P2H.3 TREE DAMAGE IN QUINTANA ROO, MEXICO CAUSED BY HURRICANE DEAN (2007)

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1. INTRODUCTION

On Sept. 12, 2007, an interdisciplinary team of researchers traveled to Quintana Roo, Mexico to conduct a three-day rapid assessment of the biophysical and socioeconomic impacts resulting from the landfall of Hurricane Dean. On 21 August, 2007, Dean made landfall as a category five hurricane near Majahual, Mexico (Figure 1). Dean maintained hurricane intensity as it crossed the Yucatan peninsula, entering the Bay of Campeche as a category one hurricane. The biophysical researchers collected data pertaining to tree damage to verify the location of the center of circulation and identify which inland communities likely experienced the fastest winds.

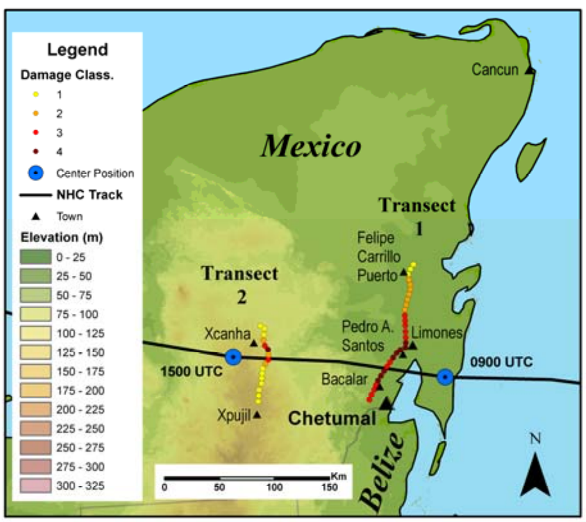

FIG. 1. Track of Hurricane Dean through the Yucatan Peninsula according to data from the National Hurricane Center, and the positions of the two transects where tree damage was assessed.

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The area assessed is covered by seasonally dry tropical forests. These forests are characterized by their canopy height and degree of deciduousness, which in turn depend on soil properties, topographic position and precipitation (Sánchez-Sánchez and Islebe, 2002). Forests developing on shallow, rocky soils or deep clayish soils have a high number of deciduous tree species and may reach heights of up to 16 m to 20 m, respectively. On the contrary, forests developing on soils that retain more water are taller (20-25 m) and several tree species retain their leaves during the dry season. The forested landscape is scattered with small villages that are the center of communal lands, except for the cities of Chetumal (137,000 inhab.) and Felipe Carrillo Puerto (22,000 inhab.). These villages strongly rely on the goods and services provided by forests to sustain the livelihoods of their inhabitants. The socioeconomic effects of Dean's damage to the forest are under investigation by the social scientists of the team.

A ground-based assessment of damage to trees after a hurricane's landfall provides important information about surface winds. Atmospheric scientists and engineers measure the severity and orientation of damage to trees to determine wind vectors during hurricane landfalls (Boose et al. 1994: Wakimoto and Black 1994). Away from the storm track, ecologists find that strong winds produced by hurricanes can still damage forests. Tanner et al. (1991) report that intense damage occurred 43 and 60 km from the closest approaches of Hurricanes Betsy (1956) in Puerto Rico and Allen (1980) in Jamaica, respectively. The current study is applicable to atmospheric scientists as quantifying the severity and orientation of damage allows us to locate the position of the circulation center and areas affected by the fastest winds, and to ecologists as we classify the amount and type of tree damage according to distance from the closest approach of Dean's circulation center.

2. PROCEDURE

Data pertaining to the track and intensity of Dean were obtained from advisories issued by the NHC (http://www.nhc.noaa.gov). The 0900 UTC advisory issued on 21 August placed the circulation center 10 km inland from the point of landfall (Figure 1). At this time, the storm had maximum sustained winds of 74 ms^{-1} with an eye diameter of 19 km, and was moving at a speed of 9 ms^{-1}. Six hours later, the circulation center was 200 km inland from the point of landfall, and maximum sustained winds were 46 ms^{-1}. Our tree damage assessments occurred between the circulation center coordinates given in the 0900 and 1500 UTC advisories.

We performed a rapid assessment of tree damage and orientation along two transects driven perpendicular to the storm track. At 5 km intervals, tree damage was quantified according to the criterion established by Brokaw and Walker (1991). We estimated the percentage of trees in each location that were uprooted, snapped, and defoliated. Uprooted trees were leaning at an angle greater than 45°, while snapped trees experienced the loss of large branches, or had broken trunks. The orientation of damaged trees helped us to infer the direction of strongest winds at each site, and we used changes in the direction of damage to locate the passage of the eye, as suggested by Boose et al. (1994).

