DIWPA News Letter

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Message from the Chairperson

Shin-ichi Nakano

We Center for Ecological Research (CER) and National Institute of Ecology, South Korea (NIE) held the 2nd CER-NIE Joint Symposium at Maskawa Hall, Kyoto University on December 9, 2017. NIE and CER have concluded the Memorandum of Understanding for Academic and Research Cooperation for our new partnership in 2016. As the first step, we held the 1st symposium at NIE and enjoyed excellent talks by professors and/or researchers from both institutions. After the symposium, we CER have successfully acquired financial support as an additional management expenses grant to CER to hold a next symposium in Japan. There were two requirements by KU: the first, the grant should be used for encouraging young researchers (graduate students and post-docs) to make something international; the second, CER had to collaborate with other institutions of Kyoto University. We CER asked Primate Research Institution (PRI) and Field Science and Education Research Center (FSERC) to collaborate for holding the joint symposium with NIE. Some professors and graduate students of those institutions visited NIE, and NIE and those KU institutions had a fruitful discussion about the 2nd symposium. At that time, we decided the main theme "Ecology in a new generation: Interdisciplinary approach to biodiversity". In the symposium, we had two plenary talks by Prof. Takashi Saito (former president of Ecological Society of Japan), Hokkaido University and Prof. Kim Jae Geun (present president of Ecological Society of Korea), Seoul National University, and each six Japanese and South Korean young researchers gave talks. For more detail, please visit to the following URL: http://www.ecology.kyoto-u.ac.jp/download/2ndCER-NIE20171209poster.pdf

Some NIE researchers gave talks about IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) because NIE is the responsible organization for IPBES in South Korea, whereas speakers from Japan gave talks about basic ecology, interestingly.

We CER and NIE will hold one more symposium at the 8th congress of the East Asian Federation of Ecological Societies (EAFES) in Nagoya, Japan, from April 21 to 23, 2018. Further information is available at URL: http://www.e-eafes.org/EAFES/2018/

In addition, I attended 9th Workshop of Asia-Pacific Biodiversity Observation Network (AP-BON) held from February 21 to 22, 2018 in Bangkok, Thailand. I will continuously provide a report to you.

Message from the Secretary General

Atsushi Ishida

International Field Biology Course (IFBC) was held in November, 2017 at the Ogasawara (Bonin) islands, locating in the subtropical North Pacific Ocean about 1,000 km south of Tokyo. We invited a young researcher (a student of Ph.D. course) from Thailand. We are pleasured to introduce her report of activities in this newsletter. Her friend came to Japan from Thailand to attend the IFBC. Furthermore, a visiting researcher (Prof. Marc Abrams) also attended the IFBC, and I took a student in my laboratory. In this IFBC, my student explained the principal of leaf gas exchange measurements and his research topic to young researchers. This would be good experiences not only for the young researchers from Thailand but also for my student. A ship, Ogasawara-Maru, is the only transportation to the islands because there is no airport in the Ogasawara islands. It takes 24 hours from Tokyo Bay to the islands by the ship. The trip of the ship is usually smooth in summer, but the ship sometimes rolls and pitches in winter because of strong north wind. Because I conducted the IFBC in November, the ship rolled and pitched especially on the return trip. The ship arrived to Tokyo Bay with a delay of 1 hour. On the next day, we visited the laboratory of Prof. Yoshikazu Shimizu (Komazawa University), who has studied forest dynamics in the islands during 40 years. We could receive his lecture and conduct lively discussions with him. The topic is mainly forest change during the recent 40 years and the future change under global climate change. We had a good time with him. I would like to express my appreciation to Professor Marc Abrams and Professor Yoshikazu Shimizu.

Report 1

DIWPA International Field Biology Course at Ogasawara Islands in Japan on November 14-22, 2017

The companionship field biology trip: knowledge and opportunity to learn new academic experience

Issara Phromma

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Fig. 1. Chichi-jima island

I am a Ph.D. candidate in Environmental Science Program. My research interests are in the area of forest ecology, forest restoration and biodiversity. Participation in 2017 DIWPA International Field Biology Course (IFBC) at the Ogasawara islands in Japan provided me great opportunities to explore new environments and to meet new colleagues. Besides enhancing my technical knowledge and skills on field biology and forest ecology, attending the workshop helped broaden my visions the interaction with colleagues. When I receive the email to notify me that I am a winner of the IFBC application, I was very excited of the opportunity to learn and see parts of the world that I have never stepped foot on. Because it was my first time going to Japan.

