ENVIRONMENT

BRAC Research Report

July 2008

Agarwood Plantation at BRAC Tea Estate: Introduction, Environmental Factors and Financial Analysis

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ACKNOWLEDGEMENTS

The authors would like to express their heartiest gratitude to BRAC Tea Estate for giving the opportunity to be part of this programme through research. The authors thank the programme personnel for giving all out cooperation; especially to the field staff without whose support and assistance it would not have been possible to conduct this study. The authors would particularly like to thank Saieed Bakth Mozumder, Director of BRAC Tea Estates for his continuous support and encouragement and showing his keen interest for this project. Special thanks also due to Lutfur Rahman, Senior Manager of Karnafully Tea Estate, Mohammad Shahedur Rahman, Manager, Development and Coordination, Abdul Kuddus Sheikh, Manager, Kaiyachara Dalu Tea Estate, and Taslim Uddin Ahmed Chowdhury, Manager, Chandpur Belgoan Tea Estate for their assistance in the field activities and for doing the hardest job of managing the field activities. Thanks to environmental research team for their support and assistance. Nevertheless special thanks to Imran Matin, Deputy Executive Director, BRAC International Programme for the interest he had and the inspiration he showed for this work.

The Research and Evaluation Division (RED) is supported by BRAC's core funds and funds from donor agencies, organizations and governments worldwide. Current donors of BRAC and RED include Aga Khan Foundation Canada, AusAID, Australian High Commission, Brigham Young University, Bill and Melinda Gates Foundation, BRAC University, NIKE Foundation, Campaign for Popular Education, Canadian International Development Agency, Charities Aid Foundation-America, Columbia University (USA), Conrad N Hilton Foundation, Danish International Development Agency, DEKA Emergence Energy (USA), Department for International Development (DFID) of UK, Embassy of Denmark, Embassy of Japan, European Commission, Fidelis France, GITAC Consult GmbH, The Global Fund, GTZ-Germany, Government of Bangladesh, The Hospital for Sick Children, ICDDR,B Centre for Health and Population Research, ICLARM/World Fish Centre, Institute of Development Studies (Sussex, UK), Inter-Cooperation Bangladesh, International Committee of the Red Cross, Japan International Cooperation Agency, International Research and Exchange Board, The Johanriter, Land O Lakes (USA), Manusher Jonno Foundation, Micro-Nutrient Initiative, NIKE Foundation, NORAD, NOVIB, OXFAM America, Plan Bangladesh, The Population Council (USA), RNE/DGIS, Embassy of the Kingdom of the Netherlands, Royal Netherlands Embassy, Royal Norwegian Embassy, Scojo Foundation Incorporation, SIDA, Sight Savers, Stanford Medical School, Swiss Development Cooperation, ULG Northumbrain, UNICEF, United Way International, University of Calgory, University of Leeds, University of Manchester (UK), World Bank, World Food Programme, and World Health Organization.

RED received wide support and cooperation from all divisions of BRAC, particularly from the field staff and the people of Bangladesh without whose sincere support and patronage no field research could be conducted smoothly. RED also received useful comments, suggestions, and guidance from researchers, reviewers, and editors from within and outside the country, which helped improve the quality of research and research outputs. RED is indebted to BRAC management for its continued support.

ABSTRACT

The Aquillaria malaccensis (known as agar) produces agarwood which is used in perfumes, incense and medicines, and thus, can be extremely valuable. Excessive harvesting of agarwood has made this species threatened. Considering its conservation value and economic benefit BRAC has started agarwood plantation at Kaiyachara Tea Estate from July, 2007. At Kaiychara tea estate, a plantation of about 17 acres has been created, where 83,400 agar seedlings have been planted between August and October 2007. In addition, 700,000 agar seedlings have been planted in two nurseries, namely 'Kaiya' and 'Sirgasia', at Kaiyachara tea estate. The survival rate of young seedlings was around 95%, which can be considered impressive. The habitat provided by the environment in the tea estate, along with the microclimatic and soil condition in that area is favourable for growing agar plants. Initially, the BRAC tea estate plans to plant 50 acres of land with agar plant, after which agarwood harvesting would take place after 12 years. Assuming 90% survival rate and 2 kg premium quality agarwood production per plant the estimated investment related to plantation would be Tk. 145,497,198 and total return would be Tk. 60,907,155,348 with the rate of return 41,861%. However, this high rate of return is an underestimate given the environmental benefits of this plantation would generate. The establishment of this plantation would also be significant in terms of the environmental conservation of this endangered species, as well as provide a carbon sink to reduce green house gases. Furthermore, there are potential opportunities that would arise in the future for improving the livelihoods of poor people in the region by providing income generating means. This report was prepared after field investigation and laboratory analysis and contains suggestions regarding proper management of the plantation as well as further research.

PART 1: ABOUT AGARWOOD

BACKGROUND

Agarwood is a resinous substance occurring in trees of the genus *Aquilaria* (a member of the Thymelaeceae family), a fast-growing forest tree which can be found growing from the foothills of the Himalayas to the rain forests of Papua New Guinea. *Aquilaria malaccensis* is one of the15 tree species in the Indo-Malaysian genus *Aquilaria*. It is a large evergreen tree, growing over 15-40 m tall and 0.6-2.5 m in diameter, and has white flowers (Chakrabarty *et al*., 1994, Sumadiwangsa, 1997). *A. malaccensis* and other species in the genus *Aquilaria* sometimes produce resin-impregnated heartwood that is fragrant and can be extremely valuable depending on the oleoresin content of the wood. There are many names for this resinous wood, including agar, agarwood, aloeswood, eaglewood, *gaharu* and *kalamabak*, this wood being in high demand for medicine, incense and perfumes across Asia, Middle East and Europe. First-grade agarwood is one of the most expensive natural raw materials in the world, with prices in consumer countries ranging from a few dollars per kg for low quality material to more than US$30, 000 per kg for top quality wood. Agarwood oil fetches similarly high prices (Agarwood "Wood of Gods" International Conference, 2003).

DISTRIBUTION AND HABITAT

Aquilaria malaccensis is widely distributed in south and south-east Asia. There are differing accounts of the countries in which it occurs. According to Oldfield *et al*. (1998), *A. malaccensis* is found in 10 countries Bangladesh, Bhutan, India, Indonesia, Iran, Malaysia, Myanmar, Philippines, Singapore and Thailand. *Aquilaria* species have adapted to live in various habitats, including those that are rocky, sandy or calcareous, well-drained slopes and ridges and land near swamps. They typically grow between altitudes of 0-850 m, in locations with average daily temperatures of 20-22o C (Afifi, 1995; Keller and Sidiyasa, 1994; Wiriadinata, 1995).

