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Impacts of floods on forest trees and their coping strategies in Bangladesh

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ABSTRACT

During recent years, the Government of Bangladesh, Non-Government Organizations (NGOs), semi-government organizations, private organizations and individuals have established a large number of plantations under different programs *viz.* social forestry, agro-forestry and avenue plantations with indigenous and exotic tree species without considering their habit and habitats. Along with the indigenous species like *Albizia procera*, *Albizia lebbeck, Mangifera indica, Azadirachta indica, Gmelina arborea*, *Trewia nudiflora* and *Artocapus heterophyllus* and many exotic species e.g. *Swietenia macrophylla*, *Albizia saman, Dalbergia sissoo, Eucalyptus camaldulensis, Acacia auriculiformis*, *Melia sempervirens, Acacia mangium* etc. have been planted randomly. With increasing trend of climate-induced floods, millions of trees have been dying due to floods and water-logging. The most affected species are *Dalbergia sissoo, Albizia saman, Acacia auriculiformis, Acacia mangium* and *Artocarpus heterophyllus* etc. This situation has caused severe impacts on socio-economic conditions of Bangladesh. The impacts involved a significant loss in terms of investment, biodiversity and afforestation program. Little investigations have been conducted to find out the causes of the deaths and also to find out the suitable adaptation practices to reduce impacts of floods on trees. This synthesis focused on the impacts of floods on plantations and also assessed the potential role of traditional forest management practices in addressing the effects flooding on forests in Bangladesh. The study added important information and revealed knowledge gaps on the causes of large forest deaths. It also provided recommendations for policy on the establishment of frequent floods resilient tree crop plantations.

1. Introduction

Bangladesh is a tropical monsoon country of South Asia. It is in an active delta of the Ganges, Brahmaputra and Meghna (GBM) and their many tributaries and distributaries. The country covers an area of 147,570 km² with about 11% under total forest cover (BFD, 2011). However, the Bangladesh Forest Department (BFD) puts the total forest cover at 17.62% of the surface area of the country (FAO, 2011). Most of the natural forests are in the hilly regions of Chittagong, Cox's Bazar and Chittagong Hill Tracts (CHT), Sylhet, Mymensingh and Panchagar. There are mangrove forests in the coastal zone along the Bay of Bengal and in the southwest region of the country in the great Sundarbans, a UNESCO World Heritage Site. The BFD manages and establishes plantations, harvests and sells the forest produce, develops parks and gardens. There is also the Bangladesh Forest Research Institute (BFRI), and the Bangladesh Forest Industries Development Corporation (BFIDC) for conducting research and processing timber and forest products respectively. More than 5000 angiosperms including a few gymnosperms have been adapted and have stabilized the ecosystems through a long succession over thousands of years. In 1871, teak (*Tectona grandis*) was introduced from Myanmar. Since then, natural forests have been replaced successively with many exotic species and monoculture was started. Among the exotics, *Acacia auriculiformis* and *Acacia mangium, Eucalyptus camaldulensis,* and *Leucaena leucocephala* are important (FAO, 2011; Jasimuddin and Inoue, 2012).

During the last 40 years, the BFD has implemented many plantation projects such as the social forestry, roadside plantation, strip avenue plantations and conservation parks etc. The NGOs, private organizations and individuals have also participated in this massive plantation program. However, five different categories of forests are found in Bangladesh namely Village forests, Tropical moist-deciduous forests, Tropical evergreen and semi-evergreen forests, Mangrove forests and Community forests (Jasimuddin and Inoue 2012; Mohammed et al., 2005; Hossain et al., 2008).

During the plantations, the policy-makers preferred fast-growing species such as *Acacia auriculiformis*, *Acacia mangium*, *Acacia nilotica*, *Dalbargia sissoo*, *Eucalyptus* spp., *Leucaena leucocephala*, *Swietenia macrophylla*, *Albizia saman*, *Melia sempervirens*,