At first, I was very excited about my long voyage to Ogasawara Islands. It took 24 hours to travel by ship from Tokyo to the Islands on Ogasawara-maru. As a result of having sea-sickness in less than an hour after boarding and slept most of the time on the ship. Chichi-jima Island, where the workshop took place was very wonderful and peaceful place (Fig. 1). We were in a group of five people: Prof. Atsushi Ishida, the Secretary General of DIWPA at Center for Ecological Research, Kyoto University; Prof. Marc Abrams, Senior American researcher of Forest Ecology and Tree Physiology at School of Forest Resources, Pennsylvania State University; Dr. Ananya Popradit, Varaya Alongkorn Rajabhat University, Thailand; Mr. Shin Matsuyama, a Ph.D. student at Kyoto University and I. They were friendly and they went to great lengths to look after my wellbeing. I had learned about history, people and nature of the Ogasawara Islands through the IFBC. Ogasawara Islands are small oceanic islands, located in the subtropical North Pacific Ocean approximately 1,000 km south of Tokyo (27˚04’ N and 142˚23’ E). We stayed at the main island, Chichi-jima with a total of 2,000 populations [1]. Chichi-jima covers an area of approximately 24 km^2. The highest elevation is 318 m above the sea level. The Ogasawara Islands were registered as an UNESCO World Heritage Area because of their incalculable natural value for the unique ecosystems in 2011. I also attained useful knowledges. First, Mr. Shin Matsuyama taught me how to use the LI-6400 (a portable leaf gas exchange measurement system). After that, I used the machine to study the physiological ecology of photosynthesis at the leaf

Fig. 2. The mesurement of leaf gas exchange with LI-6400

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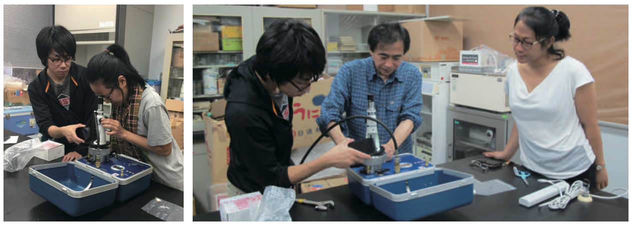

Fig. 3. The mesurement of leaf water potential with a pressure chamber

level (Fig. 2). It was difficult for me because it was my first hands on experience with the machine.

Secondly, we examined leaf water potential with a pressure chamber by studying the dehydration process of plants in 5 endemic species in the Ogasawara Islands and compared the differences of leaf water potential between daytime and night time. Prof. Atsushi Ishida explained the measurement procedures (Fig. 3), which all were new to me. I was surprised and very excited to see the analysis and it sparked my interest in dehydration processes of those endemic plant species. I was impressed with the ingenious machine.

Thirdly, we had a field study in eco-physiology of woody plants. I learned about of the usefulness of tree annual rings which Prof. Marc Abrams showed me how to identify the rings that represent tree history and their environments (Fig. 4).

Fourthly, during the field trip I learned about different forest ecosystems in the Ogasawara National Park. They are vastly different from the forest in Thailand. The typical vegetation adapted to dry climate, subtropical rainforest in cloud at high elevations and thin soil. The number of plant species and the proportion of endemic species within the forest are high, making the plant communities on the Islands very unique. I observed about six plant species. Some are similar to what I saw in Thailand, but the majorities, especially those endemic species in Ogasawara Islands, are new for me. For example, *Lantana camara, Stachytarpheta jamaicensis, Hibiscus tiliaceus, Hibiscus rosa-sinensis, Bougainvillea spectabilis, Pandanus boninensis etc.*

Finally, I learned about forest conservation and national park management by cutting trees alien

Fig. 4. A field study in Eco-physiology of woody plants

Fig. 5. The seed removal tools

tree species for conservation native species. People use the seed removal tools on clothes and shoes before entering National Park to prevent the spread alien species (Fig. 5). I have never seen these tools in Thailand. It helped me to better understand that effective forest conservation needs technical forestry knowledge. We visited Prof. Yoshikazu Shimizu at Komazawa University on the last day of the trip. He has studied forest dynamics for 40 years in the islands. He gave me ideas to develop my research data.

2017 DIWPA IFBC provided me opportunities to learn new knowledge in Forest Science, to develop my knowledge and to have useful discussions with other experts and participants. I gained valuable experiences for my Ph.D. research. We shared our experiences to facilitate understanding, as well as ways to conserve natural forest ecosystems. Furthermore, it was a wonderful trip to Chichi-jima with great foods and friendly companions. It was my pleasure to meet everyone who embarked on this trip with me. I hope to visit Ogasawara Islands again to study in depth about field biology, forest ecology, forest restoration and biodiversity in the future. Thank you very much again for giving me a chance to join the 2017 DIWPA IFBC.

Reference

Ogasawara Village Population Vision (Japanese) (PDF). March 2016. Retrieved 2017-09-08.

Report 2

Present Status and Future Opportunity of Agar Cultivation in Bangladesh

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Introduction

Agarwood or aloeswood is a dark resinous heartwood which forms in *Aquilaria* and *Gyrinops* trees (Blanchette 2006), large evergreens native to Southeast Asia when they become infected naturally or artificially. In the beginning of the infection, the heartwood is scentless, relatively light and pale colored. However, with the passage of time, the infection progresses and the tree produces a dark aromatic resin, called agar or aloes. This aromatic resin has many common names including gaharu, aguru, agar, oud, ude, ud, oodh, oode, jinkoh, jinko, Ch'Ing Kuei Hsiang, Ch'En Hsiang, Chan Hsiang, Chi Ku Hsiang, Huang Shu Hsiang, kalambak, grindsanah, eaglewood and so on. It is a high-priced incense that is extremely rare. One of the main reasons for the relative rarity and high cost of agar is the reduction of the wild resource (Broad 1995). Since 1995, *Aquilaria malaccensis*, the primary source of agar has been listed as a threatened species by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2005). At the end of 2004, all *Aquilaria* species were listed as a threatened species. Though, a number of countries have excellent conservation of *Aquilaria* species regarding that listing.