ENVIRONMENTAL AMPLITUDES

Climate descriptors

- Altitude range: 29 – 1,000m
- Mean annual rainfall: 1,500 – 6,500 mm
- Rainfall regime: summer
- Dry season duration: 0 – 4 months
- Mean annual temperature: 22 - 28ºC
- Mean maximum temperature of hottest month: 22 - 40ºC
- Mean minimum temperature of coldest month: 14 - 22ºC
- Absolute minimum temperature: 5ºC
- Soil texture: light; medium
- Soil drainage: free
- Soil reaction: acid; neutral
- Special soil tolerances: shallow; other

Silvicultural characteristics descriptors

- Tolerates drought; shade
- Ability to suited for coppicing

Silvicultural practice descriptors

- Seed storage recalcitrant
- Stand establishment using natural regeneration; planting stock

Pests recorded

Phialophora parasitica

PRODUCTION OF AGARWOOD

Three hypotheses exist regarding agarwood formation, namely that it is the result of pathological, wounding/pathological and/or non-pathological processes (Ng *et al*., 1997). According to Ng *et al*. (1997), studies have not provided conclusive evidence for any of these hypotheses. Oldfield *et al.* (1998) states that resin production is in response to fungal infection, and Heuveling van Beek (TRP, *in litt.* to TRAFFIC International, 2 May 2000) said that it is in response to wounding. The author also adds that fungal infection can increase resin production as a host response to increased damage due to fungal growth. *Aquilaria* trees are naturally infected by a variety of fungi including: *Aspergillus* spp., *Botryodyplodia* spp., *Diplodia* spp., *Fusarium bulbiferum*, *F. laterium*, *F. oxysporum*, *F. solani*, *Penicillium* spp., and *Pythium* spp. (Anon., 1998a; Santoso, 1996, cited in Soehartono and Mardiastuti, 1997; Wiriadinata, 1995). However, the ecological interaction between the host tree and the wound and/or the fungi in order to produce agarwood is poorly understood. Other factors such as the age of the tree, differences in the tree caused by seasonal variation, environmental variation and genetic variation of *Aquilaria* spp. may also play an important role in agarwood formation (Ng *et al*., 1997). Not all *Aquilaria* trees produce agarwood; Gibson (1977, cited in Ng *et al.*, 1997) estimated that only approximately 10% of wild *Aquilaria* spp. produces resin. Gianno (1986, cited in La Frankie, 1994) suggested that only one-tenth of mature trees above 20 cm diameter at breast height (dbh) produce agarwood. According to Chakrabarty *et al*. (1994), infected trees produce resin from the age of 20 years onwards; Sadgopal (1960, cited in Soehartono and Mardiastuti, 1997) suggesting that the best yields are obtained from trees aged 50 years and over. Recent studies undertaken by The Rainforest Project (TRP) in Vietnam have shown that agarwood formation can occur in cultivated trees as young as three years of age, as confirmed by chemical analysis (H. Heuveling van Beek, TRP, *in litt.* to TRAFFIC International, 2 May 2000). The yield and qualities of the resinous agarwood also varies considerably (Hartadi, 1997; Ng *et al*., 1997; Oetomo, 1995; Wiriadinata, 1995). Research conducted in West Kalimantan, Indonesia, shows that the yield of *Aquilaria* resin does not correspond with tree diameter or timber volume, even when trees have similar indications of infection (Soehartono and Mardiastuti, 1997). Gianno (1986, cited in La Frankie, 1994) suggested that those trees above 20 cm dbh that produced agarwood provided approximately one kg of agarwood per tree.

However, a recent discovery from the University of Minnesota has revolutionized the agarwood production. Through a method of inoculation of specific chemicals, the rate of agarwood formation is increased. The patent right document prepared claims that agar would production through the use of this inoculation increases to 30 percent as opposed to the 7 percent that occurs naturally and more importantly this inoculation can be done at an younger age than that mentioned above.

HARVESTING

Agarwood is extracted from trees by felling and splitting them to reveal the resinous product. The roots of *Aquilaria* trees may also contain resin and if so are also harvested for trade. As noted above, only a relatively small percentage of *Aquilaria* trees are likely to produce agarwood. Dying trees are thought especially likely to contain agarwood, indications that trees

are dying including yellowish leaves, leafless branches with swollen spots along the branch and trunk and very dry bark. Although infected trees apparently exhibit certain symptoms outlined above, it is not possible to identify agarwood-producing trees in a reliable manner by visual inspection. Additionally, according to Heuveling van Beek (TRP, *in litt.* to TRAFFIC International, 2 May 2000) many trees produce very small amounts of low-grade agarwood that is difficult to detect if the harvester is searching only for high-grade dense deposits.

USES OF AGARWOOD

Agarwood has three principal uses: medicine, perfume and incense. Smaller quantities are used for other purposes, such as carvings. These uses are described in more detail below.

Use in medicine

Agarwood has been used for medicinal purposes for thousands of years, and continues to be used in Ayurvedic, Tibetan and traditional East Asian medicine (Chakrabarty *et al.* 1994; Fratkin, 1994). The *Sahih Muslim*, which dates back to approximately the eighth century, refers to the use of agarwood for the treatment of pleurisy and its use is referenced in the Ayurvedic medicinal text the *Susruta Samhita*. Agarwood is prescribed in traditional East Asian medicine to promote the flow of *qi*, relieve pain, arrest vomiting by warming the stomach, and to relieve asthma (Anon 1995a). High-grade agarwood powder is prescribed in Chinese medicine (Yaacob 1999) and is also used in the production of pharmaceutical tinctures (Heuveling van Beek and Phillips 1999). Burkill (1966) reported that Malaysians used agarwood mixed with coconut oil as a liniment, and also in a boiled concoction to treat rheumatism and other body pain. Chakrabarty *et al.* (1994) reported that the often-discarded uninfected wood is used as *Kayugaharu lemppong* by Malaysians to treat jaundice and body pains. Agarwood is also prescribed for dropsy, as a carminative, a stimulant, for heart palpitations, and as a tonic taken particularly during pregnancy, after childbirth and for diseases of female genital organs (Chakrabarty *et al*. 1994).

