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Impact of Thane Cyclone on Tree Damage in Pondicherry University Campus, Puducherry, India

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ABSTRACT

The heavy wind along with high rainfall of the catastrophic windstorm "Thane" cyclone cause defoliation, uprooting and snapping of stems and branches of trees in Pondicherry University Campus, Puducherry. A total of 1181 (20%) trees (>3.2 cm DBH) in Pondicherry University Campus were uprooted due to the Thane cyclone. Tree mortality (uprooted) and damage (broken) were observed more in *Acacia auriculiformis* than other species in response to Thane cyclone in Pondicherry University campus. In the present study, wood density did not show any significant relationship between the damage, mortality and resistance (standing with defoliation and minor branch fall). *Acacia auriculiformis* was more susceptible to Thane cyclone followed by *Tectona grandis.* However, *Azadirachta indica* and *Mangifera indica* were observed more resistance to thane cyclone. The greater uprooting in introduced plantation species such as *Acacia auriculiformis* and *Tectona grandis* was higher than native species *Azadirachta indica* and *Mangifera indica* which could be attributed to spread their roots in the surface soil and they do not penetrate deeper into the soil.

Key words: Tropical cyclone, Thane cyclone, tree damage, wood specific gravity, severe winds.

INTRODUCTION

Heavy wind is known to alter the structure and functioning of forest ecosystems, agro-forestry systems and plantations. The intensity and frequency of severe wind events are likely to increase deterioration to the forests. It is important to understand the species and substrate-specific effects of these disturbances. The immediate impacts of tropical cyclones – defoliation, limb loss, snapping of stems and uprooting of trees – have profound impacts on tropical forests[1-4]. These catastrophic disturbances create canopy gaps, which can cause significant changes in forest microclimates in the understory and canopy[5-9], and complex vegetation and faunal responses to newly created light, temperature and humidity regimes[10-12]. The resulting altered environmental conditions can initiate other changes to the forest. The buildup of debris caused by cyclone damage is coupled with dry weather; there is a risk of fire incursion into forest[13]. The increased light intensity in the forest floor due to canopy gaps can release suppressed seedlings of pioneer species/ light demanding species, which may alter floristic composition[4]. Storm intensity, topographic protection and disturbance history could influence cyclone damage while certain functional traits of trees can also be important[4]. Severe cyclones cause widespread defoliation of canopy trees, removal of vines and epiphytes, along with the breakage of crown stems and associated tree falls[3,4,8,14-17]. Cyclonic disturbance has also been shown to accelerate invasion by exotic tree species leading to a decline in biodiversity of native species[18].

Cyclones modify the structural components which include the stripping of leaves from branches and the breakage of branches, roots, and stems[19]. Factors mitigating these effects include plant attributes, such as properties of wood[20], leaves and petioles[21-22], roots and buttresses[23-24], forest level physiognomy[25-27], properties of the wind event itself[28], as well as resource availability[29-30].

Effects of cyclone on the structure and production of forests are often species-specific[19-20,25,28,31-33]. Species may vary in their capacity to resist wind (resistance), offset the effects of injury (tolerance), and recover from injury (resilience). It is unlikely that any one taxon will display all three of these characteristics (resistance, resilience, tolerance). This is because of site- and habitat-specific resource limitations which will force a tradeoff among them[3,19].

Severe wind events, including cyclones, tornadoes, typhoons and thunderstorm downbursts, occur in nearly all forest systems throughout the world. Forest composition, structure, and functioning are affected by the severity and frequency of these events. Although much information on the effects of wind have been gathered from Caribbean, North America, South American forest systems and Australian rainforests, data remain limited for the old World tropics, and in particular to south India i.e., Tamil Nadu and Pondicherry (impact of cyclones on crop damage in terms of economical return and general damage in the prospective of economy has been generated in order to provide relief fund, however scientific generation of data on damage in the ecological perspective in Tamil Nadu and Puducherry was almost nil). The earlier cyclone namely Nisha, Jall and now Thane cyclone have affected Tamil Nadu and Pondicherry. No published information of Nisha and Jall cyclones on tree species damage is available. Therefore, the data generated from the present study would be the baseline data for further comparisons and prediction of future impacts of cyclone intensities. The 'Thane' name was given simply by weather reporters so as to reach the people easily. Due to thane cyclone power production was affected at the Neyveli Lignite Corporation as the mines were submerged. Puducherry was cut off from the neighbouring districts of Villupuram and Cuddalore, in Tamil Nadu[34]. It has caused to fell several trees across the roads due to the impact of gale. Published information on the impacts of cyclone on tree mortality and damages are not available in Tamil Nadu and Puducherry. Therefore, the present study was intended to assess the impact of severe tropical cyclone "Thane" on forest tree species damage in Pondicherry university campus, Puducherry, India. The present study would also to address the following questions: a) which tree species is suitable for raising plantation near to the tropical coastal region in the red soil conditions? b) Whether wood density provides resistance to the severe winds?

