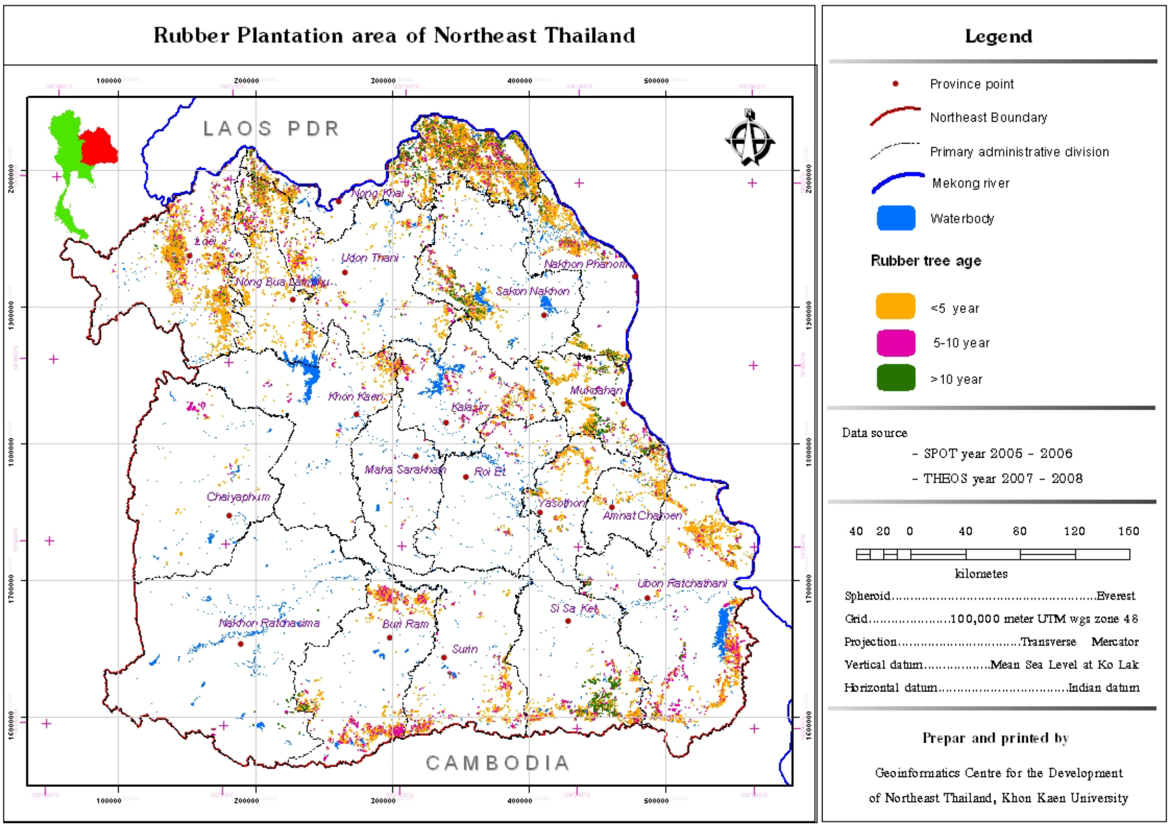

Figure 2 Rubber plantation area of Northeast Thailand

A board pattern of the plantation areas is concentrated at the borders of Thailand-Lao-PDR and Thailand-Kumphuchea particularly along the Mekong reach. Those areas are located in Nong Khai, Loei, Buri Ram, Ubon Ratchathani, Udon Thani and Si Sa Ket provinces, representing 29.24, 12.16, 9.12, 9.03, 7.72 and 5.43% of the total plantation areas respectively. The lowest plantation areas could be found on the western and central parts of the region where the mean annual rainfall is less than 1,200 mm. (Figure 3). The identified plantation areas of over 90% are predominantly occupied on the middle/high terraces, dissected erosion surface and denudational hills which are well drained landform types (Table 3). The low terrace, flood plain and other types with poorly drained lands were used for the plantation with less extent. The poorly drained lands planted to rubber tree were ridged to drain the excess water during the rainy season. The extensive soils cultivated to rubber plant included Paleustults, Haplustults and slope complex.

Table 3 The plantation area and landform

Landform type	**percent**	**Sq.km.**
Flood Plain	0.88	19.72
Low Terrace	8.36	187.47
Middle Terrace	47.67	1,069.57
High Terrace	10.40	233.40
Dissected Erosion Surface	23.04	517.05
Denudational Hill	9.30	208.67
Other	0.35	7.92
Total	**100.00**	**2,243.80**