Agarwood is highly valued for its perfumery and medicine properties. Both agarwood smoke and oil are commonly used as a perfume in the Middle East (Chakrabarty *et al.* 1994). Agarwood incense is burned to produce a pleasant aroma, which is used ranging from a general perfume to an element of an important religious occasion. Taiwanese consumers use agar incense sticks in prayers during many traditional festivals and ceremonies to bring safety and good luck (TRAFFIC East Asia-Taipei, *in litt*. To TRAFFIC International 1, May 2, 2000). In Japan, it is considered as sacred and used to anoint the dead body. It is more expensive than gold (Japan Talk, August 26, 2012). In Buddhism, it serves as a major ingredient in many incense mixtures, and it is considered to be one of the three integral incenses, together with sandalwood and cloves (Barden *et al.* 2000). Although several commercial synthetic agarwood fragrance compounds are available, they can produce only low-quality fragrances, owing to the chemical structure of natural agar oil (Van Beek and Phillips 1999). Agarwood incenses have also been used as a fragrance in soaps and shampoos (Schippmann 2001). Besides perfume, 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 and Fratkin 1994). High-grade agarwood powder is used for aromatherapy (Lafrankie 1994), and also used in the production of pharmaceutical tinctures (Van Beek and Phillips 1999). It 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 (Hajar 2013). Burkill 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 (Burkill 1966).

Agar remains the world's most expensive natural raw

Mother plant for BRAC agarwood plantation at Colonel's garden

'Sirgasia' nursery in 60%-40% shade

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materials today. It is sold in the form of woodchips, wood pieces, powder, dust, oil, incense ingredients and perfume for several thousand US dollars per kilogram (Lafrankie 1994, Barden *et al*. 2000, Gunn *et al.* 2004 and Compton 2007). Agarwood chips start at US$30 per kg up to $9,000 per kg depending on its resin percentage (Babatunde 2015). Agarwood oil fetches similarly high prices (Agarwood "Wood of Gods" International Conference 2003). The highest grade agar oil is produced in China and is reported to cost over Tk.0.9 million (US$11,500) per kg. The second-best quality agar oil is sourced from Vietnam (Rahman *et al.* 2015). When agarwood chips are processed into oil, the agarwood oil was sold at US$30,000 per kg (Nanyang Siang Pau August 15, 2005). A whole range of qualities and products are on the market, varying in quality with geographical location, botanical species, the age of the specific tree, inoculation method and the section of the tree where the piece of agarwood stems from (Jung 2011). The value of agarwood shipped out of Singapore alone each year has been estimated to exceed US$1.2 billion (Hansen 2000). The current global market for agar oil and other related agarwood products is estimated to be in the range of US$6 to 8 billion (Akter *et al.* 2013) and the major industry buyer of agar oil, is expected to exceed US$36 billion in 2017 (http://www.ouddh.com/?C =2065877).

Recently, near about 300 agar-based enterprises producing agar chips, agar oil and agar related products in Bangladesh (Rahman *et al.* 2015). Around 25,000 to 30,000 workers are involved in agar cultivation, collection, processing, and agar-based products marketing throughout the country (Baksha *et al.* 2009), which might be much higher in the future. The net annual return from an agar-based enterprises is BDT0.8 million. Using local raw materials, indigenous inoculation methods and harvesting technology, they are exporting about BDT5.00 million to BDT100 million per year (Stakeholders consultation meeting, SME Foundation 2013). But there are no official data about agar oil or agar products exporting from Bangladesh and the entrepreneurs used to carry agar wood and agar oil in their hand bags to Dubai or Mumbai (major regional markets) to sale in cash. Because of its attractive financial contribution, *Aquilaria* trees are being planted both in the government-owned forest sites and in privately-owned homestead forests of Bangladesh which also plays a vital role in biodiversity conservation. As agar is a highly priced non-timber forest product, we have to ensure its quality and market. Otherwise, we will lose this potential productive sector. Keeping above in view, the objective of the study is to review the present status and future opportunity of agar cultivation in Bangladesh.

History of agar in Asia and Bangladesh

Agarwood is also known as the 'Wood of the Gods' which has at least a 3,000-year history in the Middle East, Japan and China (Le 2003). There are references of agar in many ancient and religious literatures. It is an essential part of culture and religious activities of Hindus, Buddhists, Muslim, Christians, Taos, Sufis and so on. The word 'aloes' has been mentioned several times in the Old Testament of Christians. As early as the third century A.D. in ancient China, the chronicle Nan zhou yi wu zhi written by Wa Zhen of the Eastern Wu Dynasty mentioned agarwood produced in the Rinan commandery (now Central Vietnam), and how people collected it in the mountains. During the sixth century A.D. in Japan, in the recordings of the Nihon Shoki (Chronicles of Japan), agarwood was mentioned as a fragrant wood. In the Nara period (710-794 A.D.), agarwood was incorporated into State ceremonies and Imperial Court functions, which was a tradition continued until the Meiji Restoration (1868) (Morita 1992). It was also mentioned in the 8th-century tomes of Shahin Muslims.