Study area and description

Pondicherry University (12° 0.97´ N 79° 51.33´ E), located 10 km North of Puducherry town, on the Coromandel coast of India (Figure 1). It covers an area of 780 acres. The climate is tropical dissymmetric type with most rainfall received during the northeast monsoon (October-December) and meager and inconsistent during southwest monsoon (June-September). The mean annual rainfall is 1282 mm for the last two decades (1990-2010).The dry season lasts for about six months (January-June), but there are summer showers too during this period. The mean annual maximum and minimum temperature are 32.58°C and 24.51°C for Puducherry. The soil is red-ferralitic, sandy in texture and heavily drained. Historically, the 780 acre land of Pondicherry University, in various portions, was composed of Tropical dry evergreen scrub, and palm savannas on the western and southern part of the campus, cashew plantations, rice, and sugarcane and groundnut cultivation on the eastern side. The landscape was modified over quarter century with buildings, roads, lawns and ornamentals. The varied topography of the campus such as forests, scrubs, savannas, scenic Grand Canyon-like Cuddalore sand-stone formation with lateritic cap, is responsible for high diversity in plant species. A natural area of the campus consists of tropical dry evergreen forest, dry evergreen scrub, scrub savanna and tropical thorn forest. The flora of the university campus was illustrated by Parthasarathy et al.[35].

Cyclone "Thane"

"Thane" was a very severe cyclonic storm developed over Bay of Bengal during last week of December 2011. It crossed north Tamil Nadu and Puducherry coast between Puducherry and Cuddalore within 06.30 – 07.30 hrs (IST) of 30th December 2011 with a wind speed of 120 -140 km/hr,[36].

The Joint Typhoon Warning Center (JTWC) issued a tropical cyclone formation alert on the system during December 25 before designating as Tropical Cyclone 06B later that day as 1-minute wind speeds near the centre reached 65 km/h (40 mph) which is equivalent to a tropical storm. The India Meteorological Department (IMD) also reported during December 25 that the disturbance had organized sufficiently to be declared Depression BOB 05, while it was located about 1,000 km to the southeast of Chennai, India. Early on December 26, the IMD reported that the depression had intensified into a Deep Depression, later on it had intensified into a cyclonic storm and named as "Thane". The JTWC reported that Thane had become equivalent to a category one hurricane on the Saffir- Simpson Hurricane Wind Scale with 1-minute sustained wind speeds of 120 km/h (75 mph) on early 26th December, while an eye feature had become visible on microwave imagery. Later IMD confirmed the same with 3-minute sustained wind speeds of 120 km/h (75 mph). Thane continued to intensify and developed a small pinhole eye of about 20 km (10 mi) on 28th December. The JTWC reported that Thane had peaked early on December 29 with 1-minute sustained wind speeds of 150 km/h (90 mph). The IMD reported that the system had peaked as a very severe cyclonic storm with 3-minute sustained wind speeds of 140 km/h (85 mph). System continued to move westwards and weakened slightly as it started to interact with land and then made landfall as a borderline during December 30 on the north Tamil Nadu coast between Cuddalore and Pondicherry. After it had made landfall, frictional forces made Thane rapidly weaken into a depression[36-37]. As per JTWC best track data the Thane cyclone was a Typhoon and would be under the Typhoon Category 1 (based on relating wind speed[38]).

Due to cyclonic storm, sea wave were 1.5 m high. Puducherry was caused extensive damages in cyclonic storm. Rainfall was 15 cm on 30th and 10 cm on 31st December 2011[36]. The Eleven number flag (Great danger- signal stated that severe cyclone to cross the cost by port official based on IMD information) was hoisted in Cuddalore and Puducherry harbor. Severe winds with heavy rainfall have damaged houses and uprooted trees. The cyclone was the severest in the history of Puducherry[34]. The first time that a high intensity cyclone was hit the Union territory after the one in the 1950's. Even in Puducherry and Cuddalore thatched huts of fishermen and wooden frames in slum areas were completely destroyed. Several trees have fallen down in private coconut plantations and cashew-nut plantations. The cyclone damage in the Pondicherry University campus was more severe i.e. several trees were uprooted and broken, damage the electric poles, bus stops and clearing the road in the campus itself took more than three days.

Methods

For the present study, entire university campus was divided in the three sub sites namely Site I (which is located near to the coastal zone within the campus, i.e. area up to 500 m from the eastern compound wall of the University campus), Site III is one km away from the eastern compound wall of the University campus and site II lies in between the site I and site III.

Cyclone effects on each tree were assessed by visually estimated or recorded uprooted and largest broken branch and standing stage in each study site in the Pondicherry University campus by quadrat method. A large number of 10 m X 10 m quadrats were laid in each site (Site I-161 quadrats; Site II-156 quadrats; Site III-93 quadrats) and noted the status of each tree and measured the girth at breast height (the values are converted to diameter at breast height (DBH)) also.