Transect one (T1) (Figure 2) spanned 140 km along the major road from Chetumal to Cancun, and was located an average of 50 km inland. Damage surveys were conducted from the roadside using a 360 degree viewpoint as it was not possible to cross fences alongside the highway. Transect two (T2) spanned 70 km of the road north of Xpujil, located approximately 170 km inland (Figure 3). As the majority of these sites occurred in unpopulated forested areas, we walked 50 - 100 m into the forest to complete the assessments. Given Hurricane Dean's forward velocity of 9 ms^{-1}, we estimate that the circulation center had been over land for nearly two (six) hours as it passed over T1 (T2).

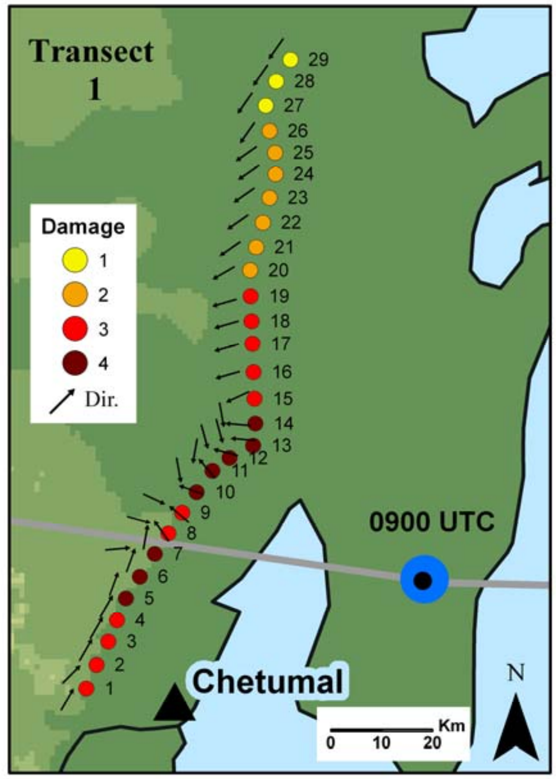

FIG. 2. Damage classification for sites along Transect 1. Sites are numbered according to the order in which sampling occurred. Arrows denote the dominant direction of snapped and uprooted trees.

After Brokaw and Walker (1991), we developed a classification scheme to compare damage occurring among the sites (Table 1). Each site was placed into the highest category for which it qualified using either the percentage of trees that were snapped or the percentage of trees that were uprooted. Given that the majority of trees at every site experienced defoliation, we did not utilize this data to inform our classification. It should be noted that the damage classification does not imply that a specific wind speed was experienced at a site, as the relationship between forest damage and wind speed and duration is complex (Boose et al. 1994).

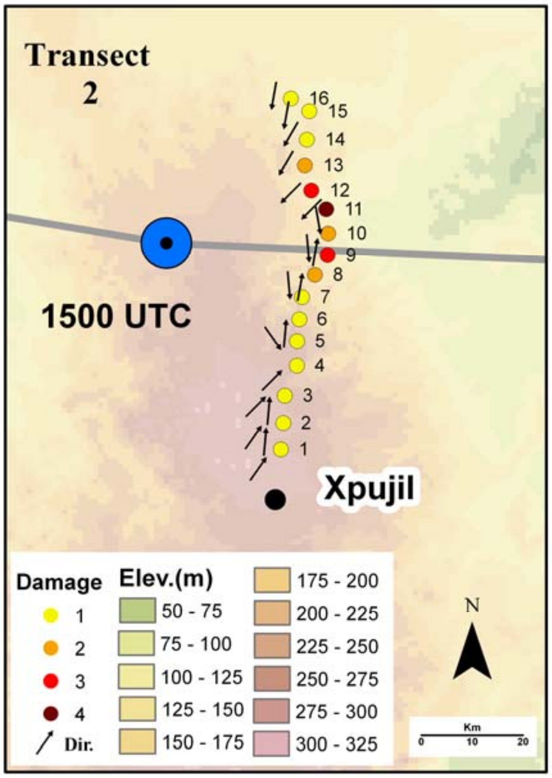

FIG 3. Damage classification for sites along Transect 2. Sites are numbered according to the order in which sampling occurred. Arrows denote the dominant direction of snapped and uprooted trees.

Table 1: Classification of tree damage severity. Each site is placed within the highest category for which it qualifies based on either the percentage of trees with large branches or the trunk snapped, or the percentage of trees uprooted.

Damage class	Snap (%)	Uproot (%)	No. obs.
4	70+	30	9
3	40-60	20	13
2	20-30	10	11
1	0-10	0	13

3. RESULTS

Along T1, the orientation and the severity of tree damage suggest that the circulation center of Dean passed over sites 7 and 8 (Figure 2). These sites are located approximately 15 km south of Pedro A. Santos, and 15 km north of Bacalar. Tree damage was oriented in two opposing directions, meaning that an abrupt shift in wind directions occurred rather than a gradual turning (Wakimoto and Black 1994). This position is in good agreement with the interpolated track plotted using the 0900 UTC and 1500 UTC NHC advisories.