In the 17th century, agarwood production was started in the Suzanagar union under Barolekha Upazila of Moulvibazar district in Bangladesh (Abdin 2014). In that time, it was forest-based only, but due to limited access, social cultivation of *Aqularia* tree was started in the household lands. As a result production of best quality natural agarwood became a time-consuming process. Therefore, artificial inoculation (nailing) was introduced in the young *Aqularia* trees. Currently, agar farmers

Agar plantation at Sylhet

Agar plantation at Madhupur

are using trees from their own cultivated gardens. An *Aquilaria* tree takes 12-15 years to produce agar. About 8-10 years old tree are being selected for ironing (putting iron nails). About 100 to 150 kg iron rod is required for ironing a medium size agarwood tree. It took about 3-4 years to accumulate agar resin around the nails.

Present agar plantation status in Bangladesh

Bangladesh has suitable weather and huge abandon hilly land for agar cultivation. The Bangladesh Forest Research Institution (BFRI) has established 2.3 ha of experimental agar plantations at Charaljani and Keochia research stations in Chittagong. Bangladesh Forest Department (BFD) has established several hectares of agar plantations sporadically in denuded and encroached forest areas throughout the country, especially in Borduara (Satkania, Chittagong), Rangamati, Khagrachari, Bandarban hill tracks, Harbang and Fasiakhali (Chakaria, Cox'sBazar) districts including 785 ha in Sylhet forest division (Hossen and Hossain 2016). In 2004 Karnafuli tea estate planted agar covering 1.56 acres with 426 plants. Later, in collaboration with Research and Evaluation Division, BRAC (Bangladesh Rehabilitation Assistance Committee) Tea Estate started an agar plantation project at Kaiyachara Tea Estate, Fatikchari in July 2007. They established two gardens for growing and nurturing agar (*Aquilaria malaccensis*) seedlings and one for plantation. BRAC Tea Estate Kaiyachara division has planted 83,400 agar seedlings covering 17 acres of land between August and October 2007 (Akter and Neelim 2008). 95% of seedlings have been sustained. Besides about 700,000 agar seedlings have been planted in two nurseries, namely 'Kaiya' and 'Sirgasia', at Kaiyachara tea estate. And furthermore, there are some privately-owned agar plantations in Modhupur (Mymensingh), Birisiri, Haluaghat (Netrokona), Sylhet, Habiganj and particularly in Maulvibazar district where many families have been engaged in production and marketing of agar and agar-based secondary products for several decades (Alam 2004, Uddin *et al.* 2008, Islam 2013 and Chowdhury *et al.* 2016).

Initially, BRAC Tea Estate plans to plant 50 acres of land with agar plant, after 12 years of which agarwood harvesting would take place. Assuming 90% survival rate and 2 kg premium quality agarwood production per plant, the estimated investment related to plantation would be $1.82 million and total return would be $761.34 million with the rate of return 41.9% (Akter and Neelim 2008).

Agar plantation managements

Among fifteen species of the genus, *Aquilaria* and eight are familiar to produce agarwood (Ng *et al.* 1997). Currently, *A. malaccensis, A. agallocha* and *A. secundaria* are the main species for agar cultivation (Broad 1995). In Bangladesh, *Aquilaria malaccensis* (Alam 2004 and Chowdhury *et al.* 2016), *Aquilaria agallocha* (Bhuiyan *et al.* 2009 and Rahman *et al.* 2015) are commonly cultivated. Agar trees were planted in monoculture and block plantations. 75% of the plantations have been established on degraded land as well as denuded hills and rest 25% were established at the homesteads of farmers (Rahman *et al.* 2015). Most of the farmers have an own nursery for raising agar seedlings and others obtained from outside. Before planting seedlings, sites were cleaned, standard-size pits were dug at a spacing of 2 m×2 m and after placing 1.5-2.0 kg of cowdung, each pit was left abandoned for at least 15 days. Few farmers use inorganic fertilizers during plantation establishment. One-year-old seedling usually planted in April or May. Weeding, the most frequently applied operation, intensively carried out in the first 3 years. Some farmers give stakes for supporting but mostly considered that staking would hamper the natural strength of the seedlings. To reduce water loss, mulch was frequently applied at the bottom of agar plants. Organic, inorganic fertilizers and pesticides were applied to promote growth and protect agar trees

