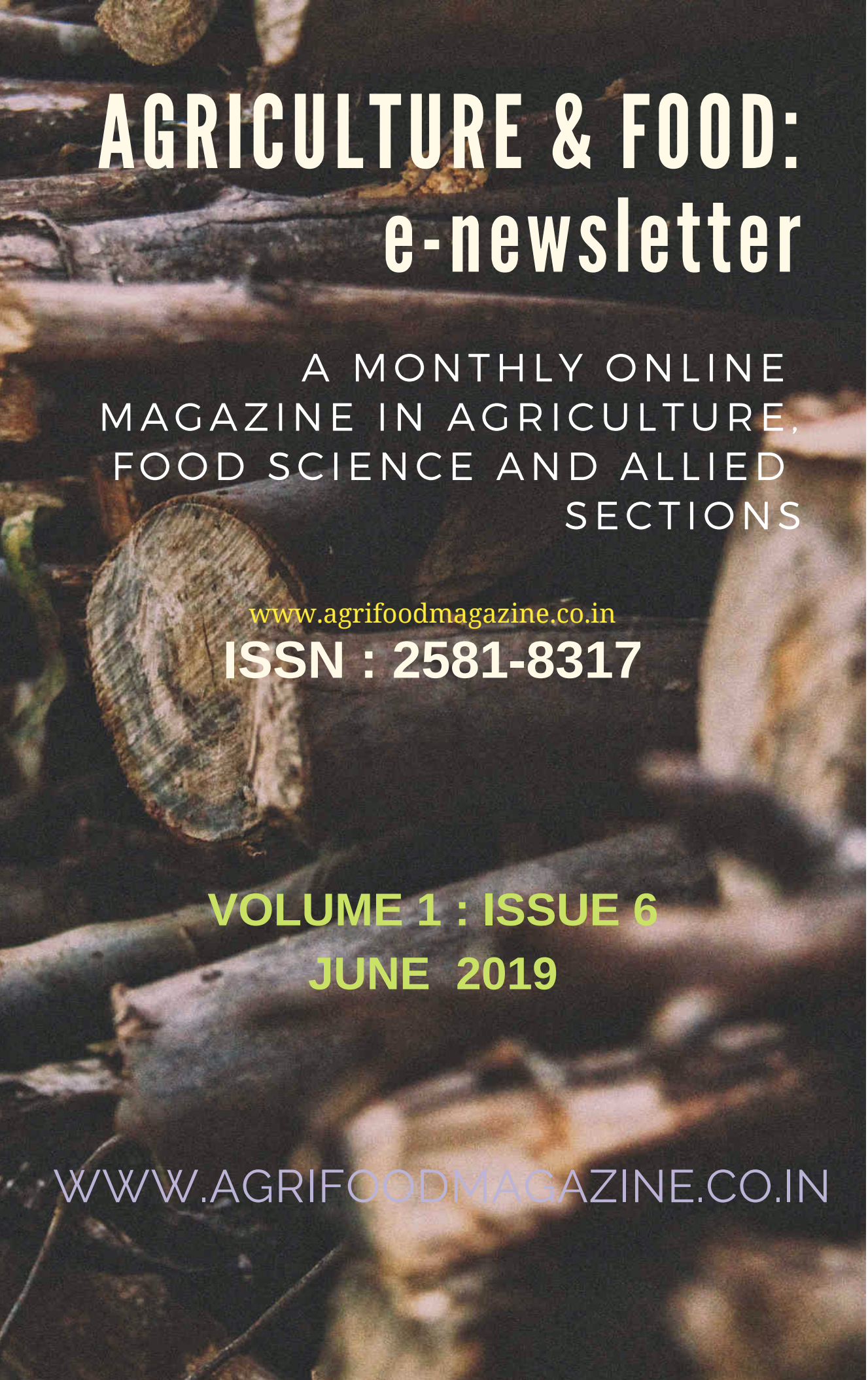

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be analyzed. Genetic restructuring, altered agronomic practices, diversification , integrated cropping and farming systems, and efficient use of biodiversity and other natural resources should meet (farm level) as well as macro level situations.