Use in perfume

The use of agarwood for perfumery extends back several thousand years, and is referenced, for example, in the *Old Testament* several times using the term ‘aloes’. Both agarwood smoke and oil are customarily used as perfume in the Middle East (Chakrabarty *et al.* 1994). In India, various grades of agarwood are distilled separately before blending to produce a final ‘attar’. *Minyak attar* is a water-based perfume containing agarwood oil, which is traditionally used by Muslims to lace prayer clothes (Yaacob 1999). Agarwood perfumes are seldompure agarwood oil, but instead use an alcoholic or non-alcoholic carrier, such as sandalwood oil. The cheapest agarwood perfumes are either synthetic or a blend of oils, each with different qualities and fragrances. Although there are several commercially available synthetic agarwood fragrance compounds, they can produce only low-quality agarwood fragrances, owing to the chemical structure of natural oil (Heuveling van Beek and Phillips 1999). Agarwood essences have also been used as a fragrance in soaps and shampoos (Kadir *et al.* 1997, cited in Schippmann 1999).

Use in incense

Agarwood incense is burned to produce a pleasant aroma, its use ranging from a general perfume to an element of important religious occasions. Irregular chunks of agarwood, usually a few centimeters long and weighing 10-200 g, may be cut or broken into smaller pieces and then burned, usually in a specially made incense burner (Heuveling van Beek and Phillips 1999). Agarwood powder and dust cannot be burned directly in incense holders, but can be used to make incense sticks or coils for indoor fragrance, and are used for religious purposes by Muslims, Buddhists and Hindus (Yaacob 1999). Taiwanese consumers purchase agarwood for

the manufacture of incense sticks, which are used in prayers during many traditional festivals and ceremonies to bring safety and good luck (TRAFFIC East Asia-Taipei, *in litt*. to TRAFFIC International[1], 2 May 2000). Both Indians and Chinese have used agarwood as an essential ingredient of incense sticks in the past, but in the present day incense sticks generally do not contain agarwood, although Indian traders report that high-quality Indian incense sticks destined for export may have a drop of agarwood oil added to them (Chakrabarty *et al*. 1994). *Agarbattis* are incense cones, which also originally contained agarwood powder but seldom, do so now because of the high price of agarwood. Instead, the light cream/brown powdery waste material obtained from oil distillation (with little or no resin content) is used to provide a basic carrier for other, cheaper, fragrant ingredients. This waste agarwood powder sells for around USD5/kg. Japanese incense products are very different, with most of the highest-grade products made using natural raw materials, which include ground agarwood extracts combined with other ingredients such as sandalwood and benzoin and then carefully molded and baked. Pure agarwood is also burned as incense in Japan. In Malaysia, Muslims burn agarwood splinters or chips to produce incense during special religious occasions, particularly at gatherings, and agarwood incense has been recorded in use there during Ramadan prayers (Chakrabarty *et al.* 1994). Agarwood incense is used for various purposes in the Middle East, especially during prayers (Yaacob 1999). Agarwood chips and splinters are also burned in bathrooms and incense is used as a customary perfume.

INTERNATIONAL TRADE IN AGARWOOD AND RELATED PRODUCTS

Accounts of international trade in agarwood date back as early as the thirteenth century, India being one of the earliest sources of agarwood for foreign markets. Agarwood is currently traded in large quantities. Over 700 tons of agarwood from *Aquilaria malaccensis* were reported in international trade in 1997, with exports from Indonesia and Malaysia taking the lead among approximately 20 reported countries of export/re-export. Although overall trade volumes may appear small in 'timber trade' terms, they are not small in monetary terms. Agarwood chips and segments may sell for several hundred to several thousand US dollars per kg. The price of oil distilled from agarwood is generally between us $ 5,000 and 10,000 per kg, but can be significantly more for agarwood oil of exceptionally high quality.

CONSERVATION STATUS

Populations of eight *Aquilaria* species have already declined to the point where they are considered threatened according to IUCN Red List Categories (Oldfield *et al.* 1998). Of these, six species are considered at risk from over exploitation for agarwood. A report by Chakrabarty *et al.* (1994) documenting India's trade in agarwood concluded that *A. malaccensis* is highly threatened in that country due to exploitation of the species for commercial purposes. Seven other *Aquilaria* species are also considered threatened according to the IUCN Red List Categories, five of which are considered to be at risk from over exploitation for agarwood: *A. beccariana* (Vulnerable); *A. crassna* (Critically Endangered); *A. cumingiana* (Vulnerable); *A. hirta* (Vulnerable) and *A. microcarpa* (Vulnerable) (Oldfield *et al.* 1998). Agarwood is now found occasionally in the wilds of Vietnam, Laos, Burma and Cambodia. It is no longer found in India, Bangladesh, Thailand or China.

CURRENT MEASURES

With the prospect of continued demand in the face of declining supplies, projects are underway in several countries to increase agarwood production via cultivation of *Aquilaria* species (e.g. in India, Indonesia, Vietnam) and through seeking to artificially induce *Aquilaria* trees to

[1] The wildlife trade monitoring network, works to ensure that trade in wild plants and animals is not a threat to the conservation of nature.

produce agarwood (e.g. in Indonesia, Vietnam). In general, such efforts do not yet appear to have succeeded in producing agarwood in commercial quantities sufficient to offset demand for wild stock. However, agarwood is being produced by *A. malaccensis* plantations in India and a programme to induce agarwood production in cultivated *Aquilaria* trees in Vietnam is reported to have succeeded on an experimental basis.

Action is urgently required on a number of fronts to reduce the current patterns of over-harvest and illegal trade. Much more needs to be known regarding the status and biology of those species in trade, especially in countries known to be exporting large volumes of agarwood, e.g. Cambodia, Indonesia, Malaysia, Thailand and Vietnam. Increased research in these and other countries should be given high priority. More needs to be known regarding the flow of benefits from agarwood harvests and trade in order to increase the opportunities and incentives for better management of harvests and trade. More effective harvest and trade controls, including improved CITES implementation and better tools for the identification of species in trade are also required. Specific attention should be paid to the making of nondetriment. Picture 1-4 are showing agar plantation, agar seed and agarwood inside agar timber.

