UGYEN WANGCHUCK INSTITUTE FOR FORESTRY RESEARCH AND TRAINING
DEPARTMENT OF FORESTS & PARK SERVICES
MINISTRY OF ENERGY & NATURAL RESOURCES

NATIONAL FRAMEWORK FOR AGARWOOD PRODUCTION & MARKETING IN BHUTAN

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PREFACE

The National Agarwood Framework, developed by the Department of Forests and Park Services (DoFPS), under the Ministry of Energy and Natural Resources (MoENR), represents a significant advancement in Bhutan's agarwood production and marketing. This initiative seeks to build a responsible and resilient agarwood industry that aligns with our nation's commitment to environmental conservation and community empowerment through improved livelihood. Agarwood, derived from *Aquilaria* species Lam, is globally treasured for its unique fragrance, high price and medicinal properties. However, its high demand has often led to unsustainable harvesting practices, endangering natural populations. As of now, in Bhutan, we have about 543552 trees planted in private lands along with 83 trees in natural stands. The Agarwood Framework addresses these challenges by promoting environmentally sound cultivation, production, and trade practices, ensuring that Bhutan's approach to agarwood aligns with both economic and ecological values.

At its core, the framework aims to promote sustainable cultivation, technology transfer, and stimulate research and innovation. Sustainable cultivation methods will ensure the long-term viability of agarwood resources, while technology transfer and training will empower local communities to create meaningful, sustainable livelihoods. By advancing research and developing locally adapted inoculation techniques, the framework enables the production of high-quality agarwood resin without pressuring wild populations. Further, by establishing robust domestic and international market linkages, Bhutan can position its agarwood as a premium product known for quality and sustainability, while adherence to CITES regulations ensures ethical trade. Bhutan's unique environment and cultural heritage, combined with responsible practices, offer a distinctive appeal to global markets. This document also aims to enhance the skills and knowledge of Bhutanese business entities, cultivators, and sellers, providing a structured approach to agarwood production, processing, and marketing. By supporting e-commerce and niche marketing, the framework enables Bhutanese producers to reach premium market segments, promoting profitable and ethical trade. Through collaboration and shared responsibility, stakeholders will build a supportive ecosystem that enables collective access to markets and best practices, ultimately empowering Bhutanese cultivators as key stakeholders in the agarwood industry.

I felicitate the Department of Forests and Park Services and to all those who contributed to this framework, which represents Bhutan's dedication to harmonizing economic growth with environmental integrity.

30/2/2025

Minister
Ministry of Energy and Natural Resources

FOREWORD

The National Agarwood Framework stands as an indication to Bhutan's commitment to sustainable resource management and community-driven development. As we navigate an era where natural resources are under increasing pressure, this framework serves as a guide to cultivate agarwood in a way that balances economic opportunity with ecological responsibility. Agarwood, highly valued for its unique fragrance and traditional uses, offers tremendous potential to enhance livelihoods in Bhutan. However, without sustainable practices, its cultivation and harvesting could lead to unintended environmental impacts. This framework, developed through extensive collaboration with experts, stakeholders, and local communities, provides a structured approach that ensures agarwood production aligns with Bhutan's environmental and socio-economic priorities.

This National Agarwood Framework is designed to promote sustainable cultivation practices, encourage technology transfer, and inspire innovation in agarwood production. By equipping the local communities with skills, and knowledge, this initiative empowers them to engage in agarwood cultivation that is both economically beneficial and ecologically sound. This Framework also includes structured guidelines to produce agarwood without hampering the natural population of agarwood, along with expansion of domestic and international markets, helping Bhutanese producers build a strong reputation for quality and sustainability. As the Director of the Department of Forests and Park Services, I am honored to introduce this framework, which represents our commitment to environmental integrity, economic resilience, and sustainable growth. I am grateful to everyone, who have contributed in shaping this document. Together, we will work towards a thriving, responsible agarwood industry that will serve as a model of sustainable development and benefit generations to come.

Director,
Department of Forests and Park Services

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The authors extend our heartfelt gratitude to Zimpon Wom Karma Tenzin (the Chamberlain), Queen's Project Office, for providing clear directions for the preparation of this important document. We also owe our gratitude to Karma Tenzin, the Director of the Department of Forests and Park Services (DoFPS) for his invaluable guidance and unwavering support for development of agarwood framework.

We also would like to thank the Agarwood Taskforce, including members from the National Mushroom Centre (NMC), the National Biodiversity Centre (NBC), and the National Plant Protection Centre (NPPC), for their expertise and collaboration. Your collective efforts have significantly enhanced our understanding and approach to build this framework.

Moreover, we would like to express our appreciation to the management of Ugyen Wangchuck Institute for Forestry Research and Training (UWIFoRT) for the continuous support and regular guidance.

The Framework established through this initiative will greatly benefit the development of the agarwood production in Bhutan by promoting sustainable practices, enhancing technical knowledge among farmers, and improving market access. By fostering collaboration among stakeholders, this framework aims to empower local communities, boost livelihoods, and ensure the long-term viability of agarwood cultivation, ultimately positioning Bhutan as a key player in the global agarwood market. We are grateful to AFoCO for their generous support in covering the publication charges.

Acronym

BFDA	Bhutan Food & Drugs Authority
BCD	Burning-Chisel Drilling
DBH	Diameter at Breast Height
DoFPS	Department of Forests and Park Services
UWIFoRT	Ugyen Wangchuck Institute for Forestry Research and Training
Cm	Centimeter
CITES	Convention on International Trade in Endangered Species of Wilds Fauna and Flora
CoRRB	Council of RNR Research of Bhutan
ISO	International Organization for Standardization
KM	Knocking Method
M	Meter
Masl	Meter Above Sea Level
Ml	Milliliters
Mm	Millimeter
MoAL	Ministry of Agriculture & Livestock
MoENR	Ministry of Energy and Natural Resources
MoICE	Ministry of Industry, Commerce and Employment
FNCA	Forest and Nature Conservation Act, 2023
MOSEL	Maehong Son Organic Social Enterprise Limited
FNCA	Forest and Nature Conservation Act, 2023
FNCRR	Forest and Nature Conservation Rules and Regulation, 2023
INR	Indian Rupee
NBC	National Biodiversity Center
NDF	Non-Detriment Findings
NPPC	National Plant Protection Center
NMC	National Mushroom Center
OGOP	One Gewog One Product
pH	Potential of Hydrogen
QPO	Queen's Project Office

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Vision

Establish a globally recognized agarwood business in Bhutan to benefit its people

Mission

Develop and manage agarwood resources, enhancing economic growth, promote environment conservation, and community empowerment through cultivation, processing, and marketing of high-quality Agarwood products.

Objectives

1. **Promote sustainable cultivation:** Promote and implement sustainable cultivation practices for agarwood, ensuring long-term environmental health and resource availability
2. **Advocate technology transfer:** Empower local communities by providing training, resources, support to engage in agarwood cultivation and processing, creating sustainable livelihoods
3. **Promote research and innovation:** Foster research and innovation in agar tree cultivation, development of effective inducer/inoculum, agarwood production, and product diversification, leveraging traditional knowledge and modern technology
4. **Explore and establish market linkages:** Develop and expand domestic and international markets for Bhutanese agarwood products, establishing a strong brand identity associated with quality and sustainability.
5. **Ensure environmental conservation:** Integrate agarwood development with broader environmental conservation efforts, ensuring that cultivation practices contribute positively to biodiversity and forest health.

Introduction

Agarwood is a highly valued aromatic resin produced in the heartwood of *Aquilaria* Lam. and *Gyrinops* Gaertn. genera. This resin is produced in response to natural and artificial injury and microbial infection, transforming the wood into infected dark, dense, and fragrant, prized for its unique aroma and medicinal properties. Agarwood is in high demand across global markets, mainly valued for perfume, incense and traditional medicines, where its rarity and scent profile make it a luxury product. Various economic products of agarwood are marketed including plant pieces, wood blocks, wood chips, oil, and waste powder (Yin et al., 2016). Possession of distinct wood instincts and valued fragrances has become one of the most expensive woods in the world. The price of first grade agarwood oil is Nu. 16623 – Nu. 831168 (equivalent to Indian Rupee) per 11.62 grams (tola) (El-Khawad and Ahal, 2019). Globally, it is widely used in perfumes, medicines, incense, alcohol, and herbal products.

In recent decades, wild populations of agarwood trees have decreased due to overharvesting, pushing resources towards ecological vulnerability. *Aquilaria malaccensis* Lam. is listed as critically endangered under criteria A2cd of the IUCN Red List Assessment (Brown, 2018) and Appendix II of the Convention on International Trade of Endangered Species (CITES, 2023). The global population of *A. malaccensis* for the last three decades is estimated to have declined over 80% (Peng et al., 2015). Agar tree is listed under Schedule II of the Forest and Nature Conservation Act, prohibiting the collection and trade of the species (FNCA, 2023). However, with the establishment of Non-Detriment Findings (NDF) in the country, the collection from cultivated private land and trade will be permitted. The depletion of wild agar tree populations is driven by the high price fetched from naturally infected agarwood which fosters illegal trade and overexploitation.

Due to overharvesting, agarwood trees in the wild are now rare, leading to increased cultivation efforts on plantations for sustainable agarwood production. Agarwood formation is constrained by its intricate process, involving the interaction between the infecting agent, the host tree, and the surrounding environment. These complexities have impeded Bhutan's capacity to produce agarwood (Mohamed, 2016). Due to Bhutan's limited technological advancements and technical support in developing inoculation techniques and delivery systems, agar tree growing farmers resort to unreliable and expensive inducers from neighboring countries for agarwood induction. There is no reliable data on the exact trade volume of agarwood at international markets, however, annually it is estimated at several hundred tonnes with a trading scale reaching millions of dollars. Currently, the two major terminal markets in international trade exist: Northeast Asia (Japan, South Korea, and Taiwan) and West Asia (Middle East) with Singapore serving as the largest international trading hub for import and export of agarwood. Agarwood product diversification at the market facet has increased the price of agarwood more than 10 times. Amid this growing global demand and high market value, research and sustainable practices are crucial for ensuring the long-term viability and benefits of agarwood production. Ugyen Wangchuck

Institute for Forestry Research and Training (UWIFoRT), Department of Forests and Parks Services (DoFPS), has been conducting a series of research trials over the years to develop locally improvised inducers and transfer the knowledge to the farmers for boosting their livelihoods. Valuing its economic potential and conservation importance, many agar tree growing regions in Bhutan, have been investing in sustainable agarwood production practices, venturing into cultivation, inoculation, harvesting and marketing.

Scope of the Framework

This framework shall guide, enhance skills and knowledge on agarwood production, processing and marketing, which is expected to help business entities, cultivars, and sellers by providing a structured approach in managing and expanding market both at local and international reach. This document will also help increase agarwood production and marketing in Bhutan through expanding sustainable cultivation through research-based plantations and inoculation of agarwood. By adopting locally established artificial inoculation methods, Bhutan can produce high-quality resin and reduce pressure on wild populations. Bhutan's rich cultural heritage aligns well with agarwood's traditional uses, enhancing its appeal for domestic and international markets. Adherence to CITES regulations will support ethical trade, while developing e-commerce and niche marketing can help tap into premium and luxury segments. Bhutan's unique environment and sustainable practices position it to become a source of high-grade agarwood in Asia. Moreover, by fostering a sense of responsibility among producers and collaboration among stakeholders, this document will create a supportive ecosystem where producers can share best practices, access markets collectively. Ultimately agarwood production shall empower Bhutanese cultivators to become key stakeholders in the agarwood industry, improving economic livelihoods and community prosperity.

This Framework provides a comprehensive guide for sustainable agar tree growers and stakeholders in agarwood production, post-harvest processing, and marketing high products adhering to environmental standards while accessing profitable markets.

CHAPTER ONE: Background

1.1. Taxonomy

There are 21 recognized agar species recorded (Lee and Mohamed, 2016), of which 15 are agarwood-producing species in the genus *Aquilaria* (Thymelaeaceae) found across Southeast Asia, South Asia and parts of East Africa (Shu et al., 2007). The Agar species that is recorded in Bhutan is *A. malaccensis*, found both in natural forests and plantations in private land in southern parts of the country. *A. malaccensis* is a shade-tolerant tree growing up to 20 to 40 meters tall, usually with a straight bole, sometimes fluted with thick buttresses up to 2 m high, bole up to 60 cm in diameter, with thin, smooth, ash colored tough bark. Wood is light, soft and porous. Branchlets are slender, pale brown, pubescent, and glabrescent.