Risk profiles of CSA practices should be understood to be prepared to reduce the vulnerability of farmers to climate risk. New studies undertaken by the south Asian programme of the CCAFS of the CGIAR has recently come up with improved **weather –based crop insurance** which offers triple wins: a) reduced premium rate, (b) expanded, most effective and timely disbursement and c) savings for the Govt. in terms of reduced subsidy , hence lesser load to the exchequer. This product is based on scientific knowledge and is a win –win situation for all the stakeholders-farmers, industry as well as the Government. In the rainy season in 2015 alone, more than 1 million farmers in Maharashtra had used it. This new product should be widely piloted and linked with the **Prime Ministers Jan Dhan Yojana**.

CONCLUSION:

Efficacies of different policies related to climate resilient agriculture and effectiveness of their implementation should be critically assesses. Policies such as those on Agriculture, biosecurity, Bio diversity, Disaster Management, Food security, water, land etc. should be synergistically converged at different levels, particularly at the grass roots such as at the level of the climate –smart villages. Institutional adjustments and interministral convergence are needed to ensure judicious implementation. Development of climate smart agriculture and germplasm conservation should be mainstreamed in to the national policy with suitable investment and financing provisions.

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ABSTRACT

The agarwood tree is a multipurpose tree species (MPTs), being exploited mainly for ethno-medicinal, ethno-botanical as well as pharmaceutical uses. The leading market demand had led to over exploitation of natural population of this species. Due to over exploitation, the species became critically endangered and vulnerable under IUCN red list. Hence, to meet the demand and to reduce the pressure on the forest and at the same time to conserve the species from being extinct, suitable agroforestry systems and silvicultural measures are to be developed. However, few farmers in India were already cultivating agarwood tree in a solitary or in integration with other crops like Tea, Patchouli (*Pogostemon cablin*), Sarpagandha (*Rouvolfia serpentine*), Jatropha, Pepper (*Piper longum*), Pineapple, Turmeric, Arecanut and with other agricultural crops. Introducing this agar tree with other crops had given additionally huge returns to them. Many literatures revealed that, the integration of agarwood with tea crop can contribute a good amount of subsidiary income up to 45% of the total annual income of the family, which is even higher than the reported 7% average annual gross income per household in Upper Assam. This means, the agarwood plantation has the potential to improve the livelihood of the rural communities or the growers to a greater extent. Furthermore, the good pollarding and coppicing capacity of agar tree has made it suitable to fit in agroforestry. Many researchers had even recommended the agarwood tree as a component in agroforestry systems. Hence, agarwood based agroforestry systems can be a viable option to the growers for improving their livelihood.

INTRODUCTION

The agarwood tree (*Aquilaria malaccensis* Lam.), also called as *A. agallocha* and *A. secundaria*), commonly known as Sasi, Sanchi, Agaru (Assamese); Agar or Agaru (Bengali); Agarwood, Malayan Aloe Wood, Malayan Eagle Wood (English); Agaru (Sanskrit), belongs to family Thymelaeaceae, is a fast-growing tropical evergreen tree (Chakrabarty *et al*., 1994; Haridasan and Bhuyan, 2016) and is highly priced for its resin or agarwood (Saikia and Khan, 2014a & b). This tree grows well over sandy loam and slightly acidic soil in high humid sub-tropical climate with rainfall 1800 - 3500 mm per annum at an altitude up to 1200 m above the sea level; and requires a good amount of sunlight with temperature variations between 20ºC to 28ºC and relative humidity around 80% (Uddin *et al.,* 2008; Kalita *et al.,* 2015).