Picture 1. Agarwood plantation in Vietnam

Picture 2. Mother plant for BRAC agarwood plantation at Colonel's garden

Picture 3. Seed of agar plant at Lauchora government forest Moulovibazzar

Picture 4. Agarwood (dark color) production inside agar timber

PART 2: AGARWOOD PLANTATION AT BRAC TEA ESTATE

PLANTATION INFORMATION

In collaboration with Research and Evalaution Division and tea estate of BRAC a project on agarwood plantation has been initiated at Kaiyachara Tea Estate, Fatikchari since July 2007. Three separate agarwood related facilities/plantation have been established. Two of those three are for growing and nurturing agar seedlings and the other is the plantation cite. Species selected for plantation has been identified *(Aquilaria malaccensis)* by Robert A. Blanchette, professor of Department of Plant Pathology, University of Minnesota, USA at his laboratory with gene sequencing from leaf sample. This sequence matches the library sequences they have for *Aquilaria malaccensis*. There are some differences in the sequence from Bangladesh as compared to A. malaccensis growing in Malaysia. According to Blanchette this may just be a difference in the population structure of the tree in the different areas (personal connection). However, this species considered highly threatened according to the IUCN Red List Categories.

Figure 1. Chloroplast DNA sequencing for *Aquilaria malaccensis* mother plant collected from Colonel garden in 2007

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ACGCAGCTGCGCTGAATAGTAGAGGAATCCGTCGACTTTGAAAATCGTGAGGGTTCAAGTCCCTCTATCCCCAAC
CTCCAAAACCCGCTGACGCTCTACCTATTTTTTTTTTTGATTTCTACCTATTTTTTATCTTACCCTCTCCTTTTG
TTAGGGGTTCAAAGTTACTTATCTTTCCCATTCATCCTATTCTTTTCCATTTTACAGGGGTATCCGAGCATCATT
TTTTCTCTTAACACAAATATAGGTACAAATCAACATTTTTGAGTAAGGAATACCCATTTGAATGATTCAAAATCA
TTACTCAGACTGAAACTTACATACAAAGTCGTCCCTTCGAAGATTCGGTCAATTCCCGTTCGCAACTTTGACTTT
GATTTTATTGGAATACTTTTTTTCGCCTTTTTTTTTTCCATTTAATTTGGATTTTTTCATTTTACCAGGCCCTCAA
TAAAAATGAGGATGAGGTCTTGGAAAGGGCGGGAAAACCAACTGGGAAAAAAAAAAAAAAAATGTGGGATAAAAGC
TGCACGCAAGCATATCAAAGGTGAGGGAGAAACCCCCACTGGAA
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PLANTATION SPECIFICATION AND CURRENT STATUS

Under the supervision of BRAC tea estate Kaiyachara division a 17 acre plantation has been created, where 83,400 agar seedlings have been planted between August and October 2007. The average spacing between each plant is three feet while the average age of the trees planted is one year. The observed survival rate is around 95%. The average elevation of the plantation is 50 meters, with two peaks of 65 meters. This is within the optimum altitude of agar vegetation and it provides a good drainage system. Thus, it is not surprising that even with 11 inches of rain in 8 hours (October 16, 2007) no major damage occurred in agar plantation. About 70 % of the plants face in the southwest direction. The rest of the plants face northeast, southeast or west.

It was observed that the plants that were planted earlier in the planting cycle have better morphological features than the plants planted later in the cycle. Given the short age of the plantation and the high survival rate, it can be deduced that the plants are adapting well to the plantation area. The diameter ranged from 0.25-0.5 inches and height ranged from 1.5-2 feet. The foliage was observed to be good, however, the leaves are turning yellowish due to the arrival of winter.

Discussions with the managers of the plantation, it was found out that there were, little threats to the plantation from water logging, pests or encroachment from other species of plants or animals. However, the manager pointed out the threats of natural disaster like cyclone and

droughts, but also believed that irrigation would not be required at this point due to the availability of enough moisture in the soil.

The plantation is under strict surveillance of the managers, who visit the site at least two times a day. There plantation has been subjected to two rounds of weeding to provide maximum nutrients to the agar plants. Also during the preparation phase, 3753 Kg. of chemical fertilizer and cow dung were added to the soil.

About 700,000 agar seedlings have been planted in two nurseries namely 'Kaiya' and 'Sirgasia' at Kaiyachara tea estate. The Kaiya nursery provides habitat for most of these seedlings. The seedlings in this nursery are under the natural shade of *garzan* trees. On the other hand, the seedlings in Sirgasia nursery are grown under bamboo sheets (with 60 % permeability to light). From field observation it seemed that the seedlings in the Sirgasia nursery are showing more robust growth. However, this could be because of the artificial environment that is being provided with optimum sunlight and nutrients.

Survival rates of seedlings are not as high as in the plantation, but that is due to the heavy rainfall, which resulted in the erosion of topsoil in the nursery beds. The average age of the seedlings are 3-4 months and the managers of the plantation are happy with their growth and expect them to be ready for the next planting season.

Apart from this, Karnafuli tea estate planted agar in 2004 covering 1.56 acre with 426 plants. Those were found growing well in that condition. Detail specification of Karnafuli tea estate plantation is given in Table 1 below.

Table 1. Agar plantation at Karnafuli Tea Estate, Chittagong

1	Year of planting	-	2004
2	Total area	-	1.56 Acres
3	No. of plants	-	426
4	Spacing	-	10' X 10'
5	Treatment done (manuring)	-	Applied cow dung every year @ 5kg/plants

Size of plant

Sl. No.	Diameter	Height	No. of plants
1	13"	16'	8
2	12"	14'	10
3	11"	13'	8
4	10"	12'	40
5	9"	10'	25
6	8"	9'	20
7	7"	8'	29
8	6"	7'	42
9	5"	6'	40
10	4"	6'	50
11	3"	5'	18
12	3"	4'	22
13	2"	4'	26
14	2"	3'	25
15	1"	2.0' – 2.5'	63

The seedlings were acquired from various sources from different parts of agar vegetation. This was to ensure robustness of the plantation and avoid monoculture. However, it seems from initial observation that most of the plants are of the same species though it may have genetic diversity and variation. Given BRAC's resources and the nature of this plantation it could be

practical to import seedlings from abroad to improve variety at BRAC plantation. However, this is also practical to use native variety to keep natural environment undisturbed.