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Gmelia arborea and *Albizia richardiana* to meet the immediate demand for timber and fuel-wood. However, in some areas, indigenous species e.g. *Albizia procera*, *Albizia lebbeck*, *Mangifera indica*, *Azadirachta indica*, *Gmelina arborea*, *Trewia nudiflora*, *Artocapus heterophyllus* and *Terminalia arjuna* were planted by the individuals and NGOs. Exotic species were given priority over the indigenous species in most of the cases due to their easy establishment, non-palatability and availability of seed and saplings. In some cases, "Plant a Tree and Save the Environment" slogan has become only a show practice to please the authority. In true sense, the deforested hills remained neglected; even though the plantation was raised in those sites, only the exotic species like *Albizia maluccana*, *Acacia mangium*, *Acacia auriculiformis*, *Eucalyptus spp.* and *Dalbergia sissoo* were utilized without considering their habit and habitats (Rahman, 2011a, 2011b). However, frequent floods especially of 1988, 1998, 2001, 2004, 2006, 2008, 2009, 2010 and 2011 have affected the plantations seriously and caused huge damages. Little or no investigations were made to assess the impacts and the causes of such loss of public property. This study has tried to ventilate the neglected and overlooked facts on forest plantation in Bangladesh and absence of documentations of the huge death of trees due to flood and water-logging. The study also provided recommendations on how to develop an appropriate plantation policy.

2. Materials and methods

This synthesis relied on ground based research work including selected interviews and information collected from different research findings, some of which was gray literature, while others were publications from different peer reviewed journals or periodicals etc. Information was also gathered by attending workshops, seminars conferences and visiting research institutions and meteorological stations. Some information was collected directly from the stakeholders, rural and urban administrative bodies, farmers and NGOs. The impacts of floods on plantations and their bearing on climate change were studied and the traditional coping practices have been investigated; their efficacy is highlighted and compared with present practices to find out the mistakes as well as to integrate the scientific basis of the traditional knowledge regarding natural and artificial mechanism followed by the people of the most vulnerable region of the earth for thousands of years. The synthesis also benefitted from research work that was conducted in 2001 and focused on linking floods and water-logging to the death of *Dalbergia sissoo*, a native tree species of India, Nepal, and Pakistan (Basak, 2006) (Figs. 1–8 and Table 1). Fifteen districts of Bangladesh that have a large numbers of *Dalbergia sissoo* plantations that were severely affected by recent flooding were surveyed between February and June, 2001. The study considered the health condition of each tree and trees were grouped into four categories such as slightly affected by flooding and water logging (0–25%), moderate (26–50%), severe (51–75%) and dead (76–100%) (Basak, 2006).

3. Causes and impacts of floods on plantations

The causes of floods in Bangladesh are related to multiple factors including climate change induced erratic and frequent rainfall, cloud outburst, monsoon downpour, synchronization of flood peaks, sea level rise (SLR), accumulation of sediments, river bed aggradations, deforestation in the upstream regions, soil erosion due to tillage, river dams, rapid urbanization, seismic and neotectonic activities and greenhouse effects (Khalequzzaman, 1991; Emery and Aubrey, 1989).

Fig. 1. Massive death of *Dalbergia sissoo* trees at Kushtia–Rajbari road in 2001 (Basak, 2006).

Fig. 2. Massive death of *Dalbergia sissoo* trees at Kushtia–Rajbari road in 2001 (Basak, 2006).

The GBM has hundreds of tributaries and distributaries flowing from the Himalayan and Burmese ranges pouring trillions of cubic liters of water with 17,000 million tons of silt every year onto the floodplain and finally to the Bay of Bengal. Due to unplanned construction of road transportation systems, agriculture, urbanization and industrial expansion across the flood plains in the recent years, the basins of the wet-bodies raised substantially, thus the water-holding capacity has been decreased significantly and floods have become a regular phenomenon every year (Rahman, 2010, 2011a, 2011b). Millions of people lose their homes, livestock and crops. Trees and homestead vegetation are also severely affected and people lose their means of income, find no work and are forced to starve (Khalequzzaman, 1991) (Fig. 7).

Trees of 1–32 years old had been found affected by floods. Fig. 8 shows the extent of damage caused by floods in various districts of Bangladesh. In general, the severity of death had been found

Fig. 3. Trees dying on the highway near Brahmanbaria (The Daily Star, 2013; Rahman, 2010).

Fig. 4. Sher-e-Bangla nagar, Dhaka (The Daily Star, 2013; Rahman, 2010).

Fig. 5. Death of trees due to water-logging and salinity in Chittagong in 2011 (Rahman, 2011).

Fig. 6. Death of trees due to water-logging and salinity in Chittagong in 2011 (Rahman, 2011).

higher in the western districts of Bangladesh in comparison to the eastern regions (Banglapedia, 2006). The highest incidence was noted in Chuadanga (64.4%) and the lowest in Mymensingh (21.7%). Other districts suffering more than 50% death were Comilla, Meherpur, Kushtia and Rangpur (Fig. 8). With the advance of time, healthy trees near the dead ones also died. Signs of damage are shown in Figs. 1–6.

