Causes of Forest Dieback in Montane Forests in Sri Lanka

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Forest Dieback

Forests are plant communities dominated by trees, which provide the main physical structures and carry out most of the primary production (conversion of sunlight energy, air, water, and minerals to food through photosynthesis) in the system.

> *"Forest dieback is a condition in which trees or group of neighbouring trees progressively die from the top downward, resulting in large areas of severely degraded forest."*

The dying of canopies of trees in forests is called "canopy dieback". This process, which leads to a formation of dead or dying forest patches could seriously affect the genetic diversity and deteriorate the vegetation causing a considerable damage to the ecosystem. There are many categories of forest dieback such as forest decline, species level dieback, cohort senescence, stand level dieback, forest dying, and forest damage. During the "decline" stage forests lose their vivacity, trees cease growing and leaves discolour and fall off leaving a bare framework of branches. This could either lead to dieback or cause what is called stag headedness. Widespread forest decline due to dieback has now become a severe problem in many parts of the world. Some of these countries include Europe, North America, Pacific Islands, New Zealand, Australia and Sri Lanka (Hauk, 2003). In Germany, it is reported that about 52% of the forests, surveyed in 1985, were affected by this phenomenon.

Forest Dieback in Sri Lanka

Dying back of Tropical Upper Montane Rain Forests[1] has become a severe environmental crisis in Sri Lanka. A forest patch with dead and dying trees were first observed in Sri Lanka by Perera (1978), Werner (1982) and Hoffman (1988) in Totupalakanda Mountains rising up from Horton Plains National Park which is covered with biologically as well as hydrologically unique tropical upper mountain rain forests. Werner (1988) reported that forest dieback from tropical upper mountain forests from Pidurutalagala ridge and "Kobonilgala" near Cobet's gap in Knuckels mountain range. Wijesundara, (1991) first observed the declining trends of trees at the summits of Hakgala Strict Nature Reserve. Also, early forester De Rosayro (1946) has reported the unhealthy nature of upper montane rain forests in Sri Lanka.

Ranawana (1999) identified that, about 654.3ha (17.2%) of forested areas in Horton Plains had been subjected to dieback. It is severe on Totupolakanda Ridge and Kirigalpotta Ridge areas, where more than 75% of the canopy trees were dead and remaining trees were also showing signs of degeneration. Forest regeneration in these areas found to be very slow. Ranasinghe et al. (2007) observed that more than 90% of canopy trees on the Thotupolakanda ridge in the Horton Plain, about 75% of the Hakgala peak and a considerable number of trees in Riversturn area of the Knuckles range have already died. This study also revealed that plants in the areas exposed to wind are more susceptible to dieback than those on leeward sites. On the summits of the most of the Mountains, the vegetation was extremely stunted and the trees were not more than 2m tall with flat topped, closely-arranged crowns that resembled a neatly-pruned tea plantation. It is known as "pigmy trees" (Fig. 1).

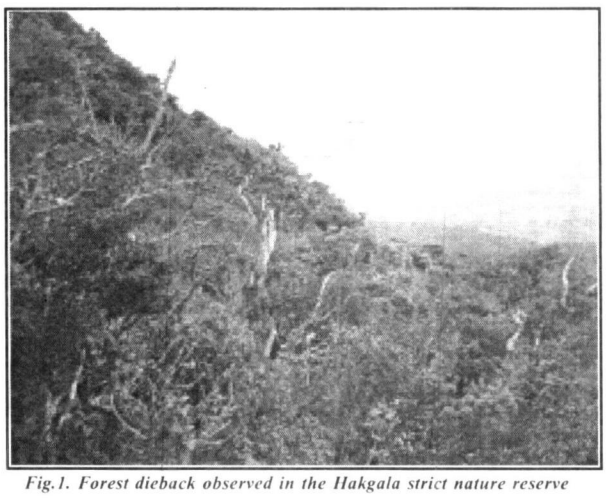

Fig.1. Forest dieback observed in the Hakgala strict nature reserve

Plant Species Affected by Forest Dieback

Satellite images of the central highlands of Sri Lanka in almost all montane forests, show that large dieback patches can be observed in 'slope' area whereas only few trees have been affected due to dieback in 'flat' area. Completely dead trees are sporadically distributed as a sign of dieback stem. Most trees showed a low branching habit. Almost all stems of the trees in lower elevations were covered with lichens. At higher elevations fewer numbers of trees were covered with lichens. The trees appeared rather unhealthy at high altitudes. It was found that *Syzygium* species and *Ilex walkeri* in Thotupolakanda have literally disappeared from the area. Adikaram and Mahaliyanage (1999) and Ranasinghe et al. (2007) have identified families such as *Lauraceae*, *Simplocaceae*, and *Myrtaceae* are highly susceptible to die back. *Syzigium rotundifolium, Syzygium revolutum, Syzygium sclerophyllum, Ilex walkeri, Symplocos bractealis, Calophyllum walkeri, Eugenia mabaeoides* and *Cinnamomum ovalifolium* are some of the dominant plant species susceptible to dieback (Fig.2). It was also found that at high altitudes, trees were unhealthy in appearance.