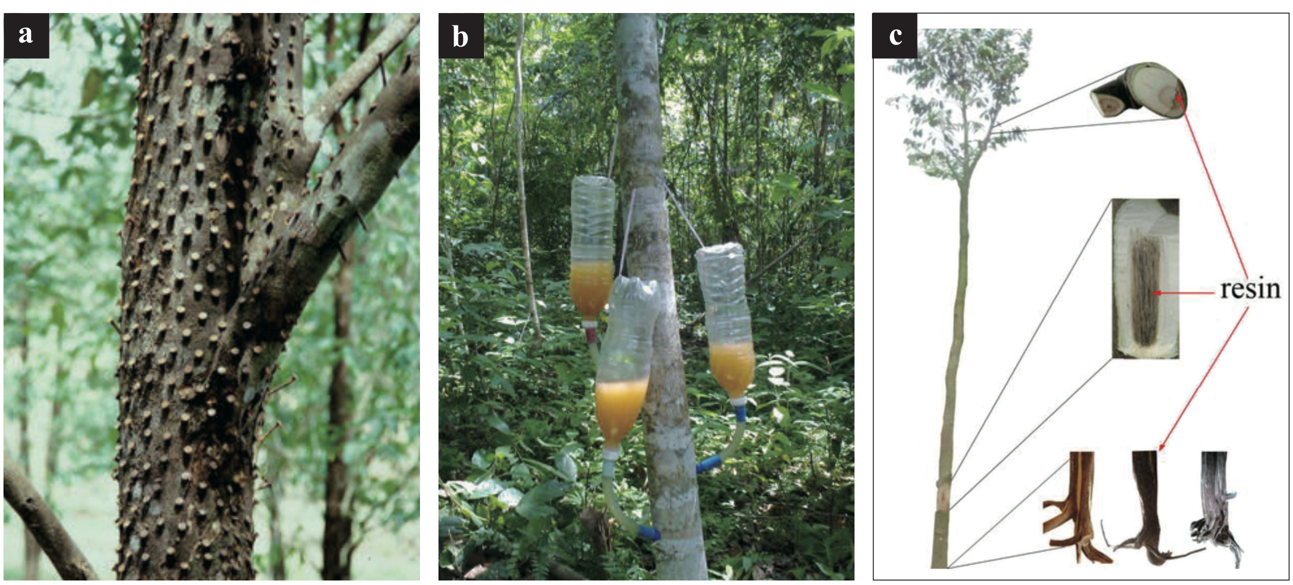

Fig. 1. Artificial inoculation (a) Nailing (b) Fungi-Inoculation (c) Agar-wit (Liu *et al.* 2013)

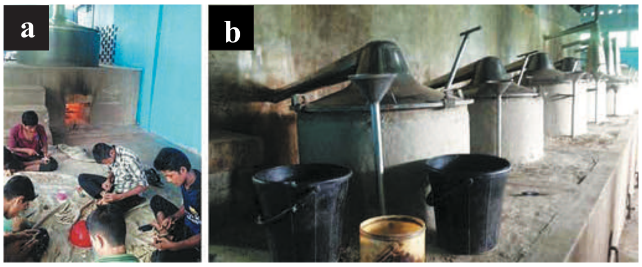

Fig. 2. Agar production system in Bangladesh (a) Workers are separating dark-colored heartwood from agar tree (b) Agar oil processing unit (Rahman *et al*. 2015)

from leaf sucker insects, respectively. Pruning was usually done only once a year preferably in the end of May, from the third to fifth or sixth year after out planting. Thinning is very rare. Sometimes fencing was used to protect seedlings from cattle and other disturbances.

Inducing methods

Aquilaria has a unique composition of phloem bundles within xylem. This network of phloem and parenchyma produce and distribute the resin around the injured area to recover the wounds (Blanchette and Van Beek 2005). This accumulated resin is known as agar. Only 7% trees are infected naturally (Ng *et al.* 1997) by ant, snails or fungus and mostly obtained at the junctures of broken branches (Gauthier *et al.* 2015). Natural fungal infected plants produce best quality agar whereas inferior quality agar is the result of artificial inoculation (Bhuiyan *et al.* 2009). Though there are several artificial inoculation methods, in Bangladesh agar farmers practice only iron nailing. Low cost, easy insertion, and local availability are the main reasons behind this practice. Farmers recommend nailing when trees reached 6 to 7 years of age. Nails are hammered in the whole tree (up to 10 cm diameter of the top) at a spacing of 2.5-3.5 cm. The length of iron nail varies from 5 to 15 cm depending on the diameter of the tree. After 3 to 5 years of nailing, the trees became ready for harvesting and the best time for harvesting is mid-October to mid-March (Chowdhury *et al.* 2016 and Rahman *et al.* 2015). Beside this drilling (Blanchette 2006), Aeration (Chowdhury *et al.* 2017 and Liu *et al.* 2013), Burning-Chisel-Drilling (Chowdhury *et al.* 2016 and Zhang *et al*. 2014) and Fungi-Inoculation methods (Beek and Phillips 1999) are also used for producing agarwood. Nowadays, Fungi-Inoculation method (Oldfield *et al.* 1998) is becoming popular. Resin production could be increased due to fungal infection as the host response very first to minimize the fungal growth damage. *Aspergillus* spp., *Botryodyplodia* spp., *Diplodia* spp., *Fusarium bulbiferum*, *F. laterium*, *F. oxysporum*, *F. solani*, *Penicillium* spp. and *Pythium* spp. could easily infect agar trees (Chowdhury *et al*. 2016, Soehartono and Mardiastuti 1997 and Wiriadinata 1995). When liquid fungal solution were inoculated with liquid rihizopus spp. inoculants into the agar tree gives very good agarwood within three month and this condition usually kept for two years. Agar-wit is also a similar method where inoculant liquid was injected through a transfusion set. Because of water transpiration pull, the inoculant was transported from root to branch within a short period of time and consequently started internal wounds (Zhang *et al.* 2012). The final agar-products via fungal or agar-wit method is very good. The market value is very high and selling is easy to international market (Fig. 1).