Table 1 shows data on age-related death of *Dalbergia sissoo* trees; among the four *Dalbergia sissoo* classes, the age-class 17–24 years suffered the highest rate of loss followed by the age-class 9–16 years. The lowest rate was found in the age-class of 1–8 year. It was found that due to the severe floods of 1987–1988, the long period of inundation and also water-logging caused root rotting, permanent wilting, defoliation of the trees; and absence of air in the root system constrained respiration. It is recognized that in some plants there are two types of wilting, one is physiological due to either water-stress or water-logging and the second one is pathogenic that happens by the infection of fungus. In the inundated areas of Bangladesh, most of the *Dalbergia sissoo* plants died of susceptibility to conditions resulting from the long duration of floods. In addition, *Fusarium solani* f. *dalbergiae* being an opportunistic fungus created disease in some of the flood-affected *Dalbergia sissoo* plants (Basak et al., 2003; Basak, 2006).

A significant correlation between soil texture, water-logging and death of trees has been found by Bakshi et al. (1957) and Basak (1994). The incidence of mortality of *Dalbergia sissoo* was low on loamy-sand or sandy soils, but increased on sandy-loams and was high on clay-loam or clay soils. Sah et al. (2001) completed a research work on the stand features of *Dalbergia sissoo* in both natural and plantation sites in the Terai region of Nepal. They had found no significant difference between soil pH and mortality; soil texture and mortality but mortality was prominent in sites of stiff clay and water-logged soils. *Fusarium solani*, the wilt fungus of *Dalbergia sissoo* lives in the soil as a saprophyte in the form of hyphae but it becomes pathogenic when the soil conditions in water-logging situation turn favorable for its infection (Bakshi, 1957). Damping-off related diseases caused about 70% deaths in *Dalbergia sissoo* nurseries (Bakshi, 1954; Bakshi et al., 1959). *Fusarium solani* can tolerate a wide range of pH (Kaushik et al., 1993). More than 31 thousand *Dalbergia sissoo* trees of 1–32 years old died in 1998–2001 in 8848 km strip plantation under social forestry (Basak, 2006). *Dalbergia sissoo, Swietenia macrophylla, Albizia procera, Albizia lebbek* and *Eucalyptus* spp., along the two highways in the district of Brahmanbaria, were found dying

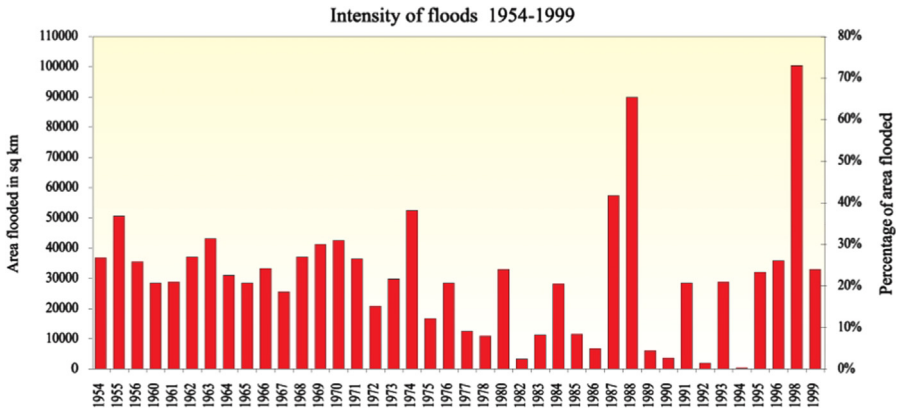

Fig. 7. Intensity of floods, 1954-1999 in Bangladesh (Banglapedia, 2006).

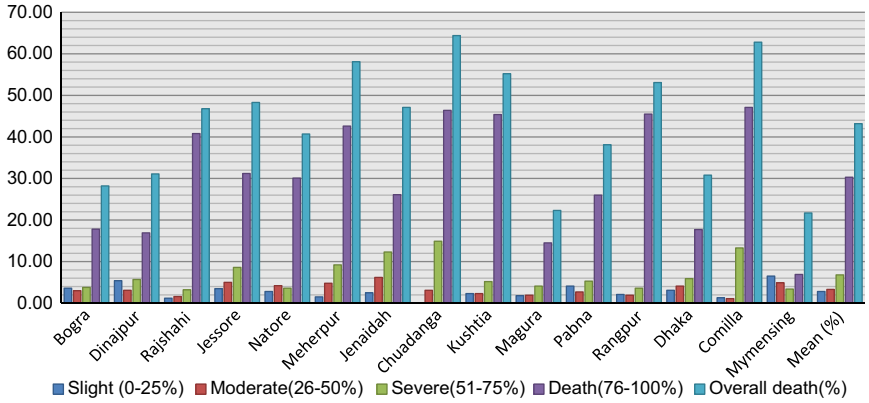

Fig. 8. Status of death of *Dalbergia sissoo* in several districts of Bangladesh in 2001 (Basak, 2006).