Since the trees were uprooted by the cyclone Thane, it was a good opportunity to collect the wood form the main trunk. Wood pieces of main trunk were collected from the uprooted trees and measured the green volume and then measured dry weight of the wood pieces by oven drying at 105°C ± 5°C for 72 hours. To determine wood specific gravity, tree species that are represented by e" 3.2 cm DBH individual in the Pondicherry University campus were considered. Wood specific gravity was determined using sample of stems (2-8 cm long and 8.9-29 cm diameter) cut at the main trunk. The volume of each sample was determined from the volume of water it displaced when submerged, according to ASTM standard norms[38]. The basic specific gravity was calculated as oven-dry weight divided by volume[40-41].

One Way ANOVA was used to test whether significant difference among the wood specific gravity of the tree species. Linear regression analysis was used to study the relationship between the wood specific gravity and tree damage.

RESULTS

A total of 1181 (19.59%) trees (>3.2 cm DBH) in Pondicherry University Campus were uprooted due to the Thane cyclone (Table 1). Among the tree species distributed in the campus, *Acacia auriculiformis* showed highest mortality (27% uprooted) followed by *Tectona grandis* (18%) and *Eucalyptus tereticornis* (11%). Snapped trees (part of the tree broken) in the university campus due to Thane cyclone were 929 (15.5%). Among the six dominant tree species *Azadirachta indica* showed higher (28%) rate of damage due to snapped off (branch fall) followed by *Mangifera indica* and *Peltophorum pterocarpum*. However, the predominant species, *Acacia auriculiformis, Tectona grandis* and *Eucalyptus tereticornis* in the campus showed less damage in term of snapped off compared to other species. Tree species standing with minor damage and defoliation were more than 58% of the total population except for *Ailanthus excelsa* and *Anacardium occidentale.*

Maximum number of mortality (uprooted) and snapped off (broken) trees observed in size classes between 9.7 - 22.3 cm DBH in all the study sites and also in the entire campus pooled data (Fig. 2). However, cyclone has caused damages on all size classes of tree species. Impact of Thane cyclone on various size classes of trees is presented in the

Table. 1: Over all tree damages due to the impact of "thane" cyclone in Pondicherry University campus, Puducherry.

Name of the species	Number of individuals /4 ha	Status of trees after the Thane cyclone (%)		
		Standing	Broken	uprooted
All the trees	6013	64.91	15.50	19.59
Tectona grandis L.f.	1174	69.68	12.44	17.89
Eucalyptus tereticornis Smith	808	78.96	9.78	11.26
Acacia auriculiformis A. Cunn. ex Benth	3045	57.60	15.34	27.06
Azadirachta indica A. Juss.	438	68.72	27.85	3.42
Mangifera indica L.	24	79.17	20.83	0
Peltophorum pterocarpum (DC.) Backer ex K. Heyne	285	70.53	20.35	9.12
Aegle marmelos (L.) Corr.	4	25.00	75.00	0
Ailanthus excelsa Roxb.	2	0	100.00	0
Albizia odoratissima (L. f.) Benth	21	71.43	28.57	0
Anacardium occidentale L.	34	47.06	47.06	5.88
Borassus flabellifer L.	36	100.00	0	0
Calophyllum inophyllum L.	6	100.00	0	0
Casuarina equisetifolia Forster & Forster f.	31	70.97	22.58	6.45
Ceiba pentandra (L.) Gaertner	1	0	100.00	0
Cocos nucifera L.	22	63.64	27.27	9.09
Ficus benghalensis L.	3	100.00	0	0
Ficus religiosa L.	4	75.00	25.00	0
Manilkara zapota (L.) P. Royen	9	66.67	33.33	00
Michelia champaca L.	1	100.00	0	0
Morinda pubescens J. E. Smith	31	80.65	12.90	6.45
Syzygium cumini (L.) Skeels	6	83.33	16.67	0
Others	28	67.86	17.86	14.29

Figure 3a&3b. In *Acacia auriculiformis*, maximum tree mortality (uprooting) were observed in the size class in between 9.8 – 28.7 cm DBH in all the study sites while snapped off (broken) were observed in the size class in between 6.5 – 25.5 cm DBH. A similar trend was occurred in *Tectona grandis* and other species in all the study sites except in the other species mortality (uprooted) in site III. However, cyclone damage on *Eucalyptus* trees did not show any specific trend in size classes.

Cyclone damage on all trees were greater in site I and site III compared to site II (Fig. 4). Cyclone resulted in greater mortality in both site I and site III than that of site II whereas snapped off (broken) was observed more in the site I than that of other study sites. A similar trend was observed on *Acacia* and *Eucalyptus* tree species. However, in *Tectona grandis* and *Azadirachta indica,* greater damage was observed in site I than that of site II.

Wood specific gravity estimated in the present study was ranged 0.559 to 0.812 g/cm^3 (Table 2). Maximum wood specific gravity was obtained in *Albizia odoratissima* followed by *Peltophorum pterocarpum, Azadirachta indica* and *Acacia auriculiformis.* However, the least was *Anacardium occidentale*. One way ANOVA analysis indicates that there is a significant difference found among the trees in the present study with respect to the wood specific gravity (F-value: 5.27; P >0.001) among the trees in the present study. Regression analysis indicates that there is no significant relationship in between the wood specific gravity and cyclone damage of trees (uprooting and broken) in Fig.5.