ENVIRONMENTAL FACTORS

We collected data on the various microclimatic factors that are important for agar plantation. The average humidity recorded for 2007 was 79.4 with 96 being the highest and 54 being the lowest. The average daily difference in humidity was 3. Similarly the average temperature was 28.36° C. The average highest temperature was 31°C and the Average lowest temperature was 26° C. Thus, the difference between the highest and the lowest temperature on average was 6° C. The temperature condition falls within the range of agar plantation habitat. The following figures provide humidity, rainfall and temperature information for 2007.

Figure 2. Humidity trend at Kaiyachara garden during Jan-Oct 2007

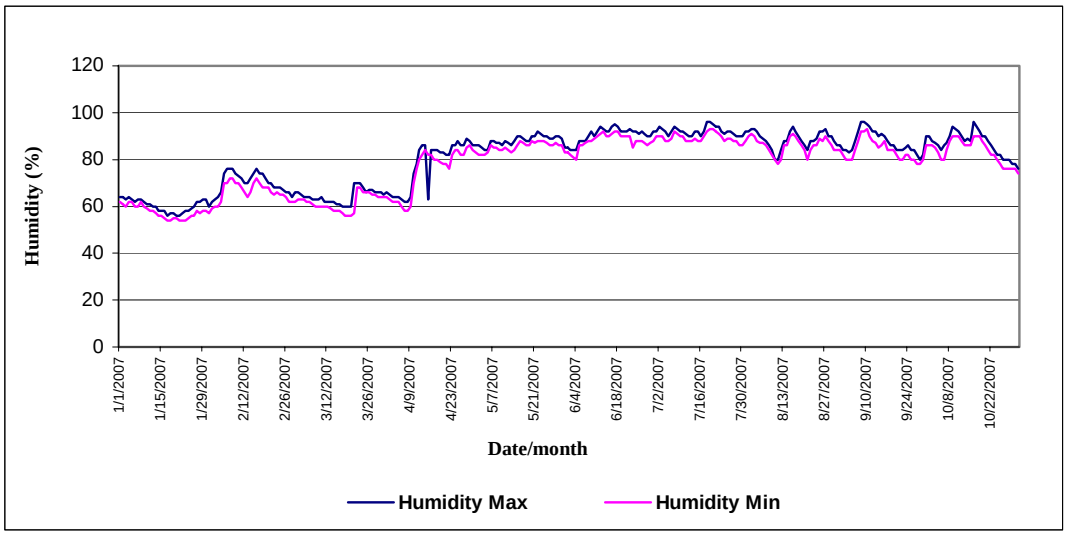
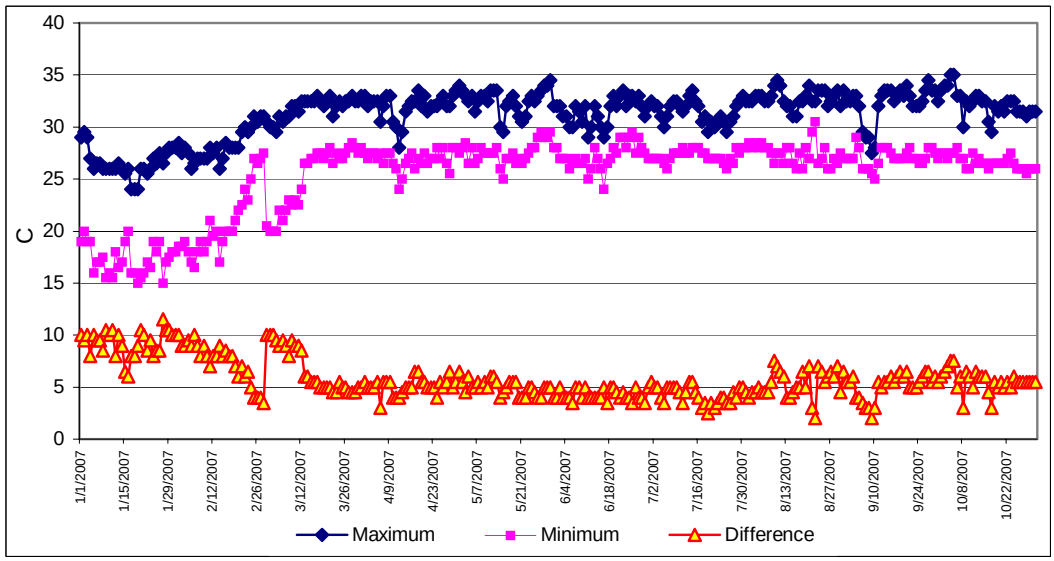
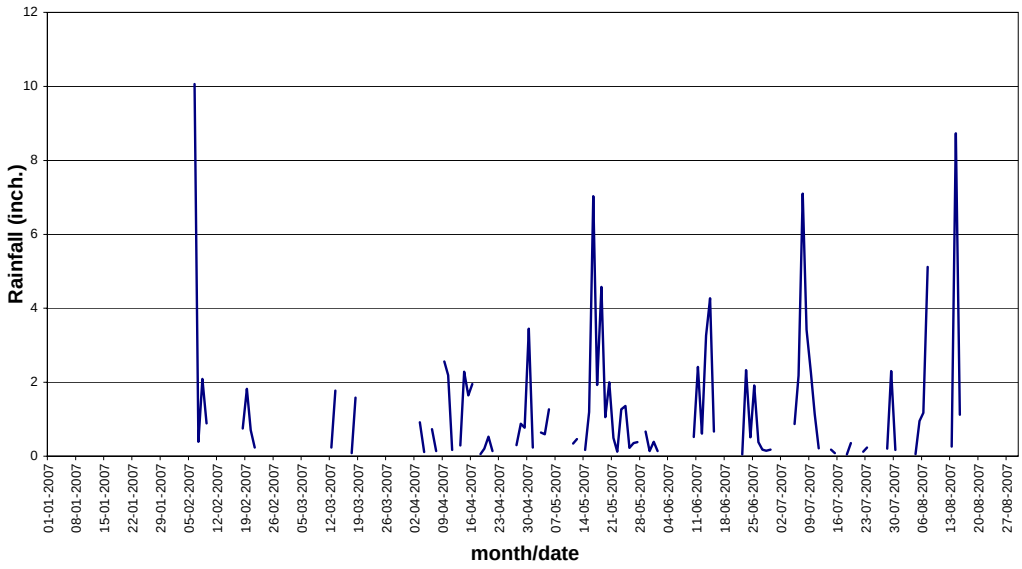


Figure 3. Temperature trend at Kaiyachara garden during Jan-Oct 2007



Rainfall is another important factor in the growth of agar trees. Agar trees do not thrive under extremely wet conditions, especially if there is water logging. Similarly, it also requires a decent amount of rainfall to grow. The following figure provides the data on rainfall patterns in Kaiyachara tea estates from January to October 2007. The total rainfall for the first 10 months of the year was 132.16 inches (3, 356.86 millimeter). This is also within the range of optimum condition for agar plantation.