Figure 1: Fruits of *A. malaccensis*

Leaves are simple, alternate; petiole 4-6 mm long; blade elliptical-oblong to oblong-lanceolate, 7.5-12 cm × 2.5-5.5 cm, chartaceous to sub coriaceous, glabrous, sometimes pubescent and glabrescent beneath, shiny, base acute, attenuate or obtuse, apex acuminate, acumen up to 2 cm long; veins in 12-16 pairs, rather irregular, often branched, elevated and distinct beneath, curving upward to the margin, plane or obscure above. Inflorescence is terminal, axillary or supra-axillary, sometimes internodal umbel, usually branched into 2-3 umbels, each with about 10 flowers; peduncle 5-15 mm long; pedicel slender, 3-6 mm long; flowers 5-merous, campanulate, 5-6 mm long, green or dirty-yellow, scattered puberulous outside; floral tube nearly glabrous inside, distinctly 10-ribbed, persistent in fruit; calyx lobes 5, ovate oblong, 2-3 mm long, almost as long as the tube, reflexed, densely puberulous within; petaloid appendages 10, inserted at the throat of

the tube, oblong or slightly ovate-oblong, about 1 mm long, slightly incurved, densely pilose; stamens 10, free, emerging from the throat of the tube, filamentous, 1.2-2 mm long, episepalous ones longer than the others; anthers linear, obtuse; pistil included; ovary ovoid, 1-1.5 mm long, 2-celled, densely pubescent; style obscure, stigma capitate. Fruit a loculicidal capsule, obovoid or obovoid cylindrical, 3-4 × 2.5 cm, usually compressed, pubescent, glabrescent, base cuneate, apex rounded; pericarp woody. Seed ovoid, 10 × 6 mm including a beak 4 mm long, densely red-haired, bearing from the base a twisted, tail-like, pubescent appendage as long as the seed (Grierson and Long, 1994).

1.2. Phenology and dispersal

Generally, there are seven phenophases in context to agarwood development, each making critical stages in its life cycle.

1.2.1. Seed germination: Tree's life cycle begins with seed germination, where seeds sprout and start to form roots and shoots. Under natural conditions, this occurs in early to mid-monsoon, depending on the local climate patterns. Seeds have a short viability period and require moist and well-drained soil for successful germination.

1.2.2. Seedling establishment: During this phase, seedlings develop their leaves, roots and stem, establishing the foundation for growth.

1.2.3. Young growth phase: Trees undergo rapid vegetative growth, with accelerated development of leaves, branches, and a thickening trunk.

1.2.4. Mature growth phase: Growth rate slows as the tree attains fully developed trunk and canopy.

1.2.5. Resin induction phase: Tree undergoes artificial and natural injury, prompting defensive response that triggers resin production.

1.2.6. Resin maturation phase: Resin accumulates in the heartwood, darkening and intensifying aroma over the years, and

1.2.7. Harvesting phase: Resin with optimal maturity, tree is harvested selectively to obtain agarwood. In addition, reproductive phenophase includes flowering and fruiting. It begins flowering and fruiting at 5-6 years of age, producing about 1.5 kg of seeds per tree. Flowering occurs from April-June and lasts for about two months. It takes about one month for fruit to set and two months for seeds to mature after flowering. Flowering is influenced by temperature and rainfall. About 10-15% of seed capsules split naturally, with seeds hanging by the funicle cord for 2-4 days before dropping or being dispersed by the wind. *A. malaccensis* is a highly cross-pollinated species, which is usually pollinated by wasps and hornet; a process known as vespicochory (RFRI, 2021).

1.3. Ecology and habitat

1.3.1. Climatic factors

Agar trees grow in tropical and sub-tropical areas characterized by high humidity, warm temperatures, and abundant rainfall. They are naturally found within altitude range of 150-1000 masl, in areas with average daily temperatures of 20-22°C, and can tolerate a maximum of 22-28°C and a minimum of 14-21°C, but cannot grow where temperatures drop below 5°C (Rabgay et al., 2020). Agar tree prefers high humidity and sub-tropical climate with rainfall of 1800-3500 mm per annum (Rabgay et al., 2020).

1.3.2. Edaphic factors

Aquilaria species naturally grow in diverse soil types, including rocky, sandy, or calcareous soils, sandy loam as well as well-drained slopes and ridges but favors light to medium-textured, well-drained, and acidic soils. The soil pH in agarwood forest ranged between 5.13 and 6.69, with a mean value of 6.15 (SD ± 0.62), indicating a slightly acidic nature (Rabgay et al., 2020). A study in India found that agar trees thrived in fine-textured soils with low pH and high organic carbon content, which can hold more nutrients and support the growth of microbial colonies, including arbuscular mycorrhizal fungi (Gogoi, 2020).

1.3.3. Silvicultural traits

The species is shade-tolerant and regenerates under the mother tree. While they are shade-tolerant and can regenerate in lower light under the canopy of larger trees, agarwood trees also require sunlight, especially as they mature. Young trees thrive in shaded areas, whereas mature trees can tolerate more direct sunlight. *Aquilaria* species are fast-growing trees, capable of reaching a diameter at breast height (DBH) of 10 cm within 4 to 6 years in areas with sufficient moisture (Blanchette et al., 2015).

1.4. Distribution of Agarwood

A. malaccensis Lam, is native to southeast Asia (Mabberley, 2008). It is distributed from Assam to South China, as well as in New Guinea, Vietnam, Malaysia, Thailand, Myanmar, Laos, Cambodia, Philippines and Indonesia, growing in a seasonally dry tropical biome (Yin et al., 2016; POWO, 2024). Their distribution is often linked to specific ecological niches within these regions, favoring areas with suitable climatic conditions.

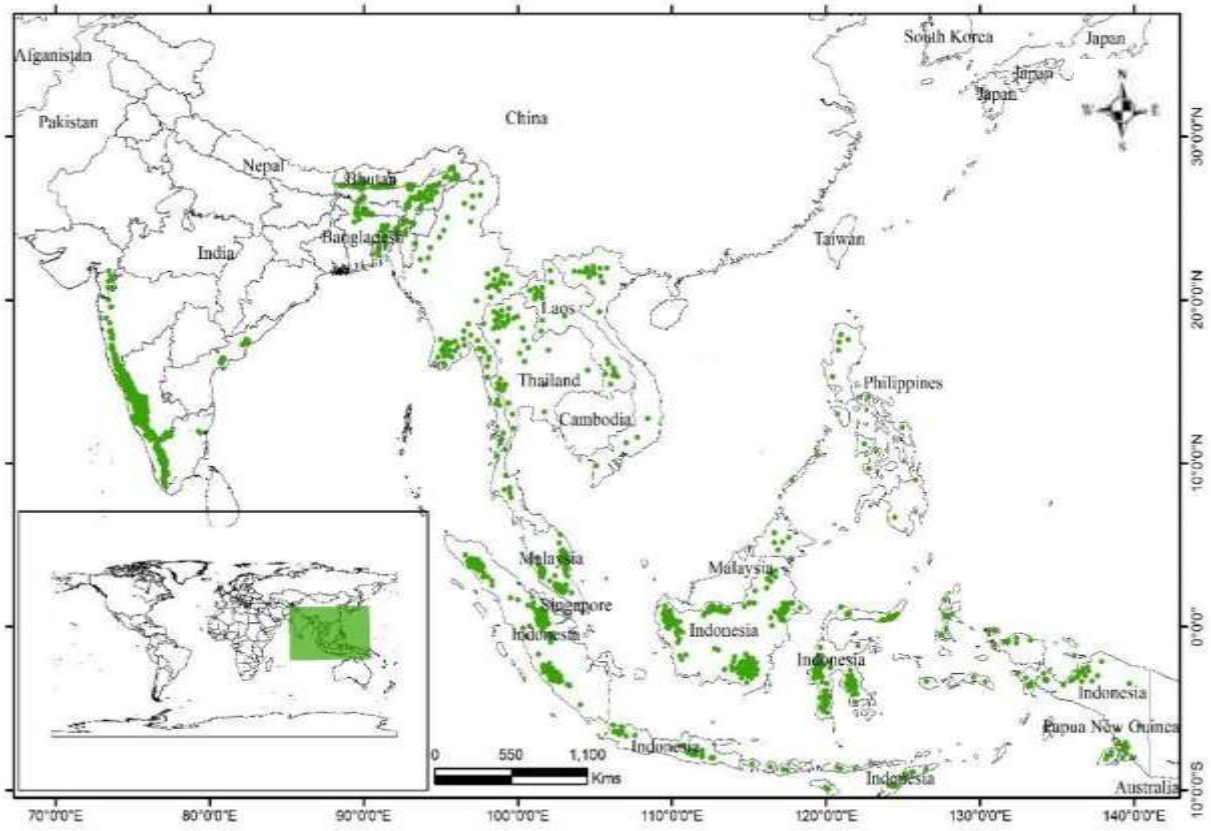

Figure 2: Distribution of agar species in the world

In Bhutan, *A. malaccensis* is distributed in the broadleaf forests of subtropical foothills in various habitats such as: plantations, research plots, nurseries, home gardens (traditional agroforestry practices) and in the wild (Wangchuk, 2009). *A. malaccensis* or aguru (common name in Dzongkha) in Bhutan is found in natural habitats spreading over seven Dzongkhags/Districts (Zhemgang, Pemagatshel, Sarpang, Mongar, Samdrup Jongkhar, Chhukha and Samtse).

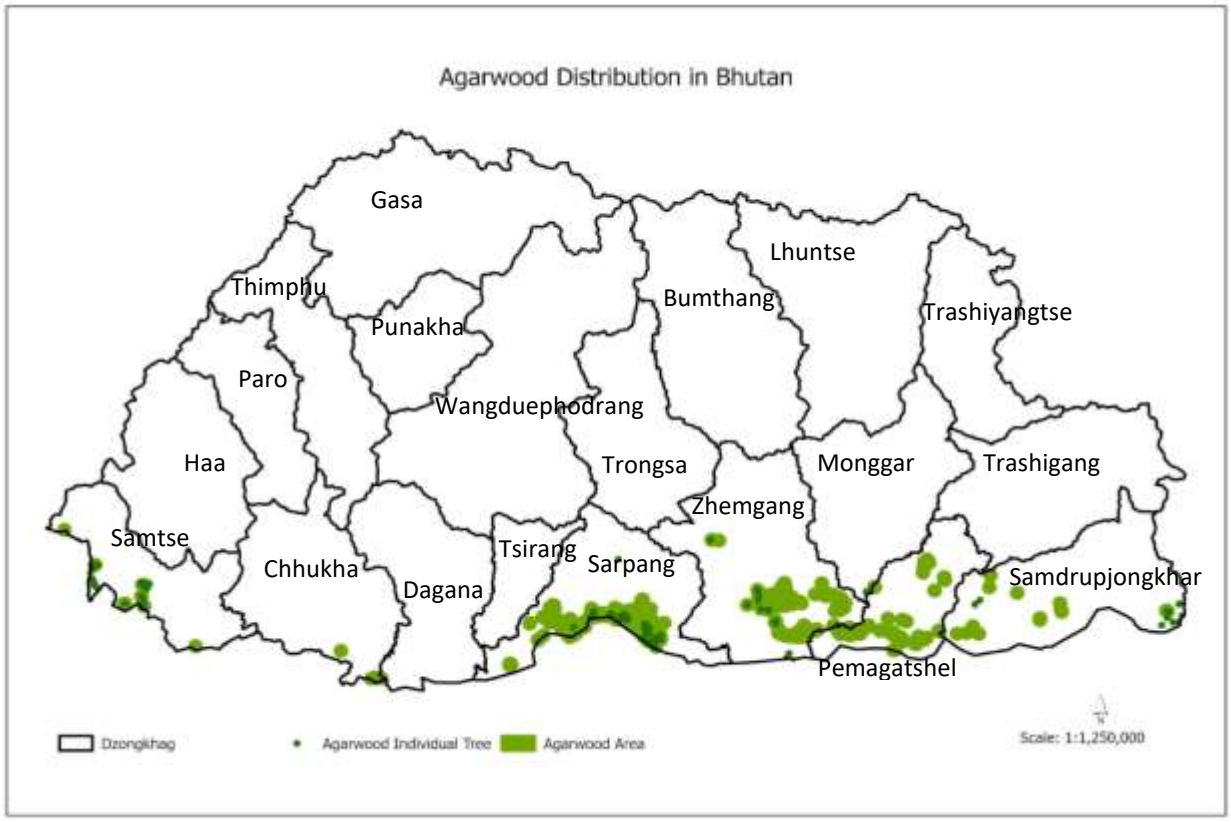

Figure 3: Distribution of agarwood in Bhutan

1.5. Agarwood research and development in Bhutan

In the early 1970s, Dasho Keiji Nishioka, began promotion of agarwood plantation in Bhutan. He planted agar trees in 50 decimals of land at Panbang (now under the Agriculture Research Development Sub-Centre). Following the plantation carried out by Dasho Keiji Nishioka, some farmers of Panbang also planted agarwood trees in their private lands in later years. However, other than planting agar trees, research into inoculation and agar resin formation were not carried out.

In 2001, the first experimental study on artificial agarwood production in Bhutan was conducted by the Agarwood Research & Development team from the University of Minnesota (UM), USA, and The Rainforest Project Foundation, Vietnam, in collaboration with the Renewable Natural Resources Research Centre in Yusipang (Chhetri et al., 2004). Professor Robert A. Blanchette, Mr. Joel Jurgens and Mr. Benjamin Held from the University of Minnesota and Henry Heuveling van Beek from the Rainforest Project Foundation worked in collaboration with the then Council of RNR Research of Bhutan (CoRRB) and inoculated six trees in Dasho Nishioka's plantation in Panbang in 2001. Details on results from the research had been presented at the first International Agarwood Conference held in November 2004, in Vietnam. In October 2004, the inoculated trees were harvested from the study site at Panbang by the RNR research team. Sections of the trees were brought to Thimphu and a subset from each tree was used to characterize the amount and quality of the resin at the University of Minnesota. The report by the research team showed that the agarwood was formed around the inoculation drill hole. The report also noted that when comparing this agarwood sample with samples Professor Blanchette obtained from other countries, it was found to be very good and appeared to represent all the fine characteristics unique to Bhutanese agarwood. Results from the field trial at Panbang field indicated that it was possible to successfully produce agarwood in plantation grown trees in Bhutan (a preliminary report Professor Blanchhette submitted to the hon'ble minister in 2004).