Causes of Forest Dieback

The reasons for the disruption of the healthy growth of a tree can be categorized into two, namely natural and anthropogenic factors. High radiation levels, heat, cold, drought, water abundance, mineral nutrition deficiency, leaf eating or sucking insects, virus, bacteria or fungal pathogens are natural factors affecting forest dieback. Anthropogenic factors which affected forest dieback include chemical substances used for plant protection, air pollution, acid rains, photochemical smog, heavy metals, UV radiation level increase, CO_2 increases and global climate changes. More than one factor can affect the health of a tree at any time. Soil and drainage conditions play a major role in determining the health or conditions of trees.

However, undue emphasis on poor soil or adverse climatic conditions such as drought and frosts as primary causes for damage to trees may prevent the more careful search for biotic influences. When forest dieback was first discovered in Sri Lanka in the 1960s, the scientists came up with numerous hypotheses such as low absorption of nutrients by plants, lowering of groundwater table, deseases, acid rain, damage caused by Sambar (*an animal*), climatic change and lead toxicity as causes for forest die back.

Fig. 2: Plant species affected due to forest dieback in Sri Lanka

Climatic Factors

Climatic stress has been proposed as the primary cause of dieback and decline of forests (White, 1986; Auclair, 1993). Drastic changes in the climate such as severe drought or flood can cause natural dieback in forests. Dieback in such areas may represent a senescing stage in the forest life cycle. However, decline and mortality of trees have been observed even at very low levels of climatic stress.

The forest dieback first observed in Sri Lanka in the western slope of the wind face of Thotupolakanda was considered to be due to severe drought, since the plant community recovered after the rains (Fig.3). However, since the peaks of the area are frequently covered with fog, it is also known to be another instigating factor for dieback. It is believed that wind and fog act as facilitators for spreading diseases that are capable of attacking healthy plants.

The hypothesis of dieback due to lowering of groundwater table has been proven unlikely, because it could not happen in a large scale. Studies conducted in Horton Plains and neighbouring montane forests show that some plant species are found to be highly susceptible to die-back. Because of strong winds, height of the trees reduces towards higher altitudes and pygmy forest formations are found close to the peaks. Strong winds experienced during the south-west monsoonal period causes leaf fall from the canopy trees resulting thick layer on the terrain of the forest ground. Loss of a considerable amount of leaves causes a stress on trees which could lead the trees to die.

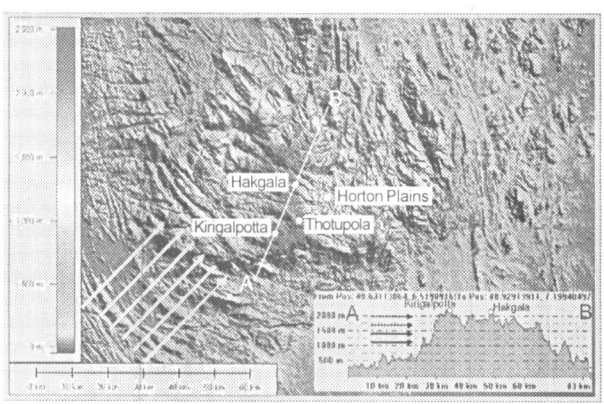

Fig. 3: Relief map of Sri Lanka and a cross section of the wind pattern and the locations of montane forests in the central highlands

Relief Factor

Montane forests in Sri Lanka show the common morphological features like ridge and valley topography or isolated hills with sharp break-in-slopes. Flat terrains are located just below the break-in-slopes. In the Hakgala Strict Nature Reserve, forest die back is intense on slopes (>35%) where the forest is exposed to strong winds. On most of the slope areas, forest has been completely disappeared leaving a few decomposing barks and allowing *Strobilanthes spp.* to spread over. A similar situation can be observed on the Thoutupola Kanda ridge too. But it was observed that die back had not affected plant species in the pygmy forest such as *Osbekia spp. Symplocos elegans, Rhodomyrtus tomentosa, Vaccinium leschenaiult.* On flat areas die back intensity is generally low (<25%) except for some specific localities where moderate intensities (25-75%) can be observed.

Sambur Damage

Sambur *(an animal)* eats the bark of many montane plant species and this causes rapid decomposition of the trunk. Most of the plant species highly preferred by the Sambur are the trees more susceptible to dieback. The damage caused to bark of *Microtopic zeylanic*, which has been recognized as a very rare species, is of much concern among the researchers. Moreover, browsing of creepers, grasses and seedlings and saplings of shrubs by sambur adversely affects their regeneration. But irreversible and lasting damage could only be caused if there is an over population of sambur. However, the role of sambur has not been proved as a major cause for forest dieback.

Fungal Diseases

Two fungal diseases, strip canker and pink disease have been found to have an association with dieback of trees in the Horton plains. Only few species of trees exhibited the symptoms of the diseases. The dieback of all species has not attributable to these diseases and hence association of these diseases with forest dieback has not been proved. Therefore, researches have shifted their efforts to identify the most susceptible dieback plants species in the montane forests in Sri Lanka.