Figure 4. Rainfall trend at Kaiyachara garden during Jan-Oct 2007



Soil analyses have been done before and after planting agar. Samples also collected from the garden mother plant growing (Colonel's Garden) from where most of the seedlings were collected. Table 2 shows the tested results of soil tests. The soil analysis indicates that the soils are different from other experimental places e.g. Vietnam. In Vietnam, soils are usually of pH 5.5 to 6.5 with a 3 to 5% organic matter. In this tea garden, the soil was found acidic with lower pH value than above and organic matter. The fertility of BRAC tea estate soils is also low (e.g. N, P, K), but this could be improved with addition of compose manure or fertilizer. However, the soil samples taken from an area that had *Aquilaria* growing (mother plant growing area at Colonel's garden) also showed similar results. Therefore, it seems that the *Aquilaria* growing in that area are adapted to the soil conditions. Further analysis of some more samples from *Aquilaria* growing at different places may help conclude the findings.

Table 2. Soil analysis of BRAC Tea Estates

ID sample	Soil test values and fertility status					
	pH	OM %	N %	P (ug/g)	K (meg/100g)	S (ug/g)
Soil analysis report (July 2007)						
Karnafuli Tea Est. Sample 0 - 9 inch	4.65 ST.A	1.40 L	0.074 V.L	2.43 V.L	0.033 V.L	5.86 V.L
Karnafuli Tea Est. Sample 9 -18 inch	4.58 ST.A	0.67 V.L	0.042 V.L	3.2 V.L	0.044 V.L	11.73 L
Karnafuli Tea Est. Sample 18 -36 inch	4.64 ST.A	0.26 V. L.	0.010 V.L	2.21 V.L	0.035 V.L	1.63 V.L
Zafarabad PIT No. 03 Sample 1 -9 inch	4.68 ST.A	0.33 V.L.	0.018 V.L	3.04 V.L	0.049 V.L	4.02 V.L
KTE Zafarabad PIT No. 03 Sample 9 -18 inch	4.50 V. ST.A	0.60 V.L	0.035 V.L	0.77 V.L	0.059 V.L	0.32 V.L
Zafarabad PIT No. 03 Sample 18 - 36 inch	4.64 ST.A	0.73 V.L	0.038 V.L	3.42 V.L	0.055 V.L	17.71 M
Kaiyacherra Dalua T.E singacia Div. Plot 01 Spot-Mannan bari tilla	**4.69 ST.A**	**0.60 V.L**	**0.030 V.L**	**1.54 V.L**	**0.087 V.L**	**0.94 V.L**
Kaiyacherra Dalua T.E singacia Div. Plot 02 Spot-Sona Miah tilla	**5.03 ST.A**	**0.80 V.L**	**0.043 V.L**	**0.55 V.L**	**0.072 V.L**	**5.32 V.L**
Kaiyacherra Dalua T.E singacia Div. Plot 03 Spot-near Anower tilla	**4.85ST.A**	**1.0 L**	**0.054 V.L**	**1.21 V.L**	**0.093 L**	**0.97 V.L**
Soil analysis report (September 2007)						
Title-Col Garden, Location mother plant, Topography tillah top Hohizon 0-9 inch	4.61 ST.A	1.07L	0.056 V.L	3.09 V.L	0.066 V.L	7.58 L
Title-Col Garden, Location mother plant, Topography tillah top Hohizon 9 –18inch	4.60 ST.A	0.67 L	0.052 V.L	1.99 V.L	0.051 V.L	4.89 V. L
Title-Col Garden, Location mother plant, Topography tillah top Hohizon18-36 inch	4.88 ST.A	1.14 L.	0.062V.L	1.65 V.L	0.052V.L	3.47 V.L
Title – Col Garden Location Nursery, Topography – tillah top Hohizon 0-9 inch	4.72ST.A	1.69L	0.094L	4.53VL	0.076V.L	3.69V.L
Title – Col Garden Location Nursery, Topography – tillah top Hohizon 0-9 inch	4.67ST.A	1.14 L.	0.060 VL	1.88 V.L	0.063 V.L	5.86 V.L
Title – Col Garden Location Nursery, Topography – tillah top Hohizon 0-9 inch	4.78 ST.A	0.8V.L	0.045 V.L	1.65 .L	0.075V.L	2.50V.L
Title-KDTE, Location Singachia Div. Topodraphy-Tillah topo Horizon 0-9 inch	**4.84 ST.A**	**2.95 M.**	**0.167 L**	**5.08 V.L**	**0.218M**	**2.82 V.L**
Title-KDTE, Location Singachia Div. Topodraphy-Tillah topo Horizon 9 –18 inch	**4.69 ST.A**	**1.0 L**	**0.054VL**	**2.21V.L**	**0.115 L**	**0.76 V.L**
Title-KDTE, Location Singachia Div. Topodraphy-Tillah topo Horizon 18-36 inch	**4.75 ST.A**	**1.34 L**	**0.076 V.L**	**1.87 V.L**	**0.099 L**	**1.63 V.L**

Note: V.ST.A- Very strongly acidic, ST.A- Strongly acidic, V.L- Very Low, L- Low, M- Medium
OPT- Optimum, KDTE – Kaiyacherra Dalua Tea Estate where agarwood is planted

FINANCIAL INFORMATION

There are several costs that are involved with building and maintaining a plantation. BRAC tea estate has spent Tk. 5,20,290 in acquiring the seedlings. This includes the transport cost as well. Tk. 75,000 was spent in preparing the land for planting agar seedlings (Tk. 4500 per acre for 17 acres). Tk. 7,500 and Tk. 22,000 were spent on buying fertilizers and compost/cow dung respectively. Total labor cost amounted to Tk. 3,25,000 which was equally distributed in preparing the nurseries and plantation. Other lump sum costs amounted to Tk. 2,50,000. This resulted in a net cost of Tk. 11,70,290.