Beginning in 2018, the DoFPS, through the former Ministry of Agriculture and Forests, partnered with Mr. Soukthavy Chowdhury (Sadik) of HSI Sole Co. Ltd., Lao PDR, on a project for the pilot distillation of agarwood oil and the manufacture of trial products, which was suspended during the Covid-19 pandemic. Mr Sadik and the research team collected some agarwood samples from natural agarwood growing areas under Sarpang and Zhemgang Dzongkhags to conduct a trial. A facility for distillation of oil was established at Shawali, Sarpang, with support from Mr Sadik. One time distillation on trial was carried out at this facility centre but significant oil was not produced. Close to 1 liter of wax was produced. Meanwhile, COVID-19 interrupted the research and further intimations were not made.

In 2018, UWIFoRT carried out agarwood plantation at Bhur covering an area of about seven acres. Over the past few years UWIFoRT had been conducting inoculation trials on this plantation site. The induction trial, initiated in October 2022 at Bhur, Gelephu, involves a research trial plantation using six mechanical methods (1. Chisel cut method, 2. Drilling method, 3. Drill with earth fill, 4. Drill with a salt-sugar mixture sealed with wax, and 5. Drill with PVC pipe insertion filled with a salt-sugar solution. In 2023, UWIFoRT had sought permission from the Department of Agriculture to conduct an inoculation trial at Dasho Nishioka's plantation at Panbang and the research works are ongoing. A distillation trial had also been conducted at Thimphu, using the facility of Terra Himalaya. But the distillation did not yield any oil as the distillation sample quantity had been very limited. UWIFoRT had also been exploring collaborations with University Putra Malaysia (UPM), Malaysia, Kasetsart University (KU), Thailand, and Maehongson Organic Social Enterprise Limited (MOSEL), Thailand, for promotion and development of agarwood research and technical cooperation in the country.

Recently, the Department issued a public notice for the registration of agarwood plantations, encouraging all private growers in the country to register with their nearest Forest office. This initiative aims to facilitate the accounting of planted trees and certification process, which is necessary for the export of agarwood as per CITES certificate (Convention on International Trade in Endangered Species of Wild Fauna and Flora) with a permit from the department. Under the auspices of the Office of the Gyalpoi Zimpon, a national agarwood taskforce had been formed with members from various departments/agencies including DoFPS, NBC, NPPC, UWIFoRT, and NMC.

Table 1: Population status of agar trees in Bhutan

SI. No	Category		Area (acre)	No. of plants	Remarks/Locations
1	Trees grown in natural forests		0.80	17.00	Agoorthang, Manas-Zhemgang
			0.50	20.00	Hatilora ridge, Manas-Zhemgang
			NA	2.00	Agar pong, Chapdempa, Bjoka-Zhemgang
			NA	4.00	Rinchengang, Zarkabla, Bjoka-Zhemgang
			5.00	40.00	Between Longar & Tshar-Tshari, Phibsoo-Sarpang
	Sub-total		**6.30**	**83.00**	
2	Plantations	Pvt. Land	456.01	527,173.00	7 Dzongkhags
		SRFL	0.50	188.00	Plantation created by Darla Research Center at Hathkhola under Norbugang gewog
		CFs	31.72	15,915.00	Plantation inside 15-Community Forests
		Institutional land	0.07	3.00	RNR Compound, Belboteng, Tashicholing-Samtse
			0.50	273.00	ARDC Compound Panbang (Dasho Nishioka plantation)
	Sub-total		**488.80**	**543552.00**	
	Grand Total		**495.10**	**543,635.00**	

CHAPTER TWO: Nursery and Plantation

2.1. Nursery development

2.1.1. Seed collection

- The seeds should be collected from the mother trees of native agar species (*A. malaccensis)* and faster agar formation availability
- The matured seeds should be collected between June-July from locally available trees of superior phenotype, healthy mother seed trees or elite trees which have good form and healthy canopy with 30-50 cm DBH or trees above nine years
- Select mother seed trees which are vigorous, tall, and have many branches, having characteristics that will yield maximum quantity of harvest wood
- Avoid seed collection from young, over mature, abnormal, disease and infested trees to ensure quality seedling production
- The fresh matured fruits may be collected from the mother trees by branch lopping and shaking method when fruits are still green
- The fleshy fruit capsules are manually cut open to collect the seed
- The fresh fruits can also be dried in the shade for about two days till they burst open and release the seed
- Label the containers with the date and place of collection if it is stored for future use

2.1.2. Seed treatment

- Soak the seeds in fungicide mixed with water for few minutes before sowing; this helps reduce the risk of fungal infection of the seeds

2.1.3. Seed storage

- Normally the seeds start to lose their germination capacity within one week but viability of seeds can be maintained up to two months by storing in a refrigerator (best storage temperature was 10-12° C) (SFED, 2020)
- Store only mature, healthy and well-dried seeds
- Seeds easily re-absorb moisture. To maintain dryness, keep seeds in air-tight containers like tin cans or glass jars with tight fitting lids. Put in some moisture absorbing material like dry wood ash, dry charcoal or small pieces of newspapers

- Before storing in containers, mix with dry ash, a powdered seed of black pepper or neem leaves to protect seeds from insects and fungi

2.2.4. Soil preparation

Good soil preparation for nurseries plays a vital role in ensuring the germination of seeds. The soil preparation is carried out as per the nursery norms and standard code of Bhutan, 2021.

- The soil must be sieved properly with iron mesh to remove stone and debris
- Mixing the sand, leaf mould & top soil in the ratio of 1:2:3 respectively has been prescribed as the good medium for raising seeds in nursery beds as well as poly pots.

Table 2: Specification for soil preparation for nursery

Sl No	Poly-pot size (Dia x ht)	Type of soil with ratio 1:2:3 (sand: leaf mould: topsoil)			
		Sand (cft)	Leaf Mould (cft)	Top soil (cft)	No of poly-pots
1	6 cm x 10 cm	7	14	21	3840
2	7 cm x 15 cm	13	26	39	3790
3	8 cm x 12 cm	10	20	30	2866
4	8 cm x 15 cm	13	26	39	2866
5	8 cm x 20 cm	17	34	51	2866
6	10 cm x 15 cm	13	26	39	1834
7	15 cm x 20 cm	26	52	78	815
8	18 cm x 25 cm	21	42	63	566
9	20 cm x 30 cm	25	50	75	458

- Prepare a soil mixing shed for all nurseries. Soil mixing shed is indispensable in all types of nurseries. This will provide shelter to employees and protect from rain, heat and other natural calamities that hampers the work progress. It will also function as the storage house of sand, leaf mould and topsoil etc. Further prevent washing off of materials and soil nutrients

- Nursery beds should be raised 15-20 cm above the ground to avoid water logging and ensure proper aeration
- The nursery beds are recommended with light shade

2.1.5. Seed sowing and germination

- Before sowing of seeds, burning leaf litter and available debris on the ready beds shall reduce the growth of weeds. Regular hand weeding is required to keep the beds weeds free and ensure quick sprouting of the seedlings
- The seeds should be sown in the nursery beds immediately after collection or within one week
- Mulching sheets can also be provided to suppress weed growth and reduce costs of weeding
- The seeds should be sown in nursery beds about 5 mm deep in a mixture of sand, leaf mould and topsoil
- The seed germinates within 2-3 weeks and normally complete in a month
- *A. malaccensis* has germination rate of 80-90% within 2-3 weeks

2.2. Seedling management

2.2.1. Transplanting

- The seedlings should be pricked out into containers after 30-45 days of germination or when they attain 3-5 cm tall. Or it is pricked out when the sprout develops two to three leaves
- The seedlings should be transplanted into poly pots/polythene bags filled with soil with required mixture/ratio

2.2.2. Watering

- Watering is necessary to keep the soil moist in order to promote germination and growth of seedlings
- The nursery beds should be watered two times a day (morning and evening)

- The seedlings in the poly pots should also be watered two times a day (morning and evening) in the initial stage. Once the seedlings establish, the frequency of watering can be reduced (one time on alternate days) in the morning or in the afternoon.
- Use water sprinklers to avoid over flushing of soil and leaves.

2.3. Hardening

This process is necessary and must be carried out before transporting the agarwood seedlings from nursery to the plantation sites

- The poly pot seedlings (height of 1 feet and above) should be kept outside the nursery for 2-3 weeks for hardening
- The seedlings should be removed to a place where there are no overhead shades
- Watering intensity should be reduced to once a week or once in two weeks only

2.4. Nursery management

- Regular weeding of nursery bed for vigorous growth and reduce competition
- Prevent pest and disease like damping-off, leaf defoliator of the seedlings in nursery caused by high humidity, fungal and insect attack
- The seedlings for the plantation should be healthy and leading shoot must be intact
- Normally *Aquilaria* species are raised in containers (poly pots and poly bags). But bare root planting can also be done if the seedlings are healthy
- The seedlings raised in the containers should be graded and shifted from time to time to avoid deep rooting
- Care must be taken during loading, unloading and transportation of the seedlings to avoid damages
- Deploy a dedicated nursery caretaker to ensure the healthy growth of the seedlings

2.5. Plantation

Plantation of agar trees in Bhutan was introduced as early as the 1970s (SFED, 2020) as agroforestry crops.

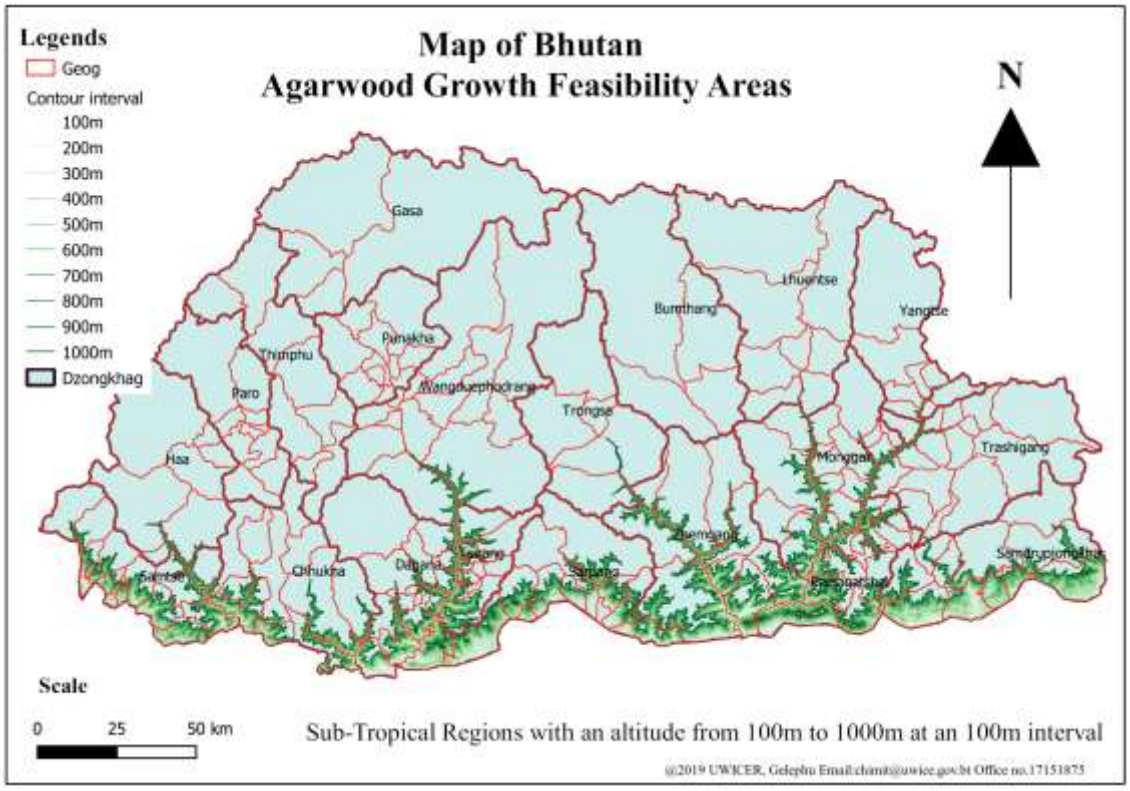

Figure 4: Agarwood growth feasibility areas in Bhutan

2.5.1. Plantation sites/site selection

Any site exceeding 1000 masl elevation is not optimally recommended for carrying out agarwood plantations. While selecting the plantation site, must avoid: swampy, water stagnant, alum, and limestone surface soils. Areas with relatively high temperature and humidity are preferred sites for agarwood plantations. For sustainable land management, the recommended plantation sites are marginal and degraded land with the following physical, edaphic, and climatic parameters.

Table 3: Suitable physical, climatic and edaphic conditions for growing agar trees

Parameter	Criteria
Altitude	Up to 1000 masl
Slope	Up to 45 degrees
Soil texture	Low fertility, stony and deep soil (light; medium)
Soil drainage	Free
Soil pH	Acidic to slightly neutral (optimum soil pH from 4-6)
Annual rainfall	More than 1800 mm per year
Temperature	Average 20-22°C; Max 22-28 °C; Min 14-21°C
Humidity	High

Though agar trees are known to grow in low fertile and stony soils, from the observation's agar trees are also found to be thriving very well in fertile agricultural lands and in sandy to sandy-clay soils as well. Fertilizing the agar plants with cow dung and manure have helped in their growth.