DISCUSSION

The heavy wind along with high rainfall of the catastrophic windstorm "Thane cyclone" have caused defoliation, uprooting and snapping of branches of trees in its path of Puducherry and Cuddalore district of Tamil Nadu as like that of earlier studies done elsewhere[1,2,15,42], either by direct wind damage (wind-throw or defoliation), or indirect effects of wind (large trees and branches damaging small trees[43]. In the present study the medium sized adult trees (6.5 – 22.3 cm DBH) were damaged due to heavy wind of Thane cyclone. Similarly medium sized trees were damaged due to heavy wind in Kolombangara[44]. In contrast, forests in Texas and Puerto Rico suffered higher mortality rates among larger diameter trees of some species[2,45]. Tree size

Table 2: Specific gravity of tree species in Pondicherry university campus

Name of the Species	Wood specific gravity (mean ±SD)	Source
Tectona grandis L. f.	0.684 ± 0.094	Present study
Eucalyptus tereticornis Smith	0.708 ± 0.016	Present study
Acacia auriculiformis A. Cunn. ex Benth	0.774 ± 0.095	Present study
Azadirachta indica A. Juss.	0.778 ± 0.015	Present study
Mangifera indica L.	0.703 ± 0.076	Present study
Peltophorum pterocarpum (DC.) Backer ex K. Heyne	0.802 ± 0.040	Present study
Aegle marmelos (L.) Corr.	0.747 ± 0.004	Present study
Albizia odoratissima (L.f.) Benth	0.812 ± 0.028	Present study
Anacardium occidentale L.	0.559 ± 0.014	Present study
Casuarina equisetifolia Forster & Forster f.	0.795 ± 0.057	Present study
Cocos nucifera L.	0.705 ± 0.033	Present study
Ficus religiosa L.	0.652 ± 0.064	Present study
Morinda pubescens J.E. Smith	0.47 ± 0.03	Mani and Parthasarathy, 2007
Syzygium cumini (L.) Skeels	0.64 ± 0.05	Mani and Parthasarathy, 2007

(DBH) did not confer any increased or decreased resistance to damage from cyclone Thane in Pondicherry University Campus among tree species. Similarly, no specific relationship was obtained by Curran et al.[46] from cyclone Larry among Mabi forest trees when tree size-classes and damage categories used for analysis. These results are unexpected, as several studies have found that larger trees experience greater wind damage[47-50], although such findings are not universal[20] and tree size did not influence mortality in Jamaica[3]. Everham and Brokaw[4] have reviewed many studies of wind damage to forest vegetation. They have suggested that lack of consistent trends between tree size and damage across studies could be attributed to such factors as variation occurred between the species and within the species regarding the relationship between tree height (which is more directly related to wind exposure) and diameter, as well as different measures of damage and different size-classes used by researchers. Furthermore, Everham and Brokaw[4] propose that traits such as crown size may give more accurate estimations of resistance. Preliminary studies on common Mabi forest species showed some relationships between damage and mean canopy spread[46]. The present study shows maximum uprooting in *Acacia* trees compared to teak and *Eucalyptus*. This may be attributed to