In the past, raw materials were imported from the neighbor and foreign countries. But it decreased sharply and now stopped entirely with the passage of time. About 70% of the enterprise collect raw materials from agar farmers and rest from their own plantations (Rahman *et al.* 2015).

There are two processing mechanisms, water distillation and steam distillation for agar oil extraction. In water distillation method, agar woodchips are soaked in water for 4-5 days and charged into the boiler. Each batch consists of 8-12 kg of agar chips and 80 liters of water. The boiler is heated slowly for 3 days and steam containing the aromatic molecules is captured and condensed where the oil floats to the top of the distilled water (Alam 2004). High temperatures sometimes destroy the most delicate fragrance molecules, needs large amounts of raw material and consume more times, this method is followed commonly for extracting and isolating the agar oil (Fig. 2).

Financial analysis of agar cultivation

The cost of agar cultivation combined with overhead and operating expenses. Overhead cost items are site clearing, pit making, seedling production and fencing. Operating costs are the summation of land rent, fertilizing, weeding, pruning, purchase, application of pesticides and artificial tree wounding. A relatively high cost is involved at the beginning of agar production and when artificial wounding is carried out. During the first 5-7 years, farmers could get a negative return but after the 10-12 years of cultivation, return starts. If the tree is left in the field for some more years then the net return would be higher. Agar trees could be grown in mono-cropping or multi-cropping systems along with companion commercial crops garden. All kind of vegetables, banana (*Musa* spp.), pineapple (*Ananas comosus*), papaya (*Carica papaya*) might be planted as an intercrop in the multi-cropping system of agar cultivation. The total expenditure for agar cultivation up to the rotation period (12 years) is BDT1.2 million per ha and the total return is Tk.6.1 million per ha. So net profit is BDT4.9 million (Rahman *et al.* 2015).

On an average, every enterprise uses 600 kg to 4 metric tons agarwood for producing 0.74-5.75 kg agar oil where production cost and total returns are BDT0.5 million and BDT1.3 million, respectively (Rahman *et al.* 2015) with a net profit of BDT0.8 million.

Marketing of agar-based products

Two kinds of raw agarwood marketing system exist in the agar cultivation area. One involves selling agar trees before artificial wounding by agreement and other is direct selling to the agar-based enterprise owner after harvesting. Sometimes middlemen interfere in the both cases. About

64% of farmers sell their agar trees directly and remaining 36% takes help of middlemen for selling to the enterprise owner with the either before or after artificial wounding where the middlemen take around 5% of the total price for their involvement (Rahman *et al.* 2015).

After processing agar oil, about 80% of the enterprise owners sold agar oil directly to the exporters who have business licenses for trading agar oil, where rest 20% resort to the middlemen or close relatives living in the export countries and having skill in international trading.

Constraints in agar plantation management and marketing

Inadequate capital is the main constraint in every step of agar production. Inadequate high quality seedlings, high investment for artificial wounding, lack of modern technology and high cost of fuel for agar processing, absence of an appropriate pricing system, inadequate support for damage recovery and over all technical support for plantation management from government agencies or non-governmental organizations are the common obstacles to the progress of this potential productive sector. Sometimes scarcity of raw materials and problems associated with international marketing, including involvement of middlemen are other major constraints for this growing up sector. Abdin tried to find out some barriers toward the development of Bangladesh agarwood industry (Abdin 2014).

Future opportunities and challenges

Despite several major limitations, agar-based enterprises are increasing day by day. In 2009, about 100 listed agar-based enterprises were located in Moulvibazar district of Bangladesh (SME Foundation 2013). But the number of enterprises has been touched 300 within next 4-5 years (Rahman *et al.* 2015). This increasing number of agar enterprises had created new employment opportunities for rural people which are playing a vital role in improving livelihoods in those areas.

Artificial wounding helps to stimulate oleoresin in *Aquilaria* trees (Beek and Phillips 1999) and there are several artificial wounding methods namely nailing, drilling, aeration, agar-wit, fungi-inoculation, burning-chisel-drilling, partly-trunk-pruning and so on (Chowdhury *et al.* 2016). In Bangladesh, farmers usually practice nailing method as a means of artificial wounding. Similar wounding is also very common in India, especially among the traditional growers (Saikia *et al*. 2012). Nevertheless, this method does not show productive results and the produced yield is inferior quality (Persoon 2007). Several scientific methods for artificial wounding have already been developed through successful experiments. Fungi-Inoculation (Oldfield *et al.* 1998), Aeration (Blanchette 2006) and Agar-Wit (Liu *et al.* 2013) are remarkable of those which produce 4–28 times higher yield as from existing agarwood wounding method. Agar farmers are not aware of these new techniques. If they adapt these methods, they would get more profit from this sector.

Most of the workers (88%) involved in Bangladeshi agar enterprises were hired by the enterprise owner. Among them, 10% has no educational knowledge and rest has completed the primary school level only. About 53% workers are unskilled, no scientific knowledge of production (Rahman *et al.* 2015). Due to lack of training and diversification knowledge, Bangladeshi agarwood sector is producing only three items namely; agarwood chips, agar oil and agarwood powder/dust where competitors like Malaysia, India, Indonesia and so on are producing eight or more items.