2.5.2. Planting specifications

The success of a plantation depends on multiple factors such as soil preparation, seedling quality, planting season and management of the plantation. Ideally plantation is done during February-April when new buds sprout so that the seedlings can grow shoots in the year of the plantation alone. However, in Bhutan, most plantations are carried out during the onset of monsoon (June-August) considering the availability of natural rain water. Agar is a long-term plantation crop that requires careful planning to produce high-quality essential oil. If personal care and attention can be provided regularly including watering the agar seedlings can be planted from the beginning of February so that the seedlings can gain one season's growth.

Table 4: Agarwood seedlings can be planted maintaining the following spacings.

SL No	Spacing distance (m x m)	Number of seedlings per acre (numbers)
1	2 x 2	1031
2	2.5 x 2.5	680
3	3 x 3	436
4	4 x 4	258
5	5 x 5	160

The following specifications are recommended for proper planting and survival of agar seedlings:

- It is recommended to use one year old poly pot seedlings for planting in the field or seedlings which have attained a minimum of 40-60 cm height, and container must be removed at the time of planting and appropriately disposed
- The spacing between the seedlings should not be less than 2.5 m x 2.5 m or at least 2 m x 2 m or to ensure that the tree attain bigger diameter which is easier for inoculation
- Saplings should be planted in 50 x 50 x 50 cm or larger pits for easy growth and root adaptation
- The pits should be dug at least two weeks prior to planting for soil aeration. The planting pit must be refilled with the same soil that was removed and the soil should be fine
- Cow dung or farmyard manure should be mixed with soil in the planting pits to create favorable nutrient conditions for the plants to establish and grow well

Figure 5: Crowded plantation not resulting into proper height and size growth

2.5.3. Plantation maintenance

Post-planting care, including fencing, consistent weeding, watering and hoeing is essential to ensure seedlings reach optimal height and healthy growth.

2.5.4. Fencing

Agarwood is normally not grazed/browsed by livestock as it is not palatable. The fencing is required mostly to prevent damage/trampling of the seedlings from livestock grazing and wildlife disturbances. The types and pattern of the fencing may vary depending on the biotic pressures and resource availability.

2.5.5. Weeding and cleaning

Due to hot and humid climatic conditions in the subtropical region, the growth of weed and climbers like *Mikania micrantha* (L.) Wild., *Chromolaena ordorata* (L.) R.M King & H.Rob, *Paederia foetida* L. etc, are very fast, thus suppressing growth of agar seedlings. Therefore, a minimum of 3-4 times weeding and cleaning during the first five years or until the agar seedlings attain heights beyond the reach of these climbers and weeds after plantation is necessary.

2.5.6. Soil covering

For the first five years of the plantation, soil covering around the root system is recommended to avoid washing away of the soils due to heavy rain.

2.5.7. Casualty refilling

The dead seedlings should be replaced in the next planting season following all the steps diligently.

2.5.8. Mixed cropping

The mixed plantation/cropping can happen in two-tier:

- Mixed cropping with other trees like citrus, litchi, mango, areca nut etc. for pest repellent and growth
- Mixed cropping with ground crops like cereals, turmeric, ginger, tea, coffee, sugar cane, etc. for ground mulching and nutrients enrichment

The planting of mixed horticulture crops and other ground level crops have the following advantages:

- The mixed crop is more resistant to pest attacks. Plant species like *Citrus & Citronella* are good insect repellants
- The availability of other plants for light and nutrient competition allows agar trees to grow faster and attain harvestable height/girth quicker than monoculture of agar trees alone
- It also ensures multiple choice of products for sustained additional income

Figure 6: Mixed cropping with horticulture ground crops and tree

CHAPTER THREE: Pest and Disease

Figure 7: Agar tree leaf defoliator

Agar trees grown in the natural environment interact with microbes and insects are usually not a management concern. However, *Aquilaria* trees in nurseries and plantations are susceptible to various pests and diseases, requiring careful management of hygiene in nurseries, during early growth, and at planting sites. There are four common pests and diseases outlined in table below (**Table 5**). The signs, symptoms, level of damage and management practices are accordingly described.

Table 5: Pest and disease of *A. malaccensis*

Sl No	Pest and diseases	Signs and symptoms	Level of damage	Management practices
1	Wood borers (Lepidoptera: Cossidae)	Stunted crown development, swelling/ depression, cancers on the bole, and appearance of dieback symptoms/ decay top branches	Moderate (kills young plants during severe infestation, as the hollowed trunk sare vulnerable to breakage	1. Trimming and removal of infected branches 2. Application of liquid-based pesticides 3. Applying neem seed kernel extract or green chili extract, or lemon oil

2	Leaf defoliators (Lepidoptera: Crambidae)	Appearance of brown, wilted leaves, coupled with a mixture of frass and silk web	Major (feeds on young shoots and stems disturbing growth)	1. Organic pesticides (plant extracts from *Capsicum annum, Allium sativum*, and Neem. A entommopathogenic bacteria & entomopathogen ic fungus. 2. Overturning and burning of topsoil during cold season 3. Biological control using natural predators, *Sycanus dichotomus, Oecophylla smaragdina*, and *Polistes* spp
3	Sap suckers (Hemiptera, whiteflies)	While fluffy spots beneath the leaf surface and presence of sooty mold fungus	Moderate (infestation could make the plant less vigorous, and cause mortality to young plants)	1. Oil emulsion spray consists of 1:1 of 500 ml soap water and oil 2. Manual leaf removal on infected region 3. Water spray to remove insect 4. Use wood vinegar (charcoal extract) to ward of insects and pests 5. Chemical spray (diluted malathion)
4	Damping off disease	1. Poor seedling emergence 2. Young shoots and leaves show irregular stain-like patches 3. Leaf decay/rotting & drying root tips 4. Browning or rotting of non-germinated seed 5. Rots near the stem collar	Minor (premature death of young seedlings)	1. Biocontrol (*Arbuscular mychirrhiza*l fungus *Glomus fasciculatum* to control Phythium's attack) 2. Prevention through use of pathogen-free seeds, media, and water 3. Raising pots one meter above ground 4. Use of fungicide containing thiabendazole, benomyl, and thiram

CHAPTER FOUR: Inoculation

This chapter has two parts: the first section deals with preparation of the inoculum/inducer and the second section deals with the delivery methods of the inoculum. Both the inoculation and the delivery methods are homegrown and some are adapted from research experiments in the field.

4.1. Development of Inoculum/Inducer

This section provides detailed steps in preparation of agar tree inoculum. The preparation of the inoculum is described in two categories – first category describes preparation of bio-inducer and the second part described organic-chemical formulation of the inoculum.

4.1.1. Bio-Inducer:

i. Preparation of potato dextrose agar (PDA)

This section contains the process of preparation of Bio-inducers including process in culturing of the agarwood fungus.

PDA is a widely used medium for culturing fungal mycelium. It provides essential nutrients for fungal growth and is relatively simple to prepare (NMC, 2024). Below are the steps involved in preparing PDA media:

Figure 8: Preparation of PDA

a. Preparation of potato broth

- Take 200g of potatoes, wash them thoroughly, and slice them into small pieces
- Boil the sliced potatoes in 1 liter of distilled water for 15 to 20 minutes
- After boiling, filter the potato broth using a cheesecloth to remove any solid potato pieces
- Adjust the volume of the broth to 1 liter by adding more distilled water, if needed

b. Adding glucose and agar powder

- To the filtered potato broth, add 20g of glucose (dextrose) and 15-20g of agar powder
- Heat the mixture until the glucose and agar dissolve completely, ensuring that there are no clumps

c. Preparation of liquid culture

- Add 20g of honey to 0.5 liter of water (4% of 1000 ml)
- Heat the mixture until the honey is dissolved in a water

d. Sterilization

- Pour the mixture into sterilized bottles or conical flasks
- Sterilize the media in an autoclave at 121°C and 19 psi (pounds per square inch) pressure for 45 minutes

ii. Sample collection and storage

The infected agarwood samples shall be collected from naturally agar stands at Norbugang (Samtse), Phibsoo Wildlife Sanctuary and Royal Manas National Park (Hatilora & Agoorthang). The sample shall be collected from naturally formed agarwood and stored in cool places before culturing (cool box).

iii. Pure culture

There are two ways of raising pure culture

- Tissue culture
- Spore culture

Tissue culture method is the most reliable and recommended for the fungal culture. In the process of spore inoculation, contaminants such as bacteria and molds may grow together making it difficult to get pure culture of the fungus.

a. Tissue culture

Tissue culture involves taking a small piece of tissue about $1cm^2$ from a fungus/sample and growing it on an agar medium, such as PDA, to propagate the mycelium. To begin, a young and healthy fungal/agarwood is selected. The infected agarwood is wiped with ethanol to sterilize its surface, and then it is carefully split lengthwise using hands, avoiding contact with the inner tissue where the sample is taken. A small, sterile piece of tissue is then excised and inoculated onto PDA media slants or petri plates under aseptic conditions, typically within a laminar airflow cabinet to prevent contamination. Over the course of approximately two weeks, the mycelium will grow out from the tissue and spread across the surface of the medium. Once fully grown, the culture can be used for further multiplication and spawn production, provided it is kept at the appropriate temperature to encourage mycelial development.

b. Spore culture

Spore culture involves growing the spores of the desired fungus on a suitable medium. The process begins by obtaining a spore print on clean paper or in a Petri plate under aseptic conditions. A small amount of spores is then collected using the tip of an inoculation loop, and a serial dilution is performed in test tubes containing 9 ml of sterilized water, usually diluted up to 10 times. The diluted spore solution is either inoculated onto agar media to isolate single spores or directly inoculated onto fruiting substrates, such as grains or sawdust. Liquid media can also be used. The first fruiting bodies grown from the grain or sawdust substrates are cultured on PDA media, followed by sawdust media. The best-performing strain, based on high yield and desirable morphological characteristics, is then selected for mass propagation.

Figure 9: Tissue culture in laboratory

iv. Identification

The identification of fungus shall be guided by relevant literature and books on fungi of Bhutan (Mata et al., 2010). The fungus like *Aspergillus spp., Botryodyplodia spp., Diplodia spp., Fusarium bulbiferum, F.oxysporum, F.laterium, F.solani, Penicillium spp*., and *Phythium spp*. like species. And these can benefit from the immunization process (Ngadiran et al., 2023). *Cunninghamella, Curvularia, Lasiodiplodia*, and *Trichoderma* are also used for this purpose in some cases. However, *Fusarium solani, Cunninghamella bainieri*, and *Lasiodiplodia theobromae* are commonly used in this Inoculation process (Rasool and Mohamed, 2016). *Fusarium solani* is the most effective agarwood-forming agent (Turjaman et al., 2016).

v. Mother spawn preparation

Mother culture refers to the propagation of the desired fungal strain on agar plates, originating from stock cultures that are prepared and preserved in a gene bank (refrigerator or deep freezer). Stock cultures are typically maintained on agar slants (in test tubes) because they can be stored for longer durations compared to agar plates. From a single agar slant, it is possible to inoculate up to five agar plates, which can then be used to prepare up to 25 bottles of mother spawn on grain or sawdust medium. This process ensures the propagation of healthy and vigorous mycelium for large-scale fungal production. The procedure to prepare mother spawn preparation are as follows:

a. Washing and boiling

The grain is first washed thoroughly two to three times with clean water. It is then boiled in a pot or rice cooker for 40 to 45 minutes. During boiling, the grain is stirred occasionally to ensure even cooking. Care is taken not to overcook the grains, as they should not burst during boiling.

b. Moisture content

The grains should have an optimum moisture content of 43 to 45%, which can be determined by weighing the grains before and after boiling. Ideally, the grain's weight should increase by 1.6 times after boiling.

c. Drying and mixing

After boiling, any excess water is drained, and the surface moisture on the grains is allowed to air dry. Once sufficiently dry, gypsum ($CaSO_4.2H_2O$) or calcium carbonate ($CaCO_3$) is added at a rate of 6 grams per kilogram of boiled grain and mixed thoroughly. This addition helps to prevent clumping and maintains the pH balance of the grain.

d. Packaging

The prepared grain is then packed into 500 ml glass bottles, with approximately 300 grams of grain per bottle. The bottle mouths are closed with cotton plugs to allow air exchange, and a plastic sheet is placed over the plugs to prevent moisture from wetting the cotton during sterilization or storage.

e. Autoclaving

To sterilize the grain bottles for spawn production, they are carefully arranged inside the chambers of the autoclave. The lid of the autoclave is initially left half-open for about 1.5 hours, allowing all the air to escape. Once this is achieved, the lid is fully closed. When the internal temperature of the autoclave reaches 121°C, the sterilization process continues for an additional hour. After the autoclave cycle is complete and the pressure gauge returns to zero, the sterilized bottles are carefully transferred to the laminar airflow cabinet

vi. Cooling and inoculation

Before transferring the sterilized bottles, the laminar airflow cabinet is cleaned with 70% ethanol and runs for 15 minutes. The entire room is also misted with 70% ethanol to maintain sterile conditions. The grain bottles are labeled with the inoculation date, the strain name, and then inoculated with mother spawn. One bottle of mother spawn can inoculate up to 20 bottles of cultivation spawn. After inoculation, the spawn bottles are incubated at a temperature of 21-23°C and 60-70% relative humidity. Once the bottles are fully colonized by the mycelium, they are transferred to a storage room until they are ready to be supplied to agarwood growers.

vii. Storing fungal spawn

The storage conditions significantly impact the longevity and quality of fungus spawn. The ideal storage temperature for spawn is between 2 to 4°C, allowing the spawn to be stored for 2 to 4 months. The spawn (wooden dowels inoculated with mycelium) can last between 8 months and a year. It is important to avoid exposing the spawn to high temperatures, humidity, or direct sunlight, as these conditions can reduce the spawn's viability. Spawn should also be protected from pests and transported during the cooler hours of the day. For best results, it is recommended to use the spawn immediately after it is supplied to ensure its vigor and productivity. Spawn that is stored for too long will lose its effectiveness.