Table 1
Age-related death of *Dalbergia sissoo* due to floods and water-logging.

Age-group (years after planting)	1–8	9–16	17–24	25–32
Death (%)	10.7–85.0	15.8–100.0	19.3–94.0	29.0–77.5
Mean (%)	37.0	51.5	54.9	46.4

following the flood situation over the highways in many strip plantations. According to The daily Star (2013), the Social Forestry Nursery Training Centre (SFNTC) in Brahmanbaria is responsible for maintenance of the trees beside about 30 km road from Ashuganj to Khatihata on Dhaka–Sylhet Highway and Khatihata to Kuti on Sylhet–Comilla Highway in the district. Many trees died in these areas (Fig. 3) but locals noted that officials hardly visited the affected areas. Rahman (2010) reported a case study of death of nearly 550 big trees in Dhaka city due to industrial pollution (Fig. 4) and several thousands of rain-trees and *Acacia* trees in many parts of Bangladesh due to water-logging (Figs. 5 and 6) (Rahman, 2010, 2011a, 2011b). Basak (2013) reported death of several *Albizia saman* of more than 100 years old died in and around Chittagong city due to water-logging and air pollution. Several *Acacia mangium, Acacia auriculiformis* and *Eucalyptus camaldulensis* died in plantations of Barabkunda industrial area due to toxicity generated on the leaves of these trees as a result of continuous emissions of sulpher dioxide from the nearby iron industries (Basak, 2013).

Long term flood causes death and decay of root system of flood-prone trees as a result of reduction of concentration of oxygen in soil, altering pH, sedimentation and impediments on roots. The distribution of species in such ecosystems represents the success of coping with these constraints and is the result of plant adaptation processes. Such situations are naturally found in riparian forests. Due to impacts on N-uptake, longer periods of flooding are assumed to influence the nutrition of trees (Kreuzwieser et al., 2002). Flooding during the growing season adversely affects all developmental stages of flood-intolerant plants, whereas flooding during dormant season has little effect. Plant responses to flooding during the growing season include injury, inhibition of germination and vegetative and reproductive growth, changes in plant anatomy and promotion of early senescence and mortality (Kreuzwieser et al., 2002; Kozlowski, 1982, 1984). Flooding enhances the development of adventitious roots in *Eucalyptus camaldulensis* (Kozlowski and Pallardy, 1997) and *Dalbergia sissoo* (Basak, 2006) while it reduces photosynthesis in *Averrhoa carambola* and in *Citrus* spp. (Gomes and Kozlowski, 1980) and in *Mangifera indica* (Joyner and Schaffer, 1989).

4. Information gap

It was established through this synthesis work that there are no recorded data with BFD and coordinated research in Bangladesh about the death of plants, their number, economic loss, and identity of the species, due to flooding and water-logging and their long term effects. In other parts of the world for instance, in the USA data are available on the contribution of floods to die-back, damage of root system and death of trees (http://www.na.fs.fed.us/spfo/pubs/n_resource/flood/toler.html; http://store.extension.iastate.edu/Product/sul1-pdf; http://www.uwex.edu/ces/ag/issues/effectsoffloodingonplants.html).

There are no administrative measures to collect and keep statistical information on different plantation activities, e.g. social forestry and community forestry and the list of the plant species,

their number and other silvicultural practices in Bangladesh. There is no published article that reflects specific reason for the death of trees after the floods.

5. Community adaptation practices and traditional knowledge on forest management

This synthesis showed that although huge plantations were done during the last four decades, the habit and habitats of the plants were not considered. Millions of dollars (mostly from external aid) have been spent on plantation program but in real sense most of the plantations were made without considering their suitability of sites (IFI Watch Bangladesh, 2006). Since most of the areas of the country are the flood-plains of the GBM and during the wet monsoon, the low-lying areas go under water every year; the wide canopy, shallow rooted plants are very susceptible to flooding and also to cyclonic storms (Rahman, 2010). Highland adapted plant species e.g. *Dalbergia sissoo*, *Acacia auriculiformis, Acacia mangium, Artocarpus heterophyllus, Toona ciliata, Gmelina arborea* and *Melia sempervirens* do not withstand the water-logging and floods.