If the costs were categorized into fixed and variable costs, the former would amount to Tk. 6,82,790[2] and the latter would Tk. 4,89,370[3]. Thus the average variable cost per acre of land would equal to Tk. 28786.70[4]. The initial plan of the BRAC tea estate was to plant 50 acres of land with agar. Given the cost, the total investment can be estimated to be Taka 21,22,114[5]. However, this investment does not include the maintenance of the plantation during its lifetime or further investment related to inoculation of plants.

Assuming a lifetime of the plantation of 12 years the total plantation cost can also be computed. If wage rate is Tk. 100 a day and 20 labourers work everyday, then the total cost per year would be Tk. 3,65,000. Given 10 % rise in wages every year due to inflation and 2 % discount rate, the total wages for the last 11 years of the plantation comes to around Tk. 59 lakh. If it is also assumed that Tk. 3 lakh annually as lump sum cost then the total lump sum cost equals (assuming 2% discount rate) to Tk. 29 lakh. Thus, the total cost related to plantation in the last 11 years of plantation would be Tk. 88 lakh. Given the initial investment of Tk. 21,22,114, the total cost related to plantation throughout its lifetime would be around Tk. 1 crore.

To populate all of the 50 acres of the agar plantation, a total of 245,294 plants will be required, of which 83,400 have been planted. If we assume a survival rate of 90 % then a total of 220,700 plants will require inoculation. Given that per unit price of inoculating a tree is about Tk. 700, the net cost equals to Tk. 15.5 crore approximately. Given that the inoculation will take place in the ninth year the present discounted value of the investment related to inoculation is Tk. 13.5 crore. The total cost related to the plantation is presented in Table 3.

Table 3. Break down of plantation cost (present value)

Description	Total (Tk.)	Total (Tk.)
Initial stages (First year) (as observed)		
Fixed cost	682,790	
Variable cost (17 acres)	489,370	
Variable cost (50 acres)	1,439,324	
Total initial investment		**2,122,114**
Second phase (predicted)		
Total labor wages	5,906,866	
Total lump sum investment	2,936,053	
Total investment in second phase		**8,842,919**
Inoculation fee		**134,532,166**
Total invesment related to plant		**145,497,198**

[2] Cost of seedling + cost of labor related to nurseries.
[3] Cost of land preparation + fertilizer cost + cost of labor related to plantation +other costs + land development tax.
[4] Total Variable Cost/17
[5] Average variable cost *50 + Fixed costs.

Similarly, a benefit stream that would be generated from the plantation can be calculated. For this analysis it will be assuming that each agar plant will produce 2 Kg of premium quality agar wood[6] and price of wood would be us $2000/kg. Exchange rate would be held constant at Tk. 70 per dollar and discount rate would be 2%. Assuming a survival rate of 90 % for this initial analysis, the total benefit generated from the plantation is represented in Table 4.

Table 4. Break down of benefits

Details	Total (Tk)	Total (Tk)
Total number of agar plants	220,700	
Total amount of agarwood (Kg)	551,750	
Revenue (us $)	1,103,500,000	
Revenue (Taka)	77,245,000,000	
Revenue at present value		**60,907,155,348**
Total Investment	145,497,198	
Total Return	60,907,155,348	
Rate of Return		**41,861%**

The rate of return was equal to the ratio of total return to total investments and it amounted to 418.61 or 41,861 %. Given that all the calculations are being done in present value terms, it means that if we invest one dollar in our agar plantation today, we will get 418.61 dollars tomorrow[7].

Table 5 shows the change in rate of return under different scenario. For all the scenarios, the price of us dollar is held at Tk. 70 per dollar, inflation rate is held at 10 %, discount rate is held at 2 percent. In the conservative scenario, each agar plant is expected to yield 1 kg. of agar, the price of agar is set at us $1800/ kg. and rate of survival is set at 70 %. In the optimistic scenario, the agar yield per plant is set to 4 kg/tree, price of agar is set to us $2,200/Kg. and the rate of survival is set at 90 %.

Table 5. Sensitivity test of agar plantation

Details	Base	Conservative	Optimistic
Total number of agar plants	220,700	171,656	220,700
Total amount of agarwood (kg)	551,750	171,656	882,800
Revenue (us dollars)	1,103,500,000	308,980,000	1,942,160,000
Revenue (Taka)	77,245,000,000	21,628,600,000	135,951,200,000
Revenue at present value	**60,907,155,348**	**17,054,003,497**	**107,196,593,412**
Total Investment	145,497,198	145,497,198	145,497,198
Total Return	60,907,155,348	17,054,003,497	107,196,593,412
Rate of Return	**41,861%**	**11,721%**	**73,676%**

The results of this sensitivity test can provide a range of financial benefits that can be obtained from agar plantation and the corresponding rate of return. It is safe to assume that the financial benefits would fall under this range as the assumptions for these different scenarios are so varying. Thus, if a dollar invests in agar plantation today can expect return in the range of 117.2 –736.8 dollars tomorrow. Just to give a reader a scenario to compare with, if BRAC was to invest a dollar on buying a savings certificate issued by the government, which pays 15 % interest per annum, for 12 years, will get a return of 4.21 dollars tomorrow.

[6] This is based on La Frankie, 1994 and patent document prepared by Blanchette.

[7] Ideally, it would be instantly, but for the sake of keeping things simple we are using the difference, i.e. a day in this case.

The calculations that are being presented in this section are purely done from a financial perspective. The economic rate of return might actually be lower than the financial rate of return. The economic rate of return is defined as the difference between the rate of return between the proposed project and the next best alternative. If the government savings certificate is considered the next best alternative, then the rate of return range will be lowered to 113-733 (approx.). However, it might be possible that there are other investments, which provide a higher rate of return than 4.21 times.

It must also be noted that no value was assigned to the environmental gains/losses that this plantation would provide. It is believed that as a result of the agar plantation there will be going to net environmental gains[8]. If this assumption were correct, the rate of return would be higher than what is mentioned earliar.

AGAR PLANTATION TO MEET BRAC VISION

BRAC considers environment as a crosscutting issue, hence it is an integral part of all programme and projects. There are some commercial ventures at BRAC, which is directly contributing to the environmental conservation, for example Agar plantation at BRAC tea estate. This plantation project would play a role in meeting the environmental responsibility of BRAC as biodiversity conservation serve a carbon sink to reduce emission of greenhouse gases (GHGs).