Figure 10: Incubation

viii. Mixing with molasses

The matured pure fungus is then mixed with molasses and kept for 14 days before inoculation.

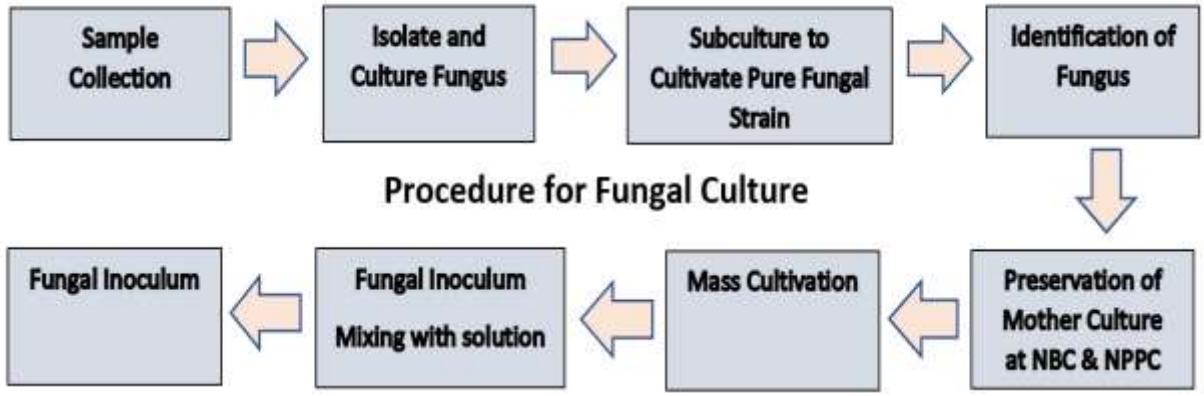

Figure 11: Fungal culture

4.1.2. Chemical (organic chemical)

This section contains process for preparation of organic chemical inoculation made from locally available materials.

Limitation: The current inoculum/inducer preparation and recommendations are based on one time research trial in the field. As per the first result of inoculation in younger trees, it was observed that the result is positive (agarwood formed) but the team didn't check the quality of agarwood formed.

i. Salt and sugar mixture

Primary Agar inducing ingredients consist of food grade salt and sugar available in the market are used for preparation of inducers. The inducer is made after mixing salt and sugar (1:1 ratio) and inoculated to the tree immediately. The inducer is thoroughly mixed aseptically in a clean container at home before injecting into the trees. The mixed inducers are packed in an airtight container (example plastic container) to avoid contamination.

ii. Molasses

An alcohol-based inoculum infused with cultured fungus is prepared at the laboratory, which was kept for fermentation and growth of fungus for a month. After there is some sign and indication of fungus growth, it is finally inoculated to agar trees.

4.2. Delivery methods

4.2.1. Guiding principle for agar tree inoculation

i. Ideal age

- Trees should be at least 7-10 years old with evidence of vigorous growth
- Older trees tend to yield more resin and higher quality resin but younger trees (3-5 years) can still produce viable resin if induced artificially (Mohamed et al., 2014)

ii. Tree diameter

- Minimum recommended diameter: 10 cm and above (Chhetri et al., 2004)

iii. Season and day –timing

- Generally during the dry season or at the end of the rainy season when the tree's growth rate slows down. This is because slower growth during the dry season encourages stress in the tree, which can enhance the agarwood production
- Morning or late afternoon can be preferable for inoculation procedures to minimize water loss and stress from midday heat, which can adversely impact the tree's overall health

iv. Optimal harvesting period

- 12-36 months post-inoculation is typically recommended to ensure adequate resin formation without over-stressing the tree, which might lead to mortality (Chong et al., 2015, Hearth and Jitendra 2023; NDF, 2023)

4.2.2. Drilling techniques

i. Burning chisel drilling technique:

The Burning-Chisel Drilling (BCD) method is also based on drilling the tree trunk at a higher temperature. The basic principle of this is to create wounds in the tree and activate its self-defense mechanism. The iron chisel or a drill bit used here is heated to red-hot around 600 Degree Celsius and is 1.2 cm in diameter. The holes created by the drilling will be approximately 20 cm apart. Following that, the holes should be instantly sealed by using sterilized paraffin wax and it avoids contamination by detrimental microbes (Chowdhury et al., 2016). It is best to avoid making holes up to 50 cm from the ground (Liu et al., 2013).

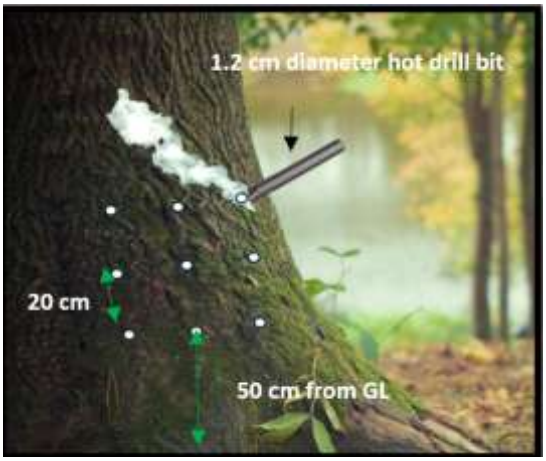

Figure 12: Burning chisel drilling technique

ii. Drilling method

An electric or hand-made drill is typically used to place drill holes in the tree trunk, limbs, and main branches (Akter et al., 2013; Faizal et al., 2017). The drilled pores were spirally placed from the ground up to the crown. Drill holes were spaced 3 to 5 cm apart and then infected with agarwood-inducing materials or remaining open to allow natural agents easier access (Chowdhury et al., 2016). This is a strategy for attracting insects to the tree to infect it. To speed up the infection, the liquid syrup can be added to pores and attract natural agents such as beneficial insects to it. Every 2-3 months, pores are examined and wounded again (Blanchette, 2006; Ngadiran et al., 2023).

Figure 13: Drilling method using electrical drilling machine

iii. Chisel cut method

- It is traditional techniques to create wounds that stimulate agarwood formation.
- Using a chisel, make horizontal cuts about 3-5 cm deep and 2-4 cm wide along the tree trunk.
- From the ground level keep 20-30 cm distance.
- Follow a vertical interval of 20 cm between cuts, spiraling up the trunk.
- Frequent re-cut is required to prevent closure of the cuts.
- To this method, chemical inducer filling can also be performed to initiate the formation of resin and sealed with wax.

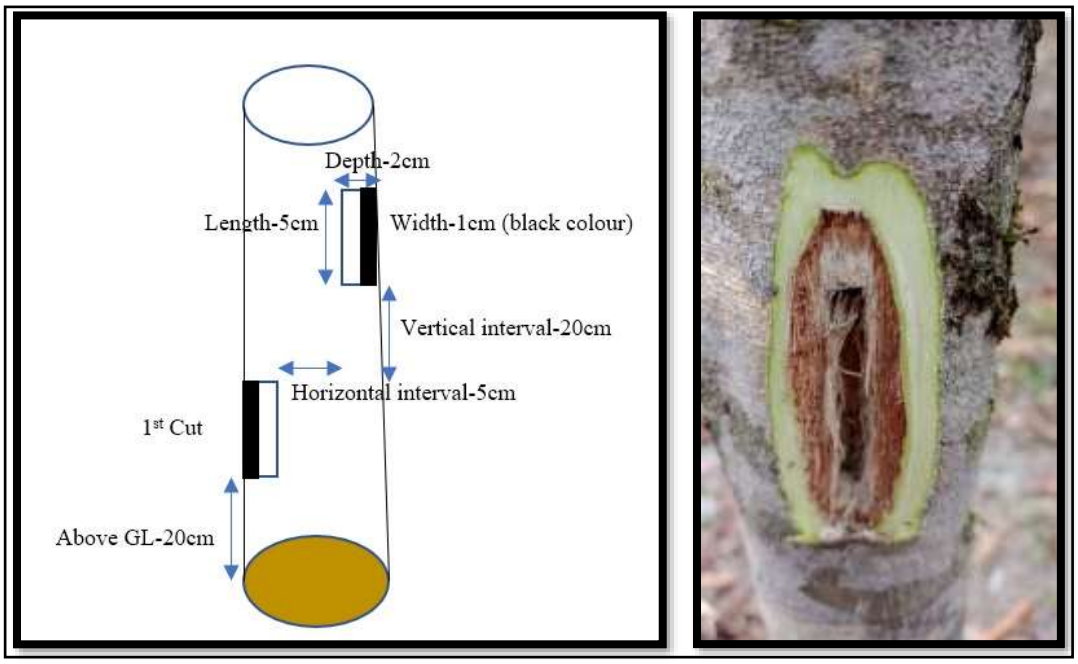

Figure 14: Showing the cut using the chisel on the agar tree trunk

4.2.3. Inoculation process

i. Pipe aeration method

- This method introduces foreign materials into artificial wounds to prolong infection and stimulate continuous resin production
- Use an electric hand drill or battery powered drill

- Drill holes of 2 cm diameter in size at an angle of 30-45 degree
- The holes should not reach the pith of the tree (hole length depends on the size of the tree diameters)
- The drilling should be slanting inward along the trunk and shouldn't exceed ⅔ of the diameter
- From the ground level keep 20-30 cm distance
- Maintain vertical distance of 20 cm and horizontal distance of 10 cm in a spiraling system
- Fill up the holes with inducers to boost resin production
- Insert a 2 cm diameter aeration device (plastic tube) in each drilled hole
- Extend the aeration device about 2-15 cm outside the tree trunk to keep the wounds open and induce sustained resin development
- The quantities of inducers for second round and third round filling up inducer before harvesting, may depend on the tree sizes

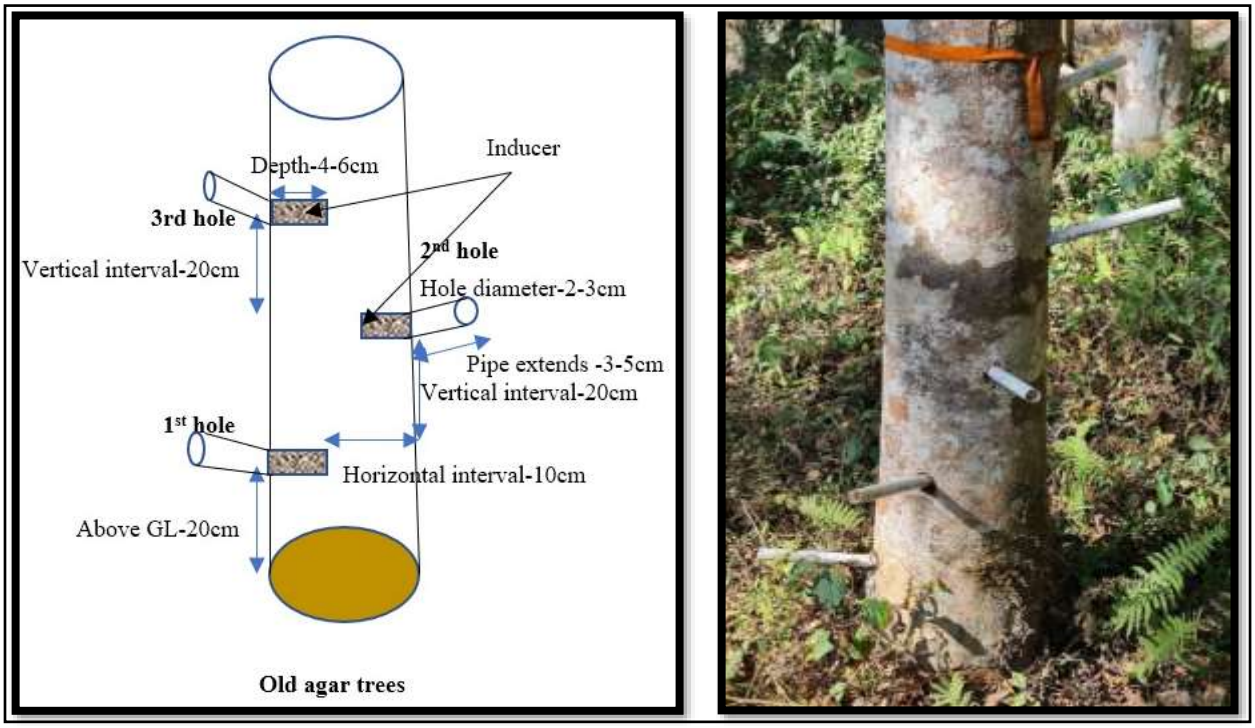

Figure 15: Showing the pipe insertion method after filling up with an inducer.

ii. Stick insertion method

The stick method for agarwood inoculation involves inserting small wooden/bamboo sticks into drilled holes in the trunk of the *Aquilaria* tree. The bamboo stick method is known as the knocking method (KM) (Herath and Jinendra, 2023). In this method, bamboo sticks are utilized to deliver a chemical agarwood inducer and facilitate aeration. The unique structure of bamboo, composed of microfibrils around the epidermis, parenchyma cells, and vascular bundles, makes it particularly suited for this purpose (Habibi and Lu, 2014). Upon insertion into a tree's trunk, bamboo gradually releases the inducer, triggering a sustained stress response that promotes agarwood formation. In healthy trees, this process can lead to the development of a dense, resinous layer, though weaker trees may suffer significant damage or mortality. For KM, electric drills create holes for 6 cm bamboo sticks pre-soaked in an inducing solution containing acetic acid, sodium chloride, and fruit enzymes (Peng et al., 2021; Ngadiran et al., 2023).