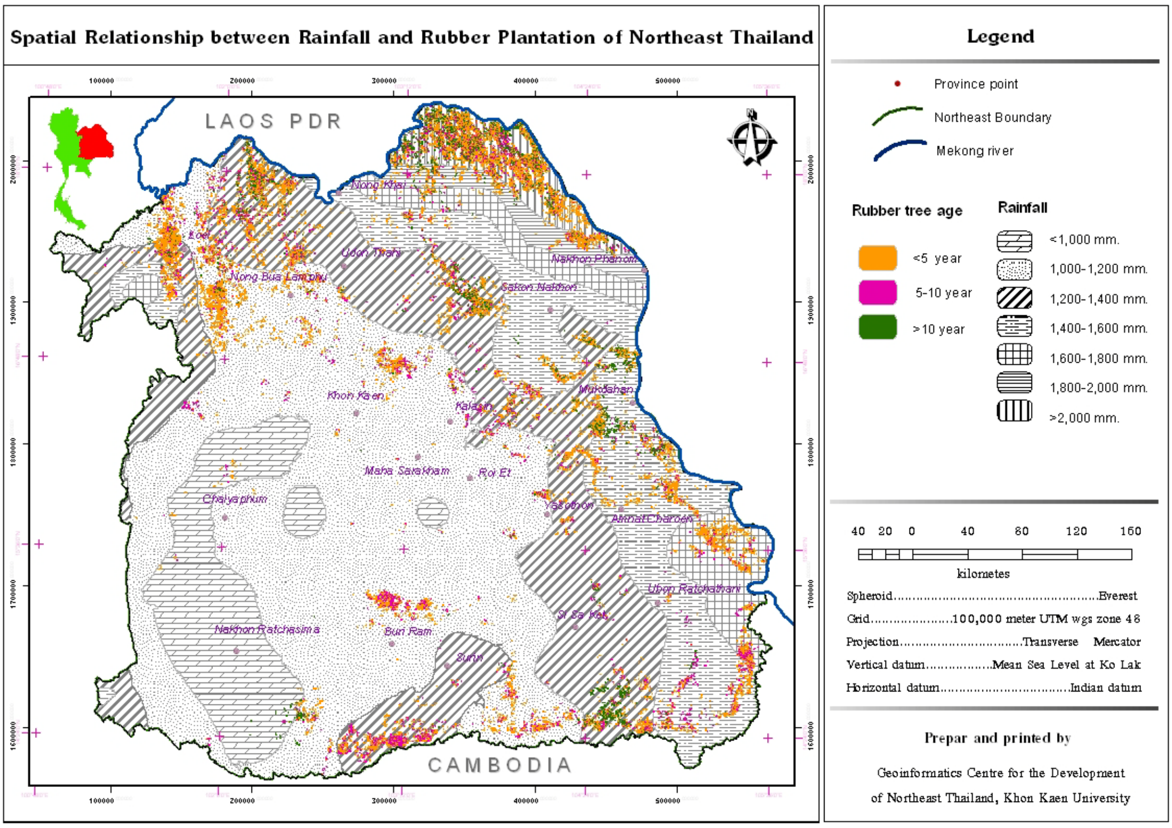

Figure 3 Rubber plantation and rainfall

To assess the reliability of the resultant map the results were checked against the ground investigation. The ground investigation of the plantation areas of 88 locations was based on the current plantation area (2010) with estimate of the plant ages back to the date of data acquisition. The Kappa coefficient of the obtained result and ground truth is 0.82. The confusion between the ground survey and the obtained map is shown in table 4. However it would suggest caution in using maps and the statistics provided. The users should take into account the acquisition dates of satellite data. The validation method was less than perfect because of a complexity of land cover and unavailable high resolution images covering the entire areas. The obtained plantation areas are inferior to the statistics of those collected by OAE and Rubber Plantation Organization we could not compare the obtained maps with those institute/office because no maps available to the publics. Basically, the established plantation areas are spatial information available covering the extensive areas over the Northeast. The missing portions of the plantation areas, recent cultivated and growing areas should be further estimated and monitored.

Table 4 The confusion between the ground survey and the obtained map

Image Classify	**Survey**				**User's accuracy (%)**
	<5	5 10	>10	Total	
<5	**47**	3	0	**50**	94.00
5 10	0	**16**	1	**17**	94.00
>10	0	5	**16**	**21**	76.00
Total	**47**	**24**	**17**	**88**	
Producer's accuracy (%)	100.00	66.66	94.00		

3.2 Main drivers in expansion of the plantation

As identified here above, the plantation areas in terms of land qualities are located in the higher annual rainfall, well drained landforms and soils. Planting the rubber tree in the region is physically possible and technologically feasible. The C-B ratio of rubber plant as compared to rice, cassava and sugar-cane for the period 1999-2007 is shown in Fig 4 . A ratio of greater than one indicates that the cultivation is viable. The C-B ratio of rubber is greater than one since the year 2003 with the lowest in 1999 and its greatest found in the 2006-2010. Attractive economic returns lead to expand the plantation areas of rubber tree. Competition for upland in the high amount of annual rainfall between rubber tree and other field crops has occurred since the last decade when rubber price is economically viable. Moreover, rubber tree is a perennial crop that can not switch to annual crops in the short run. The annual crops can be changed to the perennial plant, depending on the attractive returns. The continuing expansion of the plantation areas is therefore evident in the past 5 years, the extension program of Thai government, granting over 40 million rubber saplings to farmers, resulted in the expansion of the plantation areas of about 160,000 ha. Recently, the government has declared to extend the granting program for 2nd phase with the same number of saplings.