From literature review and discussion it was found that the demand for agarwood currently far exceeds the available global supply. Over harvesting and over-exploitation of *Aquilaria* species from the nature for agarwood production has made this plant threatened. Therefore, BRAC's agarwood plantation would help reduce the pressure on natural *Aquilaria* species and to conserve it. On the other hand, successful production and harvesting of agarwood would earn foreign currency and create employment opportunity specially for women in agar producing industry.

[8] Owing to carbon dioxide absorption and biodiversity conservation as Agar is a native threatened species.

CONCLUSION

BRAC has initiated agarwood plantation on experimental basis at the Kaiyachara tea estate since July 2007 with the aim of financial gain and environmental conservation in terms of species conservation and reduction of GHGs. Environmental condition and habitat at tea estate were found suitable for growing *A. malaccensis* as a source of agarwood. This is the similar species producing agarwood in Malaysia.

Financial benefits from agarwood production seem impressive in hypothetical financial analysis done in this report based on available literature. Therefore, actual production and benefits may vary in real situation which need more study and practical demonstration before final production.

However, an environmental benefit also is a considerable issue for this project. Six *Aquilaria* species are already considered threatened by over exploitation. Unless further actions are taken to control agarwood harvests and trade, it seems likely that wild populations of *A. malaccensis* and other agarwood-producing species will continue to decline. The negative impacts of such declines will be felt not only in terms of biodiversity loss but also in terms of the reduced availability of a highly valuable forest resource. Therefore, agarwood plantation initiated by BRAC is a timely effort.

For this project following things are suggested to consider

Management issues:

1. Exploring potential market for agarwood export
2. Business permit from the government as trade of this plant is prohibited according to CITES
3. Establishment of agar oil manufacturing industry employing rural poor women
4. Filling the gap by planting new seedlings where the seedlings died. May also plant new seedlings in a regular distance from 4-5 years old plant

Research issues:

1. Survival and growth rate of seedlings over the year
2. Genetic diversity of agar plants and best species/variety identification for best agar production
3. Vegetation study of agarwood habitat of tea estate (to see the pattern of biodiversity at that ecosystem)
4. Environmental parameters (selected) including soil nutrient content analysis from different agarwood plant location
5. Review of agarwood production rate in different country (naturally and with inoculation)

Regular monitoring of plantation is needed to identify any abnormalities and take remedial measures. Monitoring should include drainage, irrigation, plant growth (height, width), leaf color (nutrient deficiency), mortality, pest attack, etc.

Picture 5-8 are showing agar nursery and plantation at BRAC Tea Estate.

Picture 5. 'Kaiya' agar nursery under *garzan* tree

Picture 6. 'Sirgasia' nursery in 60%-40% shade

Picture 7. Agar plantation area at Kaiyachara tea garden

Picture 8. Agar plantation area at Kaiyachara tea garden

REFERENCES

Afifi (1995). *Proses pengolahan pohon gaharu sampai siap diperdagangkan dan tata cara pembudidayaannya, serta proese gaharu pembentukan gubal*. *In:Lokakarya Pengusahaan Hasil Hutan Non Kayu (Rotan, Gaharu, dan Tanaman Obat). Departemen Kehutanan*. Indonesia-UK Tropical Forest Management Programme. Surabaya, 31 July-1 August.

Anon (1995a). *A Coloured Atlas of the Chinese Materia Medica Specified in Pharmacopoeia of the People's Republic of China (1995 Edition).* Pharmacopoeia Commission of the Ministry of Public Health, P.R. China. Joint Publishing (H.K.) Co., Ltd., Honk Kong.

Anon (1998a). *Medicinal Plant Significant Trade Study (CITES).* India Country Report. TRAFFIC India and WWF-India, New Delhi. 103pp.

Burkill I (1966). *A Dictionary of Economic Products of the Malay Peninsula*, I. Government of Malaysia and Singapore. The Ministry of Agricultural and Cooperatives, Kuala Lumpur.

Chakrabarty K, Kumar A and Menon V (1994). *Trade in Agarwood.* TRAFFIC India and WWF-India, New Delhi. 51pp.

Fratkin J (1994). *Chinese Herbal Patent Formulas: A Practical Guide*. Shya ublications, Colorado, USA. 356pp.

Hartadi I (1997). The hunt for gaharu. *ConservationIndonesia*, July-September.

Heuveling van Beek H and Phillips D (1999). *Agarwood: Trade and CITES mplementation in Southeast Asia*. Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia.

Kadir AA, Ng LT, and Chang YS (1997). A review on agar (*gaharu*) producing *Aquilaria*species. *Journal of Tropical Forest Products* 2(2): 272-285.

Keller P and Sidiyasa K (1994). *Trees of Balikpapan-Samarinda Area, East Kalimantan, Indonesia: A Manual of 280 Selected Species*. The Tropenbos Foundation, Wageningen.

La Frankie J (1994). Population dynamics of some tropical trees that yield non-timber forest products. *Economic Botany* 48(3): 301-309.

Oldfield S, Lusty C, and MacKinven A (1998). *The Word List of Threatened Trees*. World Conservation Press, Cambridge, UK. 650pp.

Oetomo H (1995). *Tinjauan terhadap pemasaran komoditi gaharu Indonesia di perdagangan Internatsional*.

Schippmann U (Comp.). (1999). *Medicinal Plants Significant Trade Study: CITES Project S-109*. Unpublished report. 88pp.

Soehartono T and Mardiastuti A (1997). The current trade in gaharu in West Kalimantan. *Jurnal Ilmiah Biodiversitas Indonesia* 1(1).

Wiriadinata H (1995). *Gaharu*(*Aquilaria*spp.) *Pengembangan dan Pemanfaatan yang Berkelanjutan. In Lokakarya Pengusahaan Hasil Hutan Non Kayu (Rotan, Gaharu, dan Tanaman Obat). Departement Kehutanan*. Indonesia-UK Tropical Forest Management Programme. Surabaya, 31 July-1 August 1995.

"Wood of Gods" First International Agarwood Conference, Ho Chi Minh City & An Giang Province, Viet Nam, November 10 - 15, 2003.

Yaacob S (1999). *Agarwood: Trade and CITES Implementation in Malaysia*. Unpublished report prepared for TRAFFIC Southeast Asia, Malaysia.