Bangladesh government has been officially declared agar production as an industrial sector in 2014. But the absence of an efficient marketing and pricing system is depriving agar farmers and agar-based enterprises of getting the equitable price. Due to lack of contemporary price information of different markets, forest-based enterprises do not receive high prices for their products (Rahman *et al.* 2010). Poor communication and transportation facilities, highly segregated markets and unequal bargaining powers between buyers and sellers make the field more favorable for the middleman (FAO 1995). If government specially consider this industrial sector and take policies like Industrial Policy, Import Policy, Export Policy, Investment policy, SME Loan Policy and so on, agar farming will be one of the major foreign currency earning sectors of Bangladesh. Duty-Free and Quota-Free (DFQF) market access will also help to reach that goal.

According to the U.N. and FAO, only 11.1% or about 1.442 million ha of Bangladesh is forested. Between 1990 to 2010, Bangladesh lost an average 2,600 ha or 0.17% per year which is still continued (http://rainforests.mongabay.com/deforestation/2000/Bangladesh.htm). Deforestation and forest degradation are one of the major causes of global warming. This degraded forest areas, especially hilly lands give opportunities to replant valuable species. Large scale *Aquilaria* tree plantation would be initiated on this land because of the wide adaptability of *Aquilaria.* It will help in carbon sequestration as well as protection of agar trees from extinction (biodiversity conservation).

Conclusion

Agar farming provides bi-directional environmental benefits, carbon sequestration and biodiversity conservation. Agar plantations and agar-based enterprises brought financial solvency of agar production areas. It is a growing economic sector. However, unskilled and detached management and marketing were identified as constraints to get full financial and environmental benefits. Skilled communication management can encourage the production and enhance financial viability. Low-cost scientific artificial wounding techniques are now a demand of time for superior quality agar production. The Government of Bangladesh can take suitable policies to uplift this sector and Non-governmental organizations can provide proper training in agar farming and agar processing. The government can also directly handle the middlemen issue and develop a duty-free and quota-

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free (DFQF) market access. Therefore if we can create awareness and flourish this sector, it would be one of the major sources for earning foreign currency and boost up the export figure of Bangladesh.

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Ashibetsu experimental site of REFRESH (Retention Experiment for plantation FoREstry in Sorachi, Hokkaido), Japan

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Forests in Hokkaido

Japanese forests are excessively harvested during World War II and the postwar reconstruction. Many degraded forests and natural forests were converted to planted forests during 1950-1980, and most of them are currently at the commercial harvesting age.

Todo fir *Abies sachalinensis* is the most dominant planted species in Hokkaido, the northernmost island of Japan. Because of concern for the butt rot, A. sachalinensis is not suitable for long rotation, so immediate harvesting and regeneration is required.

Amid criticism for large-area clear-cutting, old planted forests have been regenerated by gap cut (<1 ha) in Hokkaido Prefectural Forest since 2000s. However, due to large costs and efforts, more effective operation which meets multiple functions of forests is desired to manage large forests at the harvesting age.

Retention forestry and REFRESH project

Retention forestry (variable retention, green tree retention) is one of the operation methods that intend to maintain structural complexity by retaining old trees and snags at the time of harvest to provide diverse habitats for organisms, and is widely practiced on more than 150 million ha of boreal and temperate forests.

REFRESH (Retention Experiment for plantation FoREstry in Sorachi, Hokkaido) project is the first experiment of retention forestry in Japan. This project has started since 2013 using 6,000 ha Hokkaido governmental forest located in Ashibetsu city, Sorachi District, central part of Hokkaido (Fig. 1). It is carried out under the corporation of Hokkaido Prefecture, Forestry and Forest Products Research Institute, Hokkaido University and Forestry Research Institute of Hokkaido Research Organization.

Fig. 1. The location of Ashibetsu site of REFRESH project

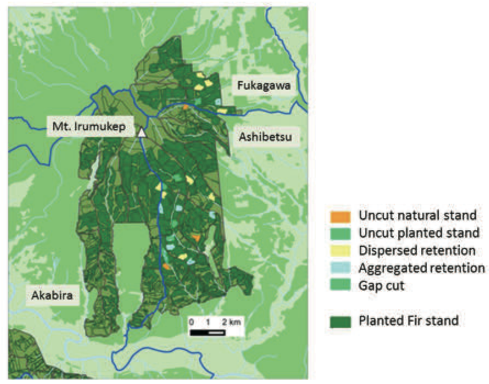

Fig. 2. The map of experimental stands of Ashibetsu site

Our objective is to illustrate the costs and benefits of retention forestry with planted *A. sachalinensis* forests.

Experimental treatments

In REFRESH project, three set of experimental units were established in planted *A. sachalinensis* that stood over 50 years within Hokkaido Prefectural Forest in Ashibetsu site (Fig. 2). The location with the highest altitude in this site is the Mt. Irumukep which is 865 m above sea level, located N 43°37′45″, E 142°06′37″ (Fig. 3).