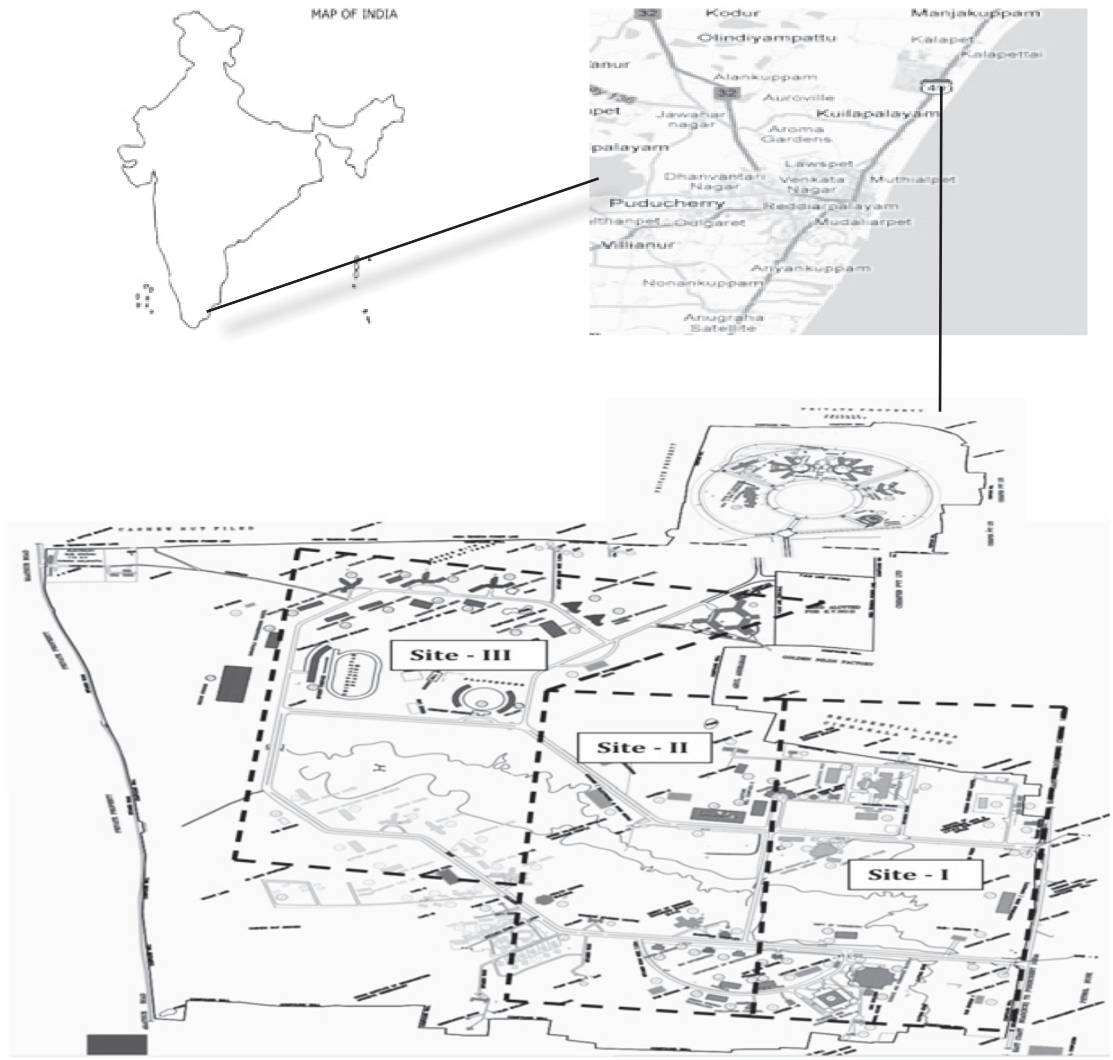

Fig.1:Location of the study area, Pondicherry University campus, Puducherry, India.

height and canopy spread because *Acacia* tree have greater height than that of the teak as well as greater canopy spread compared to *Eucalyptus* trees.

Twenty present (1181) of trees were uprooted in Pondicherry University Campus due to Thane cyclone. This value is greater to overall mortality on plots of subtropical wet forest in Puerto Rico following hurricane Hugo[48] and in lower montane rain forest in Jamaica in response to hurricane Gilbert[51-52], although it is within the range for catastrophic windstorms[4].

Tree mortality (uprooted) and damage (broken) in Pondicherry University campus showed that the greater values in individuals of *Acacia auriculiformis* are more than that of other species in response to Thane cyclone. Other studies have also shown differences between tree species in susceptibility to death or damage during severe windstorms[14,25,42,53]. These differences may be linked to wood properties[2,47] or tree architecture[25].

Wood density appears to be a trait fundamental to cyclone resistance[54]. However, in

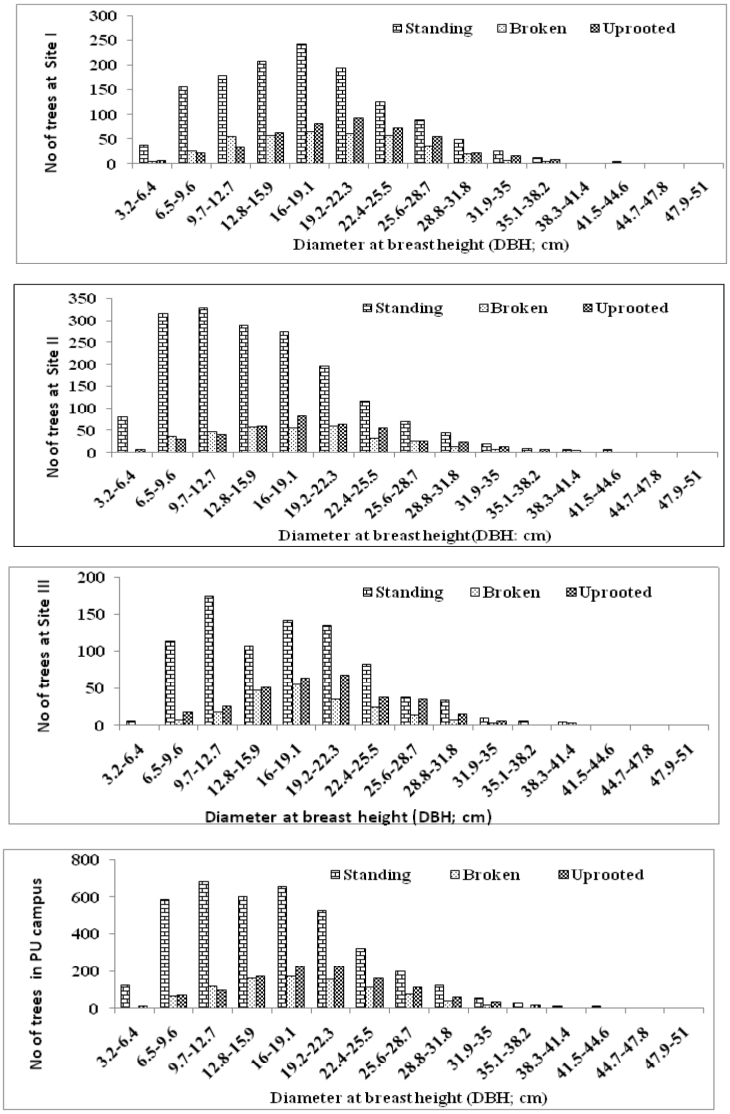

Fig. 2: Trees size classes wise status after the "Thane" cyclone effect in Pondicherry, University Campus, Puducherry, India.