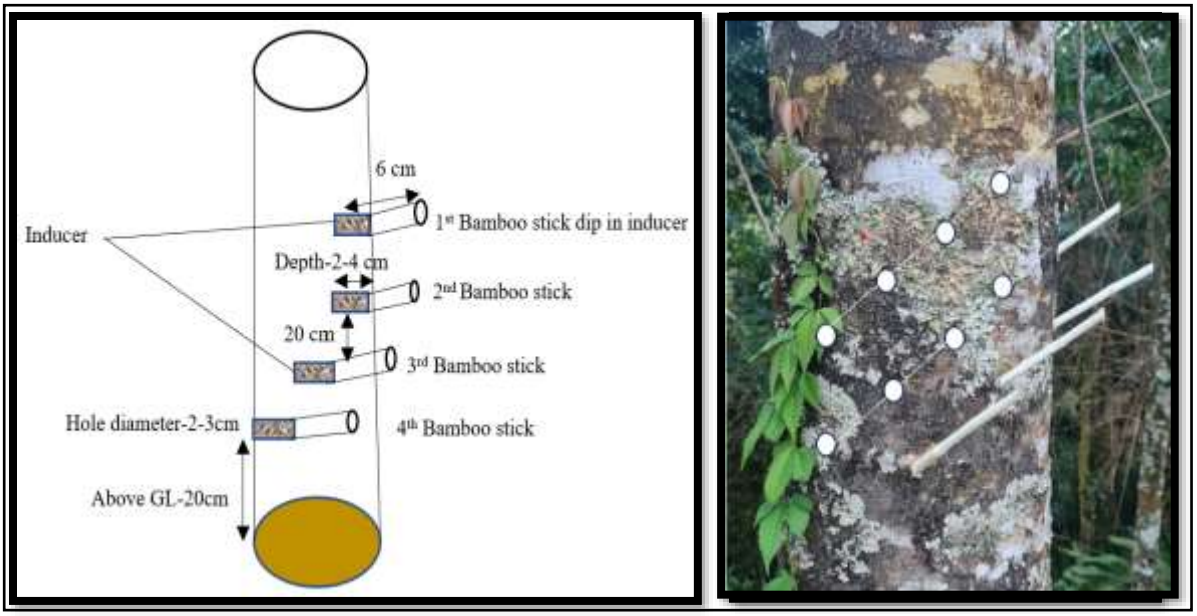

Figure 16: Stick insertion method

The bottle-dipping technique involves connecting a bottle to inoculation holes to deliver the agarwood inducer in a controlled drip. Parafilm is used to seal the inoculant, preventing leaks, while a hose connects the bottle to the wound, which is then sealed with clay to secure the setup (Justin et al., 2020). This method enables a gradual release of 10-20 ml of inoculant per hole,

amounting to approximately 1–3 liters per tree over time (Mustapa et al., 2022). The gradual delivery optimizes the inoculant's effectiveness in stimulating agarwood formation while minimizing resource waste.

iii. Bottle injection method

Figure 17: Bottle injection method

iv. Drilling and wax sealing method

- Use an electric hand drill or battery powered drill
- Drill holes of 2 cm diameter in size at an angle of 30-45 degree.
- The holes should be made up to the xylem of the tree.
- From the ground level keep 30-50 cm distance.
- Maintain vertical distance of 20 cm and horizontal distance of 10 cm in a spiraling system.
- Fill up the holes with inducers to boost resin production
- Once filled, seal each drilled hole with paraffin or beeswax. This helps to retain the chemical inducer, prevents contamination and sustains pressure inside the hole promoting effective resin formation.

Note: The success of all these methods is influenced by temperature, humidity, and soil quality, emphasizing the need for a controlled cultivation environment.

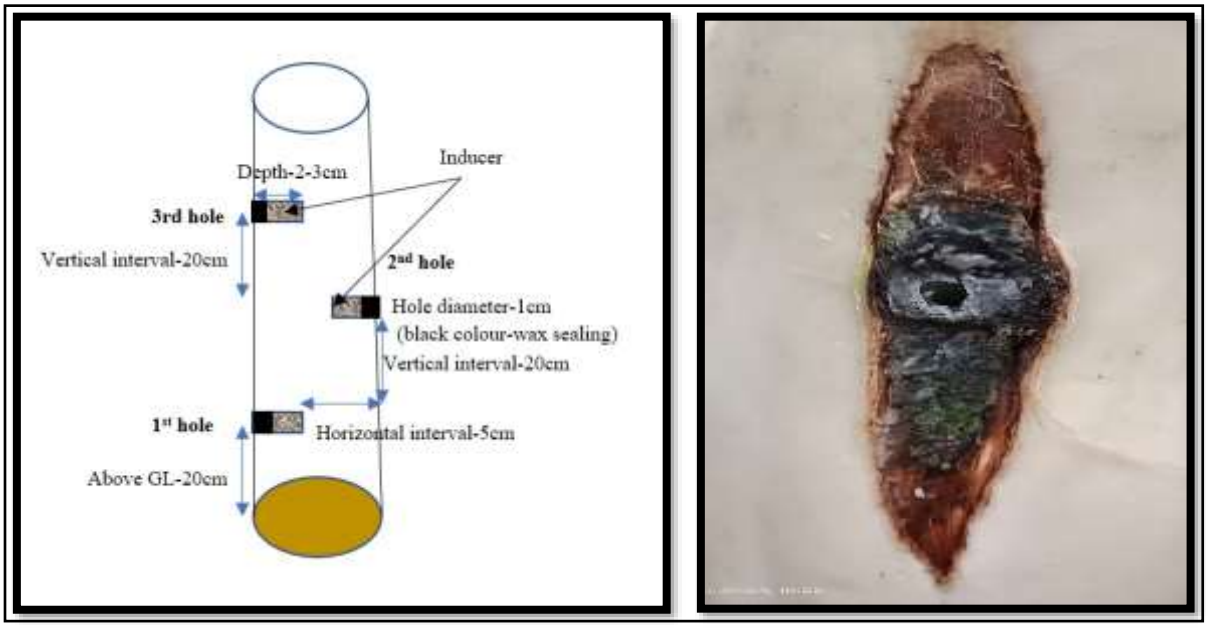

Figure 18: Drilling and wax sealing method

CHAPTER FIVE: Agarwood Formation & Harvesting

5.1. Agarwood formation

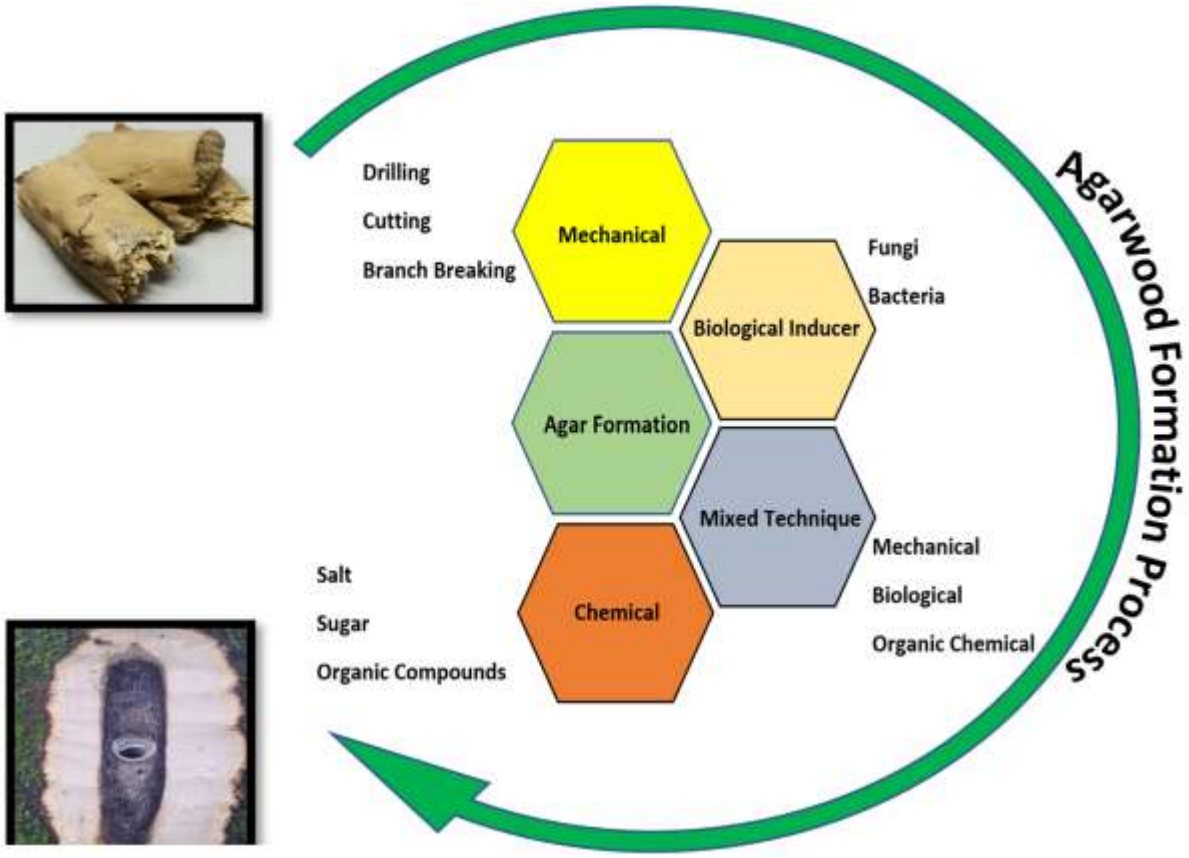

Figure 19: Agarwood formation process

Agarwood is formed as a result of the tree's defense mechanism against external threats, making it a unique and valuable product. This process is part of the plant's evolutionary adaptation, creating physical and chemical barriers to protect against pathogens before or after tissue injury. Infected agarwood is characterized with dark resin that forms in the stem, branches, or roots of *Aquilaria* trees following tissue damage and infection by specific fungi or other factors. In nature, this wounding can result from strong winds, lightning, or insect activity, triggering the tree's defense response. Generally, this involves activating biosynthetic pathways that produce secondary metabolites, mainly sesquiterpenes, through enzymes called sesquiterpene synthases, which regulate the mevalonate pathway. These compounds accumulate around the damaged area, forming a barrier that limits microbial spread. Over time, the build-up of these metabolites becomes the resin known as agarwood. However, in the wild, agarwood formation is often a lengthy process (Deep and Tajuddin, 2019).

5.1.1. Natural agarwood formation

Insect damages, as well as other natural damages to trunks or branches, are commonly responsible for formation of agarwood in the natural environment. Bacterial, fungal infections, physical damage from wind, and lightning strikes may also be factors in the formation of agarwood inside trees (Xu et al., 2013). Some caterpillars and beetles also bore the trunk, causing agarwood formation (Turjaman et al., 2016). It has been observed that these things have a very low probability of occurring and naturally inducing the agarwood (Subasinghe and Hettiarachchi, 2013). Around 10 % of trees will produce agarwood in their natural habitat (Chowdhury et al., 2016; Liu et al., 2013).

5.1.2. Artificial agarwood formation

Artificial agarwood induction is an approach for obtaining a fruitful agarwood harvest from commercial agarwood plantations (Yin et al., 2016). Agarwood can be produced artificially through mechanical injuries, injection of chemical and organic solution into the agar trees. Mechanical injuries to agar trees like drilling, nailing, chopping, cutting can also help formation of agarwood.

5.2. Sign & symptom

The external symptoms that aid in identifying the initiation or formation of agarwood in agar trees include appearance of borer holes, oozing out of watery substances from fresh borer holes, and accumulation of frass at the base of the tree. Other signs include the closing of borer holes by the growth of host tissue leaving a small spindle-shaped mark, longitudinal cracks on the trunk or bole, swelling or depression, and sometimes canker formation on the tree stem. Appearance of hordes of ants in the tissue, formation of ant nests, smaller and yellowish leaves, overall abnormality and ill health of the plant, and hearing a hollow sound when the trunk is hammered also indicate agar formation. The presence of black patches on the plant's bark indicates infection. By observing these black patches, infected trees, whose further growth is arrested, can be selected for harvesting. In nature, agarwood formation generally takes up to 40-100 years, but this process can be accelerated through artificial inoculation, reducing the agarwood formation time to 18 months to 15 years.