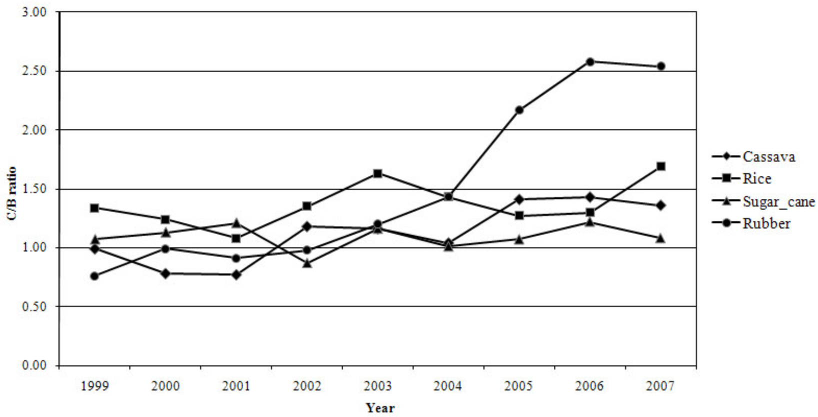

Figure 4 The C-B ratio of rubber plant as compared to rice, cassava and sugar-cane

4. CONCLUSIONS

Differentiation and classification of rubber tree of different tree ages can be derived from the cover tone and pattern of images. The panchromatic images could resolve the young rubber plant through the plant spacing pattern. Integrating rainfall, landform and soil could help the estimates of rubber plantation areas effectively and rapidly. The main drivers in the expansion of the plantation areas included a combination of annual rainfall amount, landform, soil types and economic return. The rapid expansion of the rubber plantation is attractive economic return which is a prospect of the farmer in the Northeast. Further analysis of the plantation areas in terms of accuracy should be made with THEOS panchromatic data.

5. REFERENCES

Department of Agriculture. 2005. Rubber tree . Technical paper No.12/2004. Bangkok: The Agriculture Co-operative Federation of Thailand. [in Thai.]

Land Development Department. 2005. Rubber tree . Technical paper. Bangkok: Office of Land Management Research and Development, Land Development Department. [in Thai.]

Meti S., Rao D.V.K.N, Usha Nair N., and Jacob J. 2008. Distribution of natural rubber cultivation in relation to soil and landscape attributes in india. In proceedings 29th ACRS 2008 at Colombo, Srilanka.

Office of Agricultural Economics. 2004. Agricultural Statistics of Thailand 2004. Agriculture Statistics No. 410. Nonthaburi: Sahamit printing Publisher. [in Thai.]

Office of Agricultural Economics. 2005. Agricultural Statistics of Thailand 2005. Agriculture Statistics No. 414. Nonthaburi: Sahamit printing Publisher. [in Thai.]

Office of Agricultural Economics. 2006. Agricultural Statistics of Thailand 2006. Agriculture Statistics No. 401. Nonthaburi: Sahamit printing Publisher. [in Thai.]

Office of Agricultural Economics. 2007. Agricultural Statistics of Thailand 2007. Agriculture Statistics No. 401. [n.p.]. [in Thai.]

Office of Agricultural Economics. 2008. Base data of Agricultural Economics 2008. Agriculture Statistics No. 413. [n.p.]. [in Thai.]

Office of Agricultural Economics. 1990-2003. Agricultural Statistics of Thailand. Unpublished paper available from Office of Agriculture Economics. [in Thai.]

Paiboonsak S., Mongkolsawat C. 2006. GIS-based Land Evaluation for Rubber Plantation in Northeastern Thailand. In proceedings Space Technology and Geo-Informatics. Phitsanulok, Thailand. [in Thai.]

Pensuk A., and Shrestha RP. 2008. Effect of Paddy Area Conversion to Rubber Plantation on Rural Livelihoods: A Case Study of Phatthalung Watershed, Southern Thailand. GMSARN International Journal, 2(4), 185-190.

Prabhakaran K.P. 2010. The Agronomy and economy of Important tree crops of the developing world. Burlington, USA: Elsevier publications.

Sombatsompop N., Markpin T., Wimolmala E., Ratchatahirun P., Premkamolnetr N., Boonradsamee B., and Yochai W. 2009. Relationship on research publications and productivity-export volumes for natural rubber. Scientometrics, 81(2), 393-405.

Suratman M.N., Bull G.Q., Leckie D.G., Lemay V.M., Marshall P.L., and Mispan M.R. 2004. Prediction models for estimating the area, volume, and age of rubber (Hevea brasiliensis) plantations in Malaysia using Landsat TM data. International Forestry Review, 6(1), 1-12.

Watson G.A. 1989. Climate and soil. In: Webster C.C. and Baul-kwill W.L. (eds), Rubber. Longman, Essex, London, pp. 125–164.