the present study, wood density did not show any significant relationship between the damage (broken) and mortality (uprooted). Similarly, no relationship was found between resistance and wood density in Jamaican forest[3], Hawaiian forests[20], nor across a variety of forest types in north Queensland following Cyclone Larry[50]. However, relationships between wood density and wind resistance have been found in a number of forest types and environments, including: tropical moist forest at Barro Colorado Island[47], subtropical wet forest in Puerto Rico[2] and tropical rainforest in north Queensland[54]. Metcalfe et al.[50] based their assertion on the observations viewed that some tree species with different wood density experienced similar types of damage, while others with similar wood density experienced different levels of damage relative to other sympatric species. Similarly, in the present study tree species with closure wood density showed different response to Thane cyclone.

Leaf traits could also determine levels of damage in the context of cyclone resistance[46]. In the present study, leaf traits may also be induced the effect of Thane cyclone on tree mortality (uprooted) in case of *Tectona grandis, Eucalyptus tereticornis* and *Acacia auriculiformis* compared to other tree species. Similarly, leaf size (such as area, length or width) and petiole length could influence defoliation by altering the drag forces experienced during a windstorm[21]. The same may be true of traits related to leaf strength. For instance, specific leaf area (SLA) (one-sided area divided by dry mass,[55] Westoby 1998) is a good, readily measured attribute for leaf strength, owing to its negative correlation with leaf force to fracture and leaf toughness (force to fracture/leaf thickness)[56] which determine the level of damage during cyclone resistance.

Physical damage from a tropical cyclone might be greatest at edges of the forest or in small

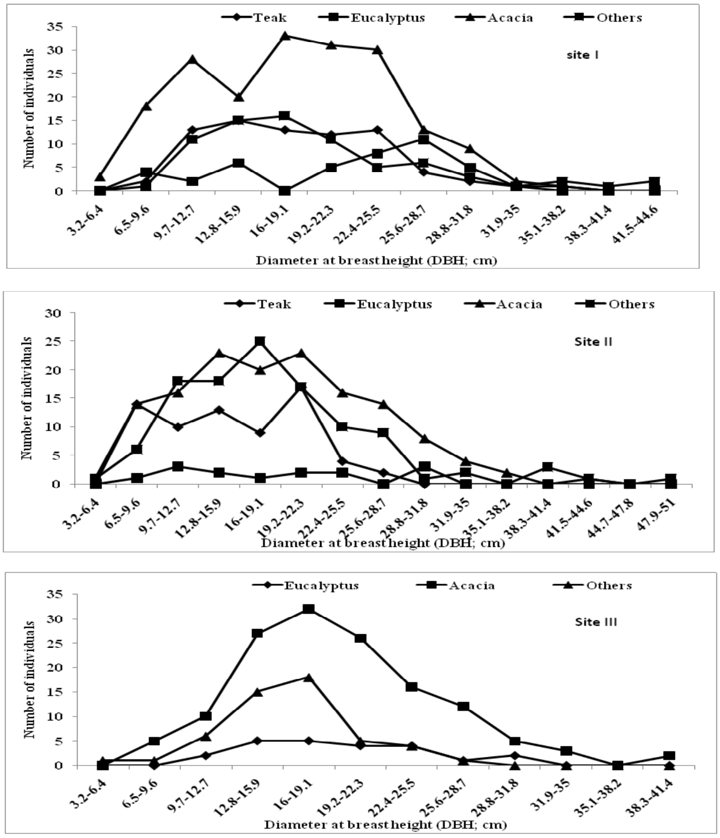

Fig 3a: Impact of Thane cyclone on tree damage (broken) at different girth class in Pondicherry University campus, Puducherry

fragments that have a high proportion of edge[57]. Similarly, the forest distance from the coastal zone is an important trait to determine the impacts of cyclone. Damage of trees due to Thane cyclone were greater in site I compared to site II and site III. The variation in damage among the study sites could be attributed to distance from coastal zone. However, site III had greater mortality of trees compared to that of site I and II even though this site was for away from the coastal zone. This may be due to greater density of trees per unit area which is mostly in an open space. The study site I that has lesser mortality because heavy wind force at few meter height is reduced by compound wall of the university campus. However, broken (snapped of branches) were greater in study site I because part of canopy of trees in site I is exposed to heavy cyclone wind. In study site II, several buildings are located which may reduce wind speed or alter or change the wind directions. This could be the reason for less damage in site II compared to site I and site III. It is likely that the high wind intensity from severe tropical cyclones overrides the modest wind protection provided by surrounding forest. Similarly, the results of the present study also indicate that the tree damage effects of cyclone are patchy at local scale of 0.05 km. The main effect of cyclone Larry at forests was to increase the spatial heterogeneity of forest structure at local scales[57]. The cyclone's effects were highly patchy at local scales (0.5–1.0 km), leading to an increase in among-site variation in forest structure and the disappearance of significant spatial autocorrelation among large remnant edge-interior site pairs which had existed prior to the cyclone[57].