The genus "*Aquilaria*" is distributed in evergreen rainforest of tropical and sub-tropical region of South East Asia (Barden *et al*., 2000). But among all the *Aquilaria* species, the tree *A. malaccensis* Lam. is the principal source of agarwood and among very few species of tropical trees that is valued for most highly priced forest products currently traded internationally. The basic chromosome number of the different genera of this family have been reported to be x=8 and 9 (Malla *et al.,* 1977). But, the species, *A. malaccensis* had the chromosome counts of n=8 and 2n=16. The karyotype is symmetric with 5 metacentric pairs and 3 sub-metacentric pairs one of which had secondary constriction but no meiotic irregularities were reported (Debnath *et al.,* 1995).

Presently, there are 21 recognized *Aquilaria* species recorded, of which 13 are reportedly fragrant resin producers and the remaining eight *Aquilaria* species is yet to be investigated (Lee and Mohamed, 2016; Talucder *et al.,* 2016). In Asia, 15 species of agarwood *i.e., A. apiculata*, *A. baillonii*, *A. banaense*, *A. beccariana*, *A. brachyantha*, *A. cumingiana*, *A. filaria*, *A. hirta*, *A. khasiana*, *A. malaccensis*, *A. microcarpa*, *A. rostrata*, *A. sinensis*, *A. subintegra* and *A. crassna* are known to produce essential oils (Sulaiman *et al.*, 2015) and only 11 species of agarwood *viz., A. malaccensis, A. crassna*, *A. subintegra*, *A. hirta, A.rostrata, A. beccariana, A. filaria, A. khasiana, A.microcarpa, A. grandiflora and A. sinensis* were reported as the domesticated species (Zuhaidi, 2016). India is the home of three *Aquilaria* species which are widely distributed in Eastern Himalaya region especially in north east India. Chakrabarty *et al.* (1994) reported the species *A. malaccensis* as a native to Arunachal Pradesh, Assam, West Bengal, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura; as well as West Bengal (Barden *et al.,* 2000). The species, *A. malaccensis* Lam. and *A. khasiana* Hall. are found in the evergreen rain forest of north eastern states of India (Chakrabarty *et al.*, 1994) whereas, the third species, *i.e., A. macrophylla* Miq. is found in the Nicobar Islands (Giri, 2003).

Chakrabarty *et al.* (1994) documented the India's trade of agarwood especially in northeast India and concluded that *A. malaccensis* is highly threatened in the country due to over exploitation of the species for commercial purposes. Among those three species, the *A. malaccensis* is considered as one of the most precious tree species found distributed sparsely in the rain forest of north east India (Barden *et al*., 2000). But, the species, *A. malaccensis* has been reported sporadically from different sites of Tropical semi-evergreen forests of the foothill areas of Kameng, Lower Subansiri, Siang, Changlang, Lohit and Tirap districts with normal forest density of 0.73% to 0.77% under natural habitat of Arunachal Pradesh and Assam (Chakrabarty *et al.*, 1994; Tabin *et al*., 2009). In Assam, this species has been reported to occur frequently as homestead or large scale plantations in the districts of Sibsagar, Sadiya, Nagaon, Darrang, Goalpara and Cachar (Atal and Kapoor, 1982). Earlier, wild population of this species was reported from plains and few places in Barak valley of Darrang, Nagoan, North Cachar, and Sivasagar districts (Chakrabarty *et al.*, 1994). There are large commercial plantations of *A. malaccensis* in the Hojai town of Assam and it's out skirt foot hill terrains (Barden *et al*., 2000). A hundreds of home gardens at Golaghat district of Assam are confined mainly to grow *A. malaccansis* for agar trade (Ahmad and Gogoi, 2000).

Over exploitation of agarwood tree has resulted into insertion of this species in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1994). The species is thus red listed under International Union for Conservation of Nature (IUCN) and also classified as 'Vulnerable' globally but 'Critically Endangered' in India (IUCN, 2009) and almost 'Extinct in wild' in Assam (Saikia and Khan, 2012).