Soil Nutrition

Dieback researches in Sri Lanka have been to a new direction after the work done by Wijesundara (1991) on the availability of nutrients in the soils of Hakgala. It revealed that total nutrient contents were high in dieback forest areas of Sri Lanka while available forms are in low concentrations. Major soil elements that he observed were nitrogen (N), Potassium(K), Phosphorus (P), Sodium (Na), Calcium(Ca),

Magnesium (Mg), and Manganese (Mn). He suspected that dieback could have been due to deficiency in the availability of major and micro nutrients. However, the results of preliminary studies on soils in Hakgala by Jayasekara (1992) reported that there was no significant depletion in available concentrations of nutrients except for potassium. According to a preliminary survey results, there was no direct relationship between nutrient levels in dieback forests and healthy forests. The same phenomenon was observed in the tropical montane forests in the Horton Plains as well (Ranasinghe and Dissanayake, 2003).

Soil Toxicity

Forest dieback in some parts of the world has been identified as a result of nutrient imbalance or soil toxicity. It has frequently been ascribed to aluminium (Al) toxicity and Al-induced nutritional disorders due to increased acidification of forest soils. Nutrition deficiency is considered as a contributory factor to canopy dieback in Montane forests in other countries too (e.g. Hawaiian Islands).

Werner and Balasubramanium, (1992) have found high levels of aluminum contents (1014-1180 ppm) in the World's End area and the Thotupolakanda ridge. A study by Ranasinghe et al. (2007) reports extractable Al levels of 11 -116 ppm from the top soils of the tropical montane forests of the Horton plains. A preliminary study of the same author also reported average extractable Al values of 46.5 – 74.4 ppm from the top 75cm depth of the Hakgala. It has been found that extractable Al concentrations of 15–20 ppm in soil can also be toxic to certain plants.

Extractable iron (Fe) content in soils in Hakgala varies between 48.1–372.1ppm whereas mean extractable iron concentration of 155 ppm in the top soil layer (60 cm) has been observed in other places in the same area. It has been found that 12 ppm Fe level is toxic to seedlings of some plant species such as *Agathis australis*. At low pH and water logging conditions, toxicity of Fe is thought to be more pronounced.

Ranasinghe et al. (2007) have detected high concentration of lead (Pb) in the soil and it can be toxic to some of the plant species. Moreover high amounts of iron in soils reduce the nitrogen absorption by plants. DTPA (Diethylene triamine pentaacetic acid) extractable Pb concentration in the soils of Hakgala varies between 0.6-2.4 ppm. The amount of lead in trees of Hakgala is 15-30 ppm. Lead levels are significantly high especially in the ridges of Thotupolakanda and Kirigalpoththa, where dieback has caused severe damage. It was also recorded that most of the Pb in soils were in acid leachable form. Similar studies on lead contents in soils have been conducted in different parts of the country and the results indicate that the lead levels of Horton Plains is as high as the levels in towns close to main roads, like Homagama and Dehiwala. Since the plant species found in Horton Plains and Hakgala are mostly endemic, they have a great risk of succumbing to the effects of foreign elements.

Researchers suggest that the focus of research on lead should be on its source. The level of lead in soil is higher than average especially in the wind face of the forests where dieback is most acute. The most plausible explanation is that lead (Pb) generated by industrial activities in the cities of south-west parts of the country, would be transferred to the montane forests in the western flank of central highlands by strong south-west monsoons.

The ratio of acid leachable and total Pb contents in soils in Horton Plains and Hakgala clearly proves an air-borne pollution related Pb deposition in the area, prior to the banning of unleaded gasoline use in Sri Lanka. Use of leaded petroleum as fuels until recently has resulted in considerable Pb pollution in stream sediments in Colombo and suburbs (2-583 ppm) as well as in cities close to Hakgala (total Pb level is 65-92 ppm in stream sediments). The emissions from vehicles could be a major source of Pb in the montain forest areas of the country. Strong monsoonal winds as well as transboundary effects could be responsible for bringing Pb from industrialized western province of the country (Fig.3). Also there is a possibility for transporting Pb from industrialized South Indian cities.

Future Directions of Research on Forest Dieback in Sri Lanka

Monitoring protocols are necessary to assess the condition of the forest, establish trends in forest health and understand the relationship between the forest ecosystem and stresses acting on it. Healthy forests exhibit a balance between growth and death of trees and have a ability to react to and overcome various stress factors such as insects, pathogens, weather, climate, air pollution and others. Quantitative knowledge of the thresholds of mortality for various tree species is a key knowledge gap; we don't know the level to which forest can withstand climatic stress before massive dieback kicks in. Thus, the existing scientific knowledge is not sufficient to accurately forecast forest dieback in response to projected climatic changes, and to assess associated ecological and social impacts. Therefore future research programs on forest dieback should be merely focussed to bridge this knowledge gap.

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