Pre-treatment survey for the first set started in 2013, and harvesting was carried out during 2014-2016. *A. sachalinensis* seedlings were planted in spring of the year after harvesting.

Eight treatments which include dispersed retention, aggregated retention, gap cut, uncut natural stand and uncut planted stand were operated in each set

Fig. 3. Mt.Irumukep and dispersed retention stand

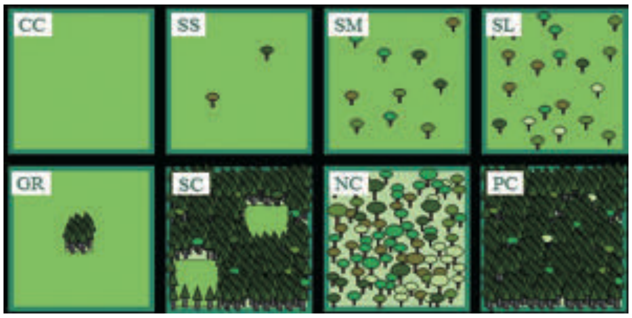

Fig. 4. Treatments of experimental stands
CC: Clear cut, SS: Dispersed retention (10 trees/ha), SM: Dispersed retention (50 trees/ha), SL: Dispersed retention (100 trees/ha), GR: Aggregated retention (0.36ha patch), SC: Gap cut (1 ha each) (2nd and 3rd set only), NC: Uncut natural broadleaved stands, PC: Uncut planted stands

(Figs. 4 and 5). The area of each treatment was 5-9 ha. Dispersed retention were set in three different density of remained broadleaved trees (10, 50 and 100 trees/ha).

As the objectives of retention were restoring structures and elements of original natural forests in the region, naturally-regenerated broadleaved trees were remained in dispersed retention plots to conserve biodiversity of wildlife and insects. On the other hand, planted Todo fir trees were remained in aggregated retention plots expecting to conserve understory plants.

Areas of Investigation

We measured harvesting productivity in each plot during harvesting operations to compare their efficiency. After harvesting and planting, we surveyed vegetation (overstory trees and understory plants), bird territory and saproxylic insects ground beetles to evaluate its biodiversity. We further investigated hydrology and ecosystem services in various experimental plots.

Perspective

Retention forestry has been used and tested in complex and diverse forests. REFRESH project will evaluate the feasibility and efficacy of using retention forestry to restore its biodiversity and enhance ecosystem services in planted forests. We aim to achieve the balance between ecological and economic values of planted forests.

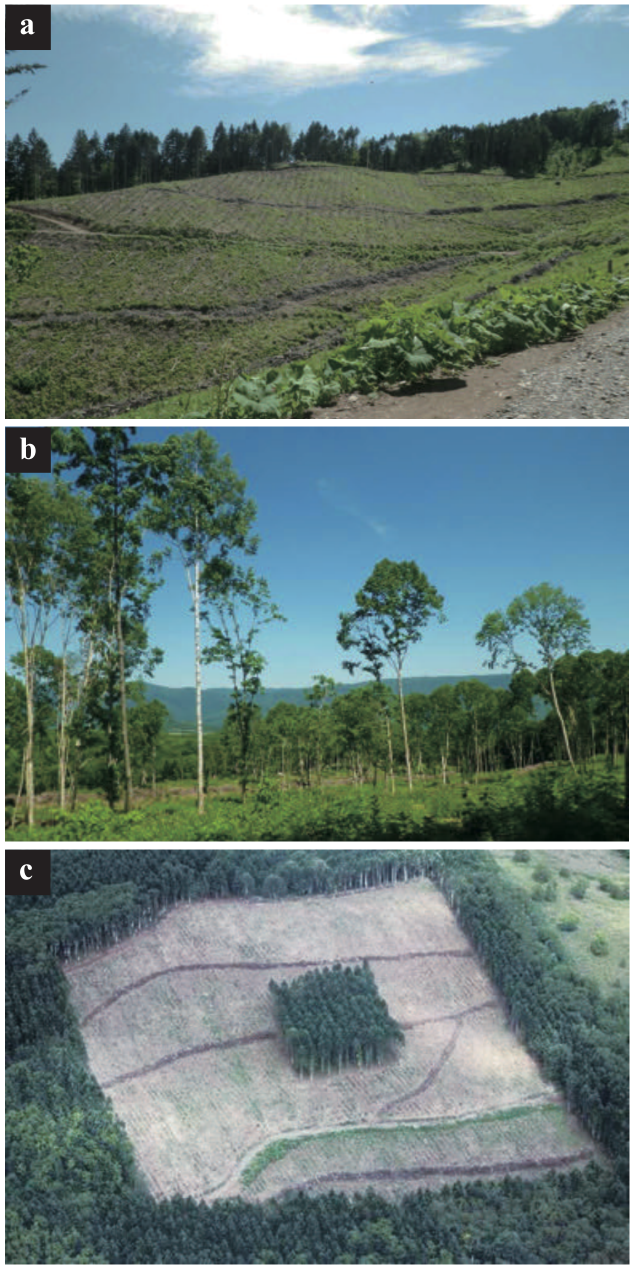

Fig. 5. Experimental stands
(a) Clear cut stand (b) Dispersed retention stand (c) Aggregated retention stand

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