Table 6: Difference between rotting and agarwood (Liu et al., 2022)

S/N	Wood decay	Agarwood
1	Caused by wood decaying fungus	Caused as result of tree defense towards inoculum/inducer and injuries
2	Black, brown & white in color	Yellowish black, black & dark brown
3	No fragrance while burning	Fragrance scent while burning
4	Usually, fragile or soft	Hard
5	Natural process	Natural & artificially induced

5.3. Harvesting

5.3.1. Harvesting age

Harvesting time depends on the extent of agarwood formation and the accumulation of oleoresin in the heartwood. Usually, the agarwood which is artificially inoculated will be harvested by the end of 18-20 months after inoculation (Borah et al., 2024).

The maturity age of agar in the tropical regions is reported as 7 years, however considering the difference in geophysical conditions and climate conditions, the rotation age/maturity age is prescribed as 10 years for Bhutan (NDF, 2023). The agar trees can be harvested when they reach 10 years of age. In some places the harvesting shall also depend on the merchantable size the trees attain.

5.3.2. Time

The dry season between January and May is preferred for harvesting to obtain the maximum yield of oil and the presence of less waxy substances in the wood (Borah et al., 2024).

5.3.3. Harvesting technique

i. Felling of the whole tree

Figure 20: Whole tree method

In this method, the whole tree is felled to collect agarwood from the infected tree. Felling the agar trees at the height of 2.6-3 feet from the ground level is recommended as agar trees produce good coppices from the pollarded stumps.

ii. Parts collection

Figure 21: Parts collection method

Only the infected portion/parts will be removed from the agar tree at one time ensuring recurrent agarwood production from the same tree over multiple years. It is well-known among farmers who cultivate agarwood for oil production. This strategy, however, is strongly recommended for trees older than 10 years (Chen *et al.*, 2018).

5.3.4. Harvest management and control measures

The agarwood harvesting in Bhutan requires a removal permit issued by Field Division/ Protected Area, DoFPS as per FNCA & FNCRR, 2023. The removal permit confirms that all fees are paid and the wood was collected from a licensed area. Bhutan will adhere to the CITES regulations, including harvest quotas and permit requirements as per the NDF, 2024.

CHAPTER SIX: Agarwood processing and marketing

6.1. Processing for agar chips

6.1.1. Wood splitting

Figure 22: Splitted agarwood

The wood splitting process for agarwood oil extraction begins with selecting mature logs exhibiting dark resinous areas, essential for optimal oil yield. Logs are trimmed to a manageable length and then split along the grain using an axe or hydraulic splitter, ensuring uniform pieces for easier resin extraction. The split wood is further reduced to smaller chunks (5-10 cm) to maximize surface area. Then, the wood was chopped into 2-3 inch long and 0.5-1 inch thin pieces using a sharp, heavy knife for fermentation (Islam et al., 2020).

6.1.2. Wood chipping

Agarwood chipping involves removing uninfected parts of the wood to isolate the infected, resin-rich sections, which are then graded for sale. Using tools like chisels, hand saws, and sharp knives, workers carefully chip away at the wood, discarding non-resinous areas and retaining only the high-quality agarwood. This meticulous process maximizes the yield of valuable agarwood, which is classified based on resin density and aroma, ensuring better quality and market value.

Figure 23: Chipping agarwood (right; removing non-infected agarwood and left; pure agarwood)

6.2. Processing for agarwood oil

6.2.1. Chopping and drying

The wood was finely chopped into pieces measuring approximately 2-3 inches in length and 0.5-1 inch in thickness using a sharp, heavy knife. These uniform dimensions were prepared specifically for the fermentation process, which is essential for optimizing the subsequent stages of agarwood processing and oil extraction. Then, the woodchip is collected and sun-dried to effectively remove any remaining moisture.

6.2.2. Grinding

In the preparation process, agarwood chips are grinded into a fine powder to accelerate fermentation and enhance resin extraction. Using a high-powered industrial grinder, the wood chips are carefully ground to a consistent fine texture. This increased surface area allows for more efficient microbial action during the fermentation stage, resulting in a higher resin yield.

6.2.3. Fermentation

The wood was soaked in a closed container for 7-28 days. For 20 kg of agarwood powder, water is added to a depth of 5-7 cm above the powder, fully immersing it. Fermentation occurs over 10 days or more, using normal water in a sealed container. Jok et al., (2015) found that a 14 days soaking period yields optimal results. To prepare 20 liters of agar powder, approximately 150-170 liters of water is added.

Figure 24: Fermentation of agarwood

6.2.4. Distillation

i. Set up the hydro-distillation apparatus

A typical setup includes a boiler tank for generating steam, a condenser to cool and condense the vapor and a separator to collect and separate the oil from water. Add water to the boiler tank and ensure the condenser is connected securely for efficient cooling.

ii. Add agarwood powder

Place the agarwood powder in the boiler containing water. The powder should be submerged but not overcrowded to ensure optimal circulation and heating.

iii. Heating

While heating, monitor the temperature closely, usually between 90 to 95 degree Celsius to avoid burning agarwood powder. As the water boils, steam will pass through the agarwood powder extracting volatile compounds.

Table 7: Heating sources for agar distillation

Aspect	Firewood	LPG Gas	Electricity
Efficiency	Low, inconsistent heating limited scalability for large batches	Moderate, consistent heat but fuel dependent	High, precise control, highly scalable for all batch sizes
Environmental Impact	High CO_2 emissions, deforestation risk	Moderate CO_2 emissions, fossil fuel based	Zero direct emissions hydroelectric power supports sustainability
Cost & Labour	Low initial cost, high labor and fuel costs over time	Moderate initial cost, high ongoing fuel costs	High initial cost, low operating cost due to inexpensive electricity
Energy Consumption	Low heat efficiency, high CO_2 per unit	Medium efficiency, lower CO_2 emissions	Very high efficiency zero CO_2 emission

iv. Condensation

The condensate, a mixture of water and agarwood oil, flows into the collection vessel. Overtime, the oil will begin to separate from water due to difference in density.

v. Separation

Allow the condensate to settle in a separatory funnel to separate the oil layer from the water. Extract the agarwood oil carefully, leaving behind only remaining water.

vi. Oil storage

The pure agarwood oil should be stored in amber colored airtight bottles in a cool dark to preserve its quality overtime.

Figure 25: Distillation units 1. Firewood heating, 2. LPG distillation unit and 3. Electrical distillation unit.

6.3. Product diversification and value addition

The primary markets for agarwood are situated mainly in Asia and the Middle East. The Gulf countries, especially the United Arab Emirates and Saudi Arabia, represent key markets where agarwood is greatly valued for its applications in incense and perfumes. Additionally, China, Japan, and South Korea are prominent consumers, employing agarwood in traditional medicine, incense production, and cultural ceremonies. In the United States and the European Union, it is utilized as a stabilizer in premium perfumes (Hearth and Jitendra, 2023). Agarwood is used as an ingredient in luxury perfumes and personal care products. The essential oil produces fragrances, which last for longer duration. Beyond perfumery, agarwood oil is valued in skincare for its anti-aging and detoxifying properties, making it a popular addition to creams and cosmetics.

6.3.1. Agar oil

Figure 26: Agar oil

Agarwood oil, also known as attar or aguru, is a luxurious essential oil extracted from infected agar trees through distillation. In the Middle East, agarwood oil is a symbol of wealth and is often used in wedding ceremonies. It is also recognized in traditional medicine for potential anti-inflammatory and antimicrobial benefits. The oil is usually sold in tola (13 g) at about Nu. 10000-100000. In addition, the value of agarwood essential oil can be as high as US$ 30,000 per kilogram. The annual global market for agarwood has been estimated to be in the range of US$ 6 – 8 billion (Akter et al., 2013), yet a large number of the trades have not been recorded.

6.3.2. Medicine

Figure 27: Agar medicine

Agarwood, particularly from *A. malaccensis*, holds significant medicinal value. Its leaves, stem, resin-infested heartwood, and essential oil are key medicinal components. The leaves possess anti-diabetic, antioxidant, antibacterial, and hepatoprotective properties and help soothe throat irritation. Agarwood oil, valued for its anti-inflammatory, anti-rheumatic, analgesic, carminative, and stomachic effects, supports detoxification, clears excess salt and uric acid, and aids skin cell repair. Traditional Indian and Chinese medicine uses the oil for various skin conditions, while Ayurvedic medicine utilizes stem paste for skin disorders and leaf paste for leprosy and itching. Increasingly recognized in both traditional and modern medicine, agarwood's therapeutic properties are drawing interest for further pharmaceutical research.

6.3.3. Chips/incense

Figure 28: Agarwood incense

Agarwood chips are used in cultural and religious practices, particularly in the Middle East and Asia, where they are often burned as incense. In Bhutan, agarwood powder is commonly utilized in the production of traditional incense. These aromatic wood pieces, either naturally formed or processed from mature agarwood trees, release a distinctive fragrance when burned, creating a calming and therapeutic ambiance. Additionally, agarwood is used in funeral pyres by some communities and as a unique aromatic additive in Taiwanese wine. Its cultural, religious, and therapeutic applications contribute to its global reverence and demand. US$ 20 – 6,000 per kilogram for the wood chips depending on its quality or US$ 10,000 per kilogram for the wood itself (Abdin, 2014).

6.3.4. Agar tea

Figure 29: Agar tea

Agarwood tea, made from the young leaves of agarwood trees, is popular for its health benefits and naturally soothing properties. Regular consumption promotes healthy digestion, clear skin, stable blood sugar levels, and improved blood circulation. Agarwood tea has relaxing qualities that may aid in reducing anxiety and improving sleep. As natural health remedies continue to gain interest, agarwood tea is becoming a preferred choice in Asia and beyond, valued for its therapeutic effects and as a calming, health-enhancing beverage.

6.3.5. Handicraft

Figure 30: Handicraft

Agarwood is highly valued in the crafting of various handicrafts, as artisans skillfully transform this precious wood into exquisite pieces. Intricate sculptures, bracelets, boxes, bead strings, and ornaments showcase the craftsmanship involved in working with agarwood. The combination of aesthetic beauty and unique fragrance makes agarwood handicrafts highly sought after in the market. These creations are not only functional but also serve as cherished decorative pieces, reflecting the cultural significance of agarwood in artisanal traditions.

6.4. Marketing

6.4.1. Certification

The certification of Bhutanese Agarwood products will follow the organic products certification procedure BFDA, 2023 and ISO, 9001 certifications for quality management systems. Additionally, Non-Detriment findings for CITES certification for the export of Agarwood and quantity to harvest shall be based on agarwood NDF report.

6.4.2. Grading

Each batch of agar products (oil, chips & carvings) is subject to rigorous quality control and testing to ensure it meets our premium standards. The oil will be assessed for its aroma, consistency, and purity before proceeding to the final stages. Standards for agarwood grading in Bhutan may be developed at a later stage similar to or with reference to the grading matrix of Mazlan and Dahlan (2010), Malaysia (**Table 8**).

Table 8: Grading matrix of Malaysia based on resin, color, size, shape, and weight (Mazlan and Dahlan, 2020).

SI. No	Grade	Resin coverage on the surface	Resin color	Wood shape
1	Super king	Entire	Total black & shiny	Solid wood chunks (500g to 3 kg)
2	Triple super	Entire	Total black & shiny	Solid wood chunks (200-500g)
3	Double super	90%	Less black & shiny	Solid wood chunks (50-200g)
4	Super	80%	Resin is black & grayish	Solid wood chunks of mixed sizes
5	A (A1-A10)	Entire	Black turning into brown	Solid wood chunks of mixed sizes
6	AB	Entire	Black turning into brown	Solid wood chunks of mixed sizes
7	B (B1-B10)	Entire	Black turning into brown	Solid wood chunks of mixed sizes
8	C	50%	Gray	Various in shape & sizes
9	D	Entire	Gray & whitish	Various in shape & sizes

6.4.3. Branding

Bhutanese agarwood is renowned as one of the finest in the world, celebrated for its superior quality, rich aroma, and purity. Grown in the pristine environment of Bhutan, it benefits from the country's sustainable and eco-friendly cultivation practices, making it both ethically sourced and environmentally responsible. The suitable altitude range, unique climate, and traditional cultivation methods contribute to its exceptional resin content and fragrance, distinguishing Bhutanese agarwood from other global producers. With its production deeply rooted in Bhutan's cultural heritage and conservation efforts, it is regarded as a rare and premium product, highly sought after in luxury, wellness, and spiritual markets around the world. These traditional practices will set out our product uniquely enabling Bhutan's Agarwood product potential in building a strong brand identity and engaging in promotional activities that will also help us carve out a niche in the global market.