Importance of agarwood tree

This species (*A. malaccensis*) had got importance in the foreign markets and the trade; and India was the main source of agarwood during that period since 600 A.D. (Chakrabarty *et al.,* 1994). The trade in agar-based products was growing rapidly in the world due to their recent adoption as an ingredient in the cosmetics and pharmaceuticals sector. Agarwood, the most exalted perfumery and fragrance raw materials obtained from the infected wood of agarwood tree due to association of borer insect (like *Zeuzera conferta* Walker) on agarwood formation, is considered as the myth of perfumery world (Kalita *et al.,* 2015).

Apart from the perfumery and fragrance value, agar and agar oil are widely used in preparations of various cosmetic products and in Ayurvedic medicines. Although, many efforts had been made to artificially inoculate the fungi in the tree for getting infection (Chakrabarty *et al.,* 1994; Barden *et al.,* 2000), but the quality of agar produced from artificial inoculation was not at par with the naturally occurring agar (Kalita *et al.,* 2015). Moreover, both agarwood smoke and oil are customarily used as perfume in the Middle East which had been highly prized by European perfumers in the mid-1990s (Chakrabarty *et al*., 1994).

Considering the above all facts and usefulness of this species, the people had started indiscriminately growing this species in their home garden in the state of Assam (Saikia and Khan, 2014b). Even few people from many north eastern states *viz*., Tripura, Assam and Meghalaya had started commercially growing this species in the form of block plantation and few were seen to grow along with cash crops like Tea plantation. The species is largely cultivated with community participation, especially in Lohit and Changlang districts in Arunachal Pradesh, Dimapur in Nagaland, Garo hills in Meghalaya, Agartala in Tripura, Upper Assam in Assam *etc*. (Haridasan and Bhuyan, 2016).

Fig. 1: Agarwood tree and it's flower, fruit and seed

Agarwood based agroforestry systems

In general, integrating any woody perennials with agricultural crops and/or pastures is known as agroforestry system and is known to be economically and environmentally sound and sustainable system than many other agricultural practices (Sarkar *et al.,* 2017a, b & c; Das *et al.,* 2017; Das *et al.,* 2019; Sarkar *et al.,* 2019; Singh *et al.,* 2019). In all the states of this region, the economy is mainly of agriculture based. Forest and agriculture are the major sources of livelihood for rural communities of north eastern states of India. Among all the resources, agarwood tree and it's product business is the one through which a great amount of return is possible. Following are some of the agarwood based agroforestry systems being described hereunder:

a. Homegarden

Homegardens are prominent land use systems of Northeastern region of India. Though, the crops like rice (*Oryza sativa* L.), sugarcane (*Saccharum officinarum* L.) and tea (*Camellia sinensis*

(L.) O. Kuntze) are the major crops of the region, but inclusion of agarwood tree as a component in homegarden had led to greater returns; and hence, the species has become an important plantation crop of Upper Assam (Saikia and Khan, 2012). They also reported that, two distinct morphs of agarwood/*Agaru* (*Bhola Sanchi* and *Jati Sanchi*) are cultivated in homegardens of upper Assam. But, the variant "*Jati Sanchi*" is a slow growing but high agarwood yielding and preferred for commercial cultivation. Because of the high economic potential, attempts are now being made to cultivate it adjoining areas of Assam in Northeast India and other parts around the world (Saikia and Khan, 2014a). In their studies, they reported tree density of agarwood ranged from 260 to 7913 (individuals ha^{-1}) in different homegardens of upper Assam with an average of 1466 (individuals ha^{-1}), which contributes 34% of the total tree density and 20% of the total annual income of the dependent family (Saikia and Khan, 2014b).

b. Plantation as cash crops

The agarwood and tea are the most commonly cultivated cash crops, found in 100% and 30% of the studied homegardens respectively in upper Assam (Saikia and Khan, 2011). They also reported that, homegarden products including agar and tea contributed a good amount of subsidiary income up to 45% (with a mean of 14% ±1.15) of the total annual income of the family, which is higher than the reported 7% average annual gross income per household of Meghalaya, Northeast India (Tynsong and Tiwari, 2011).