The present study reveals that the Thane cyclone has caused high rates of defoliation, uprooting and snapped off stems and branches to trees in their path particularly in Pondicherry University campus, Puducherry, India. *Acacia auriculiformis* was more susceptible to Thane

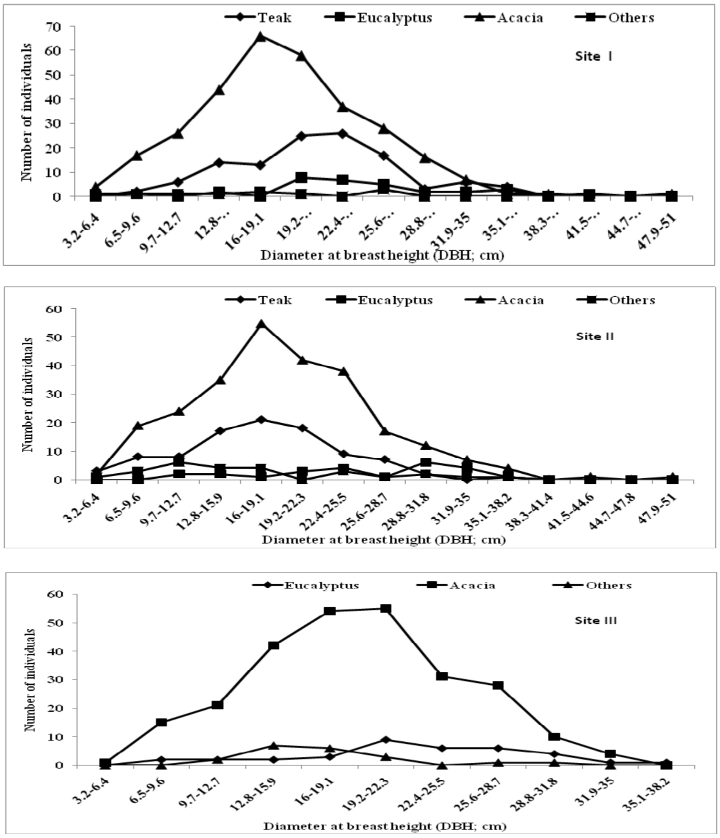

Fig. 3b: Impact of Thane cyclone on tree mortality (uprooted) at different girth class in Pondicherry University campus, Puducherry

cyclone followed by *Tectona grandis.* However, *Azadirachta indica* and *Mangifera indica* were more resistance to thane cyclone. This could be attributed to the roots of all introduced species which do not penetrate deeper into the hard red soil. Instead they spread their roots as reported by Narasimhan and Oppili[58].