To ensure Bhutan Branding:

- Avoid importing inoculants from outside which might contain harmful chemicals
- Use locally prepared and advocated organic inoculants
- Restrict import of non-native seedlings from outside
- Develop proper market linkages for Bhutan Brand Agarwood

6.4.4. Export quota

The main objective of setting the export quota for Bhutan Agarwood is based on the recommendations of NDF with the following objectives:

i. To encourage the development of Agarwood infrastructure, including distillation units, value-added product developments, and packaging units in the country.
ii. To enable the maximum return to farmers and individual sellers from the trade of Agarwood oil instead of unprocessed Agarwood and its derivatives such as the chips of powder.
iii. The quota for harvest and export is predicated upon the applicant's requisition and the availability of matured trees. The stipulated quota for Bhutan Agarwood is delineated as follows:

- Agar chips: One mature tree (ten-year-old) is estimated to produce 3 kg of agarwood chips/powder (Liu et al., 2013, Borah et al., 2024). The annual quota for agarwood chips is set at 150000 Kg dry weight (267857 kg wet weight (Agarwood, 2024)) for the whole country which means annually 50,000 trees can be harvested considering the rotation period of 10 years with the current existing populations
- Agarwood oil: Given that 1000 Kg of Agarwood yields approximately 300 g of agarwood oil, the annual oil quota has been set at 45000 grams (or 45 kg) for the whole country
- Agarwood oil: Given that 1000 Kg of Agarwood yields approximately 460 g (Islam, 2014) of agarwood oil, the annual oil quota has been set at 69000 grams (or 69 kg) for the whole country

6.4.5. Approval of permit process

The agarwood permit process in Bhutan is overseen by the DoFPS under the MoENR. This process ensures that agarwood cultivation, harvesting and trade comply with Bhutan's conservation laws and international regulations, such as CITES.

i. **Application for harvesting permits**: Landowners or cultivators seeking to grow agarwood or cultivators must apply for a permit, providing details on quantity & location. The application is reviewed by DoFPS to confirm sustainable practices and alignment with conservation standards.

ii. **Inspection and verification**: Before permit for export are granted, officials shall inspect the cultivated agarwood to verify adherence to sustainable practices and to authenticate the source of harvesting. This includes verifying tree age, resin quality, and compliance with inoculation methods for resin formation.

iii. **Export Permit**: For international trade, an export permit shall be obtained as per Section 291 of the FNCRR, 2023, alongside the CITES Permit for export (Annexure XVIII of FNCRR, 2023), from the competent Management Authority.

iv. **Other documents**: The other relevant documents like trade license, MTA and Phyto-sanitary shall be processed as per requirement.

CHAPTER SEVEN: Agarwood Business Plan in Bhutan

The business plan, titled *"From Soil to Fragrance: Empowering Bhutanese Farmers Through Agarwood Production,"* presents a visionary strategy to incorporate Agarwood cultivation into Bhutan's economic framework. Leveraging the country's favorable agro-climatic conditions and the growing global demand for Agarwood, the plan outlines a structured approach to promote sustainable production while addressing socio-economic and environmental challenges. This review analyzes the plan's key components, assesses its alignment with national priorities, and proposes its integration into Bhutan's National Agarwood Framework for Sustainable Development.

7.1. Strengths of the business plan

7.1.1. Alignment with national goals

The plan aligns closely with Bhutan's national priorities, particularly:

i. **Poverty alleviation and rural development**: By targeting rural farmers and promoting Farmer Producer Groups (FPGs), the plan creates a pathway to diversify rural income streams.

ii. **Sustainability**: The emphasis on eco-friendly cultivation, organic inoculation techniques, and alignment with CITES regulations reflects Bhutan’s commitment to environmental conservation.

7.1.2. Economic potential (demand)

i. The global Agarwood market, estimated at USD 0.265 billion in 2023, is projected to grow to USD 0.435 billion by 2032. Bhutan’s entry into this premium market positions the country to tap into high-value exports, particularly in the Middle East and Asia.

ii. A robust financial analysis demonstrates a benefit-cost ratio of 31.9 and an internal rate of return (IRR) of 44%, underscoring the plan’s profitability and feasibility.

7.1.3. Comprehensive risk management

i. The business plan tackles risk like climate variability, market volatility, and crop failure through crop diversification, insurance schemes, and contingency planning.

7.1.4. Innovative approaches

i. The plan promotes modern inoculation technologies and the establishment of local distillation units to enhance value addition and product quality.

ii. It emphasizes organic certification and compliance with CITES Non-Detriment Findings (NDF), crucial for accessing international markets.

7.1.5. Business model

Under the proposed model, a government agency or an established NGO would initially lead efforts to promote Agarwood cultivation by organizing farmers into Producer Groups (FPGs),

providing training, facilitating loans, supplying quality seedlings, assisting with tree insurance, and ensuring competitive marketing of Agarwood. A cluster-based approach is suggested, targeting a minimum of one acre for cultivation, while individual farmers or FPGs can access financial support through loans, grants, or subsidies to develop infrastructure and systems for sustainable Agarwood production.

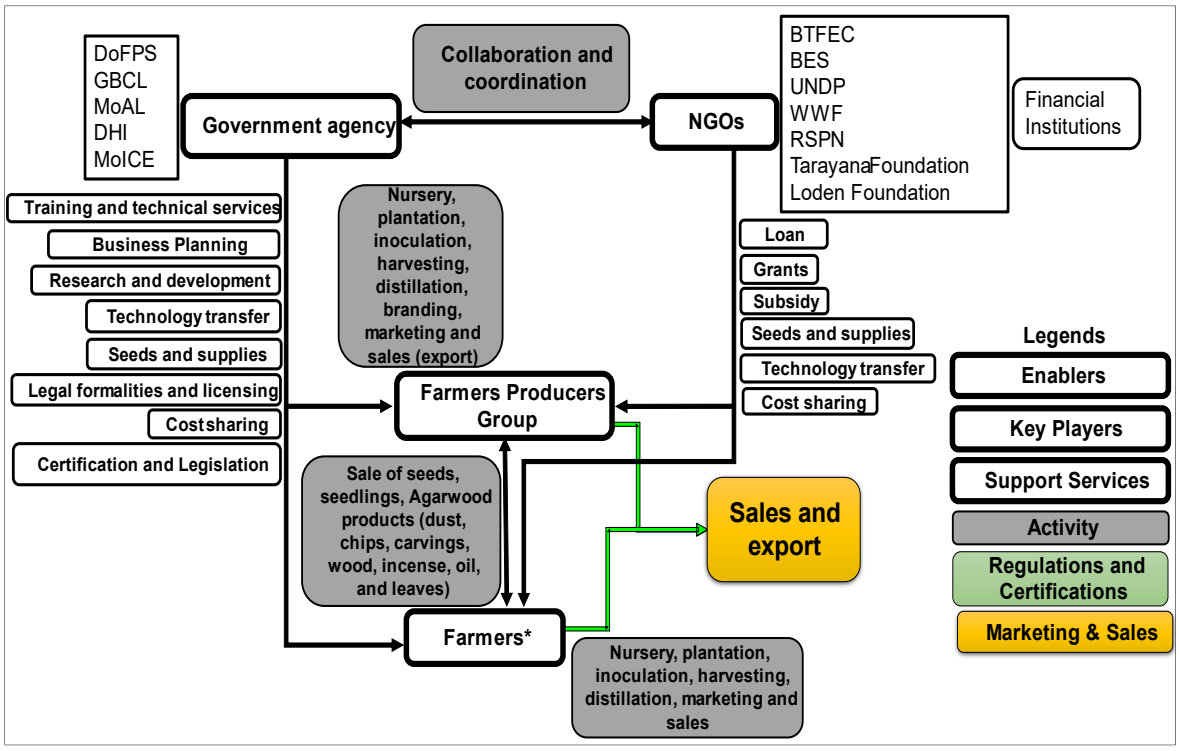

Figure 31. Diagrammatic representation of the proposed business model for Agarwood

7.1.6. Critical areas for improvement

i. Policy and Regulatory framework

- While the plan highlights the need for policies governing Agarwood trade, certification, and pricing, a detailed roadmap for policy formulation is absent
- The absence of CITES-certified export processes and essential infrastructure (e.g., distillation units) could delay market entry

ii. Limited market data

- The plan lacks detailed projections for the international trade of Bhutanese Agarwood products, particularly essential oils and chips
- Insights into pricing and competition within the global market need expansion to better inform farmers and policymakers

iii. Capacity building

- The training component for farmers could be expanded to include modules on quality control, advanced cultivation techniques, and market dynamics
- There is limited focus on leveraging digital tools and platforms for market access and promotion

iv. Sustainability concerns

- While the plan proposes sustainable practices, there is insufficient emphasis on monitoring environmental impacts, particularly regarding deforestation and biodiversity loss
- Guidelines for equitable benefit-sharing among stakeholders are not fully developed

CHAPTER EIGHT: Coordination & Collaboration

8.1. Stakeholder

Stakeholder involvement is crucial for the successful development of the agarwood business in Bhutan, requiring coordinated efforts among key organizations. The DoFPS shall lead initiatives, to ensure sustainable management of agarwood resources. Supporting agencies such as the National Biodiversity Centre (NBC), National Mushroom Centre (NMC), and National Plant Protection Center (NPPC) will collaborate closely to provide expertise in cultivation of fungus & agar plantation management. The One Gewog One Product (OGOP), under Queen Project Office (QPO), BFDA & MoICE can help in marketing and promoting agarwood products, while the Ugyen Wangchuck Institute for Forestry Research and Training (UIWFoRT) can contribute by conducting research and providing training to local communities. Together, these stakeholders can establish a sustainable and profitable agarwood industry that aligns with Bhutan's environmental and economic goals.

8.2. Inter-agencies collaboration & roles

i. DoFPS (UWIFoRT)

- Establish an agarwood nursery and related technology
- Supply agarwood seedlings to enhance livelihoods
- Build capacity of staff and facilitate knowledge exchange with agarwood experts
- Conduct research to identify effective inoculum/inducers and inoculation techniques
- Develop a national agarwood framework, proposal and acquire the Non-Detriment Findings (NDF) from CITES
- Establish prototype agarwood processing unit, which will function as learning centre for the agarwood growers throughout Bhutan
- Advocacy and transfer of research finding & knowledge to farmers
- Facilitate and acquire related approval and documents for cultivation and export of agarwood

ii. BFDA

- Facilitate standardization and certification
- Ensure quality control and standards

iii. NPPC

- Identification and control pest management on agar plantation
- Archive agarwood pest on agar trees

iv. QPO

- Promote market linkages and agarwood products diversification

v. NMC

- Provide training to forestry staff on fungus culture

vi. NBC

- Facilitate Material Transfer Agreement (MTA)
- Preservation of fungus strain or mother culture

vii. MoICE

- Diversification of exports in the regional and international markets through promotion of Brand Bhutan and Trade Agreements.
- Ensure quality control and certification

ix. NGOs

- Facilitate grants and financial supports
- Collaborate with DoFPS for establishment of agarwood business in Bhutan
- Facilitate and collaborate with DoFPS to transfer technology
- Support agarwood research and development in Bhutan

x. Financial institutes

- Facilitate financial support for farmers to establish agarwood

xi. End consumers

- Ensure improvement of agarwood products through feedbacks
- Promotion and marketing of products

xii. Local communities

Farmer/Farmers Production Group (FPG)

- Established agar tree plantation
- Adopt agarwood inoculation and delivery technologies
- Promote agarwood products
- Collaborate with concern agencies
- Develop agarwood nursery and produce seedlings for plantation

xiii. Human resources

Agarwood cultivation, harvesting, processing, production, capacity building and knowledge transfer demands significant human resources for effective management and execution, necessitating additional personnel to ensure smooth operations.

xiv. Advocacy and technology transfer

Advocacy

- Awareness on significance of agarwood and opportunities
- Use of organic inducer for inoculation, product diversification & marketing

Technology transfer

- Training on nursery and plantation management
- Training on inoculum development, delivery and harvesting techniques

CHAPTER NINE: M & E

The Agarwood Task Force consists of UWIFoRT for research and technology, NMC for fungal cultivation, NPPC for pest management, FRPMD for plantation and management, BFDA/MoICE for certification and marketing and the Queen's Project Office for overall coordination.

9.1. DoFPS, UWIFoRT

UWIFoRT will assess the effectiveness of the developed inoculum, and delivery techniques adopted in agarwood research. This includes evaluation of various research trials to determine the most effective inoculum & successful methods for agarwood production.

By systematically analyzing the results, UWIFoRT will recommend the best practices identified through research and trials. This comprehensive monitoring and evaluation process will ensure that the most effective strategies are adopted, ultimately contributing to the advancement of sustainable practices in agarwood cultivation and enhancing the overall quality of production.

9.2. DoFPS, FRPMD

DoFPS (FRPMD & FMID) will oversee various aspects of agar tree cultivation & plantation management. This includes monitoring the health and productivity of plantations and ensuring certification compliance. DoFPS will also monitor the legal procedure for cultivation, harvesting and transport of agarwood products.

9.3. DoFPS, Territorial Division

Territorial Divisions play a crucial role in authenticating and validating data or information at the field level to ensure accurate reporting and informed decision-making for agarwood production. They are also responsible for monitoring and preventing illegal activities, including unauthorized movement and harvesting of agarwood trees.

9.4. NPPC

NPPC will monitor the preserved fungus strain and pest related to agar trees based on the report from the field.

9.5. NMC

The NMC will implement a robust system of monitoring and evaluating fungal cultivation to ensure high-quality agarwood production.

9.6. BFDA/MoICE

BFDA and MoICE will ensure product qualities and certification along with facilitation of export.

9.7. NBC

NBC will actively engage in monitoring the MTA approval of agarwood products for export.

9.8. QPO

QPO plays a vital role in coordinating and integrating all stakeholders, ensuring that project activities align with the overarching goals of sustainable agarwood production. This includes monitoring project milestones, resource allocation, and stakeholder performance. Evaluation efforts focus on assessing the effectiveness of coordination mechanisms and the efficient use of resources across various project components. By fostering communication and adapting plans based on progress, the monitoring and evaluation process under the Queen Project Office enhances the project's impact and ensures alignment with national objectives, thereby contributing to the sustainability of agarwood production initiatives.

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