c. Block plantation

In many of places in Bangladesh, monoculture and block plantation of agar tree are very common (Rahman *et al.,* 2015). But, there is hardly any information available regarding the block plantation (monoculture) in Northeast of India, even though few block plantations are seen to exist in the state like Tripura.

d. Boundary plantation

Ha and Nghi (2011) reported that, agarwood tree is suitable for growing on field boundaries and even on borders of gardens, school compounds, office compounds, parks and residential sites. Besides, agarwood tree has been successfully grown for strip planting along banks of ponds, tanks, canals and roads. In hilly areas / tillas, it can be planted on poor soils on hill slopes and tilla tops which can help in reducing soil erosion and land sliding (Shinde *et al.,* 2019) caused by rushing water during rainy season (Ha and Nghi, 2011). Similar type of plantation can also be followed in this region.

e. Agarwood tree based agroforestry systems

The agarwood tree was reported to be intercropped with cassava, sweet potato and oil palm in agroforestry systems in other countries like North central Viet Nam (Ha and Nghi, 2011). Even, this tree can also be intercropped with acacia, upland rice and pineapple. In Viet Nam, the agar

tree is used to integrate with fruit trees in their home and forest gardens (Ha and Nghi, 2011). In asian countries, the same tree can be intercropped with a combination of agricultural crops and fruit trees such as upland rice, cassava, beans, sweetpotato, yam, banana, pineapple, jackfruit and many more (Talucder *et al.,* 2016). Blanchette *et al.* (2015) reported that *Aquilaria* has been grown with rubber, teak, banana and even oil palm in Southeast Asia.

In Northeastern region of India, Gera and Bhojvaid (2013) reported that, Patchouli based agarwood agroforestry model can be a promising system. Kunio and Lahjie (2015) reported that the future of forest industry would be better diverted to the non timber forest products by cultivating vanilla and agarwood with agroforestry system. Agar tree could successfully be introduced in Social Forestry and also in Afforestation Programme (Anon., 2004). Even, agarwood can be grown as a shade tree in tea plantation (Blanchette *et al.*, 2015). Borah *et al.* (2014) also reported that, this species has been identified as an potential agroforestry species in homestead plantations as well as in communities lands in combination with Patchouli (*Pogostemon cablin*), sarpagandha (*Rouvolfia serpentine*), Jatropha, pepper (*Piper longum*), pineapple, tea, turmeric, arecanut and with other agricultural crops.

CONCLUSION

The garwood tree (*Aquilaria malaccensis*) is mainly exploited for multiple uses *viz.,* traditional medicine, cosmetic industries as well as uses in pharmaceutical industries. Due to it's high demand in the current trade and business, the natural population of this species got over exploited and the species became critically endangered and vulnerable under IUCN red list. Hence, sustainable agricultural and forestry practices are necessary for the further development and utilization of agarwood. Hence to meet the demand and to reduce the pressure on the forest, the farmers had started cultivating agarwood tree in a solitary or in integration with other crops. This ultimately led to a potential ex situ reservoir for the future conservation and management of this threatened tree. This tree is one such promising component for diversified agroforestry systems of this region due to its favorable climatic and edaphic conditions. It was also revealed that, the integration of agarwood with tea crop can contribute a good amount of subsidiary income up to 45% of the total annual income of the family, which is higher than the reported 7% average annual gross income per household in Upper Assam. This means, the agarwood plantation has the potential to improve the livelihood of the rural communities or the growers to a greater extent. Furthermore, the good pollarding and coppicing capacity of agar tree has made it suitable to fit in agroforestry. Many researchers had even recommended the agarwood tree as a component in agroforestry systems, which can be a viable option for improving livelihood.

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Biofertilizers in vegetable production

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