Traditionally, Bangladesh people established plantations in the homesteads and roadsides choosing the age-old-adapted species following adaptation patterns of these plants (Rahman, 2004). However, to gain the opportunity, some people selected and encouraged plantation using inappropriate species, mainly alien ones as monocultures, especially, along the roads across the flood-plains which caused death of millions of trees throughout the country. It is a great loss to the country in terms of money and resources. To get short-time benefits without considering the environment, in many cases, people were biased and planted many exotics like *Dalbergia sissoo, Acacia auriculiformis, Acacia mangium* and *Melia sempervirens* replacing thousands of years adapted plants like *Mangifera indica, Syzygium* spp., *Tamarindus indica, Borassus flabellifer, Cocos nucifera, Artocarpus heterophyllus, Neolamarckia cadamba, Bischofia javanica, Toona ciliata, Streblus aspera, Lagerostroemia* spp., *Litacea* spp., *Saraca indica, Terminalia arjuna, Terminalia belerica, Alstonia scholaris, Phoenix dactylifera, Aphanamixis polystachya, Caryota urens, Baringtonia acutangula, Diospyros* spp., *Ficus* spp., *Pithecellobium dulce, Trema orientalis, Sesbania grandiflora, Cratea vanuravula* and *Areca* spp. etc. (Larson et al., 1989; Prain, 1963; Ahmed et al., 2008; Alam et al., 1996; Basak and Alam, 2013). After doing research and correlating the mortality of *Dalbergia sissoo* against environment and management parameters, Webb and Hossain (2005) and Asian Biodiversity Webnet (http://www.aseanbiodiversity.info/Abstract/51004215, 2013) suggested for changing of plantation species rather than practicing management strategies in Bangladesh and Nepal.

In India, a recommendation was made to plant flood-resistant tree crops in flood-prone areas such as *Acacia nilotica*, *Terminalia arjuna*, *Ficus recimosus*, *Neolamarckia cadamba*, *Garcinia gummigutta*, *Alastonia scholaris*, *Syzygium cumini*, *Mangifera indica*, *Murraya paniculata*, *Glochidion* sp. and *Caryota urens* (http://www.aseanbiodiversity.info/Abstract/51004215, 2013). In Pakistan, flood-tolerant trees suggested for planting are *Phoenix dactylifera*, *Ficus carica*, *Albizia procera*, *Zizyphus jujube*, *Casuarina cunninghamiana* and *Casuarina equisetifolia* (Ali et al., 2008).

For a long time, communities in Bangladesh used naturally adapted trees which have multipurpose usages and are resilient to grow in association and can utilize light and shade and act as windbreak or shelterbelt. It is recommended that such trees be the ones used in plantations. Many exotics do not allow undergrowth e.g. *Tectona grandis, Acacia mangium, Eucalyptus camaldulensis, Albizia saman* etc. and most of them are not eco-friendly especially for the wildlife. Exotics usually create problems with encroachment instigating quarreling among neighbors. From this synthesis, it is recommended that such plants must be discouraged in Bangladesh. Miniature fruit-tree culture by grafting and pruning that reduce timber crops also do not serve the purpose of shelter belt and as a result, these practices need to be discouraged (Ansari et al., 1999; Rahman, 2004, 2011a, 2011b).

6. Conclusion

Every plant species has its own adaptation according to climate and physiographic conditions. Choosing a suitable plant for a specific place of landscape is a prime issue which must be taken care of. It is the responsibility of everyone to consider a suitable environment for the growth of plants. Mere short-term gain must not supersede the long-term benefits of the nation and the society from a healthy plant environment. Since Bangladesh is a flood-prone country, the impact of floods and water-logging should be considered before choosing a species for a particular area. There should be a clear policy with necessary monitoring measures in place to encourage people to plant appropriate species that are adaptive to particular land at proper time. It should be considered an offense punishable by law to ignore such measures. BFD should consider the habit and habitats of the plants before advising people about plantation activities to avoid such damages in future. Moreover, proper documentations of the deaths, epidemics, illegal logging and deforestation and climatic adversity etc. are needed so that appropriate measures can be taken against such events. Bangladesh is a Least Developed Country that depends on financial assistance and as result it is pertinent that these funds are used to the benefit of the country.

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