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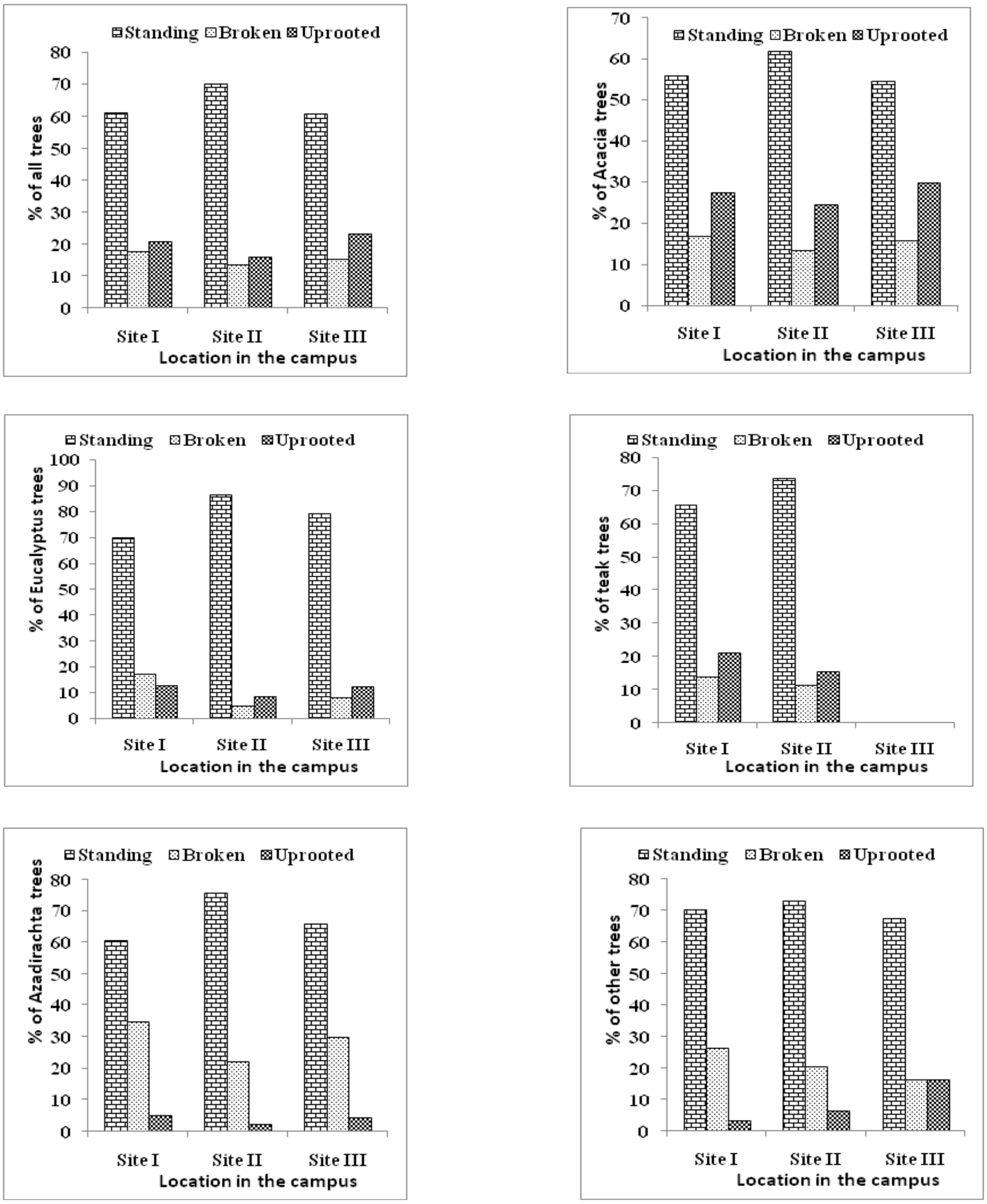

Fig. 4: Impact of "Thane" Cyclone on tree damage in different location at Pondicherry University campus, Puducherry, India.

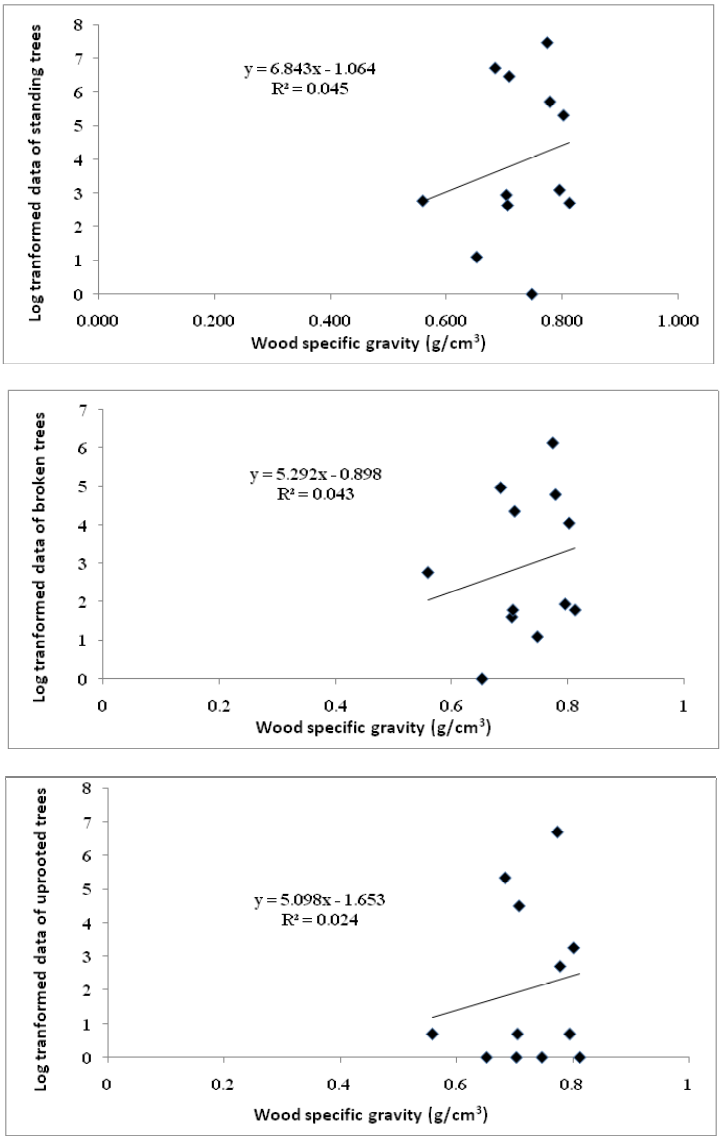

Fig. 5: Relationship between the wood specific gravity and status of tree species after the Thane cyclone at Pondicherry University campus, Puducherry, India

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