The most severe crown damage and percentage of uprooted trees along T1 occurred 5-10 km south of Pedro A. Santos at sites 10 and 11, indicating that the maximum winds passed through this area. The town of Limones, approximately 22 km north of the circulation center, also received Class 4 damage. Damage with a strong westerly component (sites 7-14) occurred prior to the passage of the circulation center. On the right side of the storm track, easterly and northeasterly winds caused tree damage during the circulation center's passage over the transect. The orientation of damage that we observed agrees well with observational and modeling studies of surface winds that occurred during the landfall of Category 5 Hurricane Andrew (1992) (Wakimoto and Black 1994, their Figure 2; Zhang et al. 1999, their Figure 4b).

At T1 sites, tree snap percentages of 70% or greater, which we classified as Class 4 damage (Table 1), occurred approximately 20 km from the circulation center on both sides of the storm track (Figure 2). Some 40-60% of trees were snapped 45 km from the storm center on both sides of the track. These numbers correspond well to the distances of intense damage reported by Tanner et al. (1991).

As Hurricane Dean was over land for approximately six hours before affecting the region where T2 is located, the maximum sustained wind speeds were lower here as compared to T1. As expected, we rated fewer sites as Class 3 or 4 as compared to T1. The circulation center most likely passed over site 10, as winds from the northwest and south uprooted and snapped trees at this location (Figure 3). This location also agrees with the interpolated track of Dean as provided by the 0900 UTC and 1500 UTC NHC advisories. The most severe damage occurred at site 11, which is near the town of Xcanha and approximately 6 km from the circulation center. We rated this site Class 4 as 30% of trees were uprooted. The pattern of tree damage this far inland agrees well with the analysis discussed by Parrish et al. (1982, their Figure 6a) after the landfall of Hurricane Frederic in 1979.

The effects of the changing elevation along T2 were evident in the orientation of tree damage on the left side of the storm track (Figure 3). A ridge over 300 m in height is located 10 km west of Site 1. Elevation decreased by 150 m over the course of the transect. The orientation of uprooted and snapped trees at sites 5 and 7 resulted from winds blowing predominantly from the northwest. We believe the position and shape of the ridge channeled northwest winds some 20 km south of the circulation center. Boose et al. (1994) discuss similar channeling of winds and resulting tree damage during Hurricane Hugo's passage over Puerto Rico in 1989.

The proportion of snapped to uprooted trees differed between the two transects. This could be due to the age and species of trees as discussed by Brokaw and Walker (1991) and Tanner at al. (1991), and/or the soil moisture content (Putz et al. 1983). Along T1, snapping was much more prevalent than uprooting. Most of the T1 trees were tall with thin crowns, and Putz et al. (1983) reports that trees with this structure are more likely to snap, while shorter-stemmed trees with thick crowns are more likely to be uprooted. Additionally, the dry conditions preceding the landfall of Hurricane Dean may have limited the number of uprooted trees along T1, as uprooting is promoted in moist soils (Putz et al. 1983).

The percentage of trees uprooted and snapped were much closer together along T2. Here we noted extensive crown damage at sites 8-13, where the canopy was lowered 2-3 m. Putz et al. (1983) find that loss of a tree's crown renders it less susceptible to snapping. Thus crown loss may have reduced the number of snapped trees even at sites where we found that topography channeled the winds through the forest.

4. CONCLUSIONS AND FUTURE RESEARCH

Three weeks after Hurricane Dean tracked through the Yucatan Peninsula, we assessed tree damage along two inland transects perpendicular to the storm's path. We estimated the number of snapped and uprooted trees and the orientation of the damaged trees to determine where the circulation center was located and which communities experienced the fastest winds. The first transect spanned part of the major road from Chetumal to Cancun, and we determined that the circulation center passed half way between Bacalar and Pedro A. Santos. The fastest winds occurred just south of Pedro A. Santos, causing more than 70% of trees to be snapped. The town of Xcanha received the fastest winds along the second transect located 170 km from the point of landfall. Fewer trees were snapped along T2, and the orientation of damage suggests that winds were channeled through the forest by the ridge located 10 km west of T2.

We believe that the dry conditions which preceded Hurricane Dean's landfall affected the amount and type of tree damage caused by the storm. For our future research, we will acquire meteorological data from several stations located near the transect sites to quantify rainfall amounts. We will also perform a detailed analysis to determine the specific characteristics at each site that contributed to the type and severity of damage that we observed. This will include the use of remotely sensed data to further assess vegetation changes in the region. Our damage estimates will also be used by the social scientists in our team. The data we collected for this study will serve as ground truth for future examinations of the consequences of tree damages as they investigate the socioeconomic changes resulting from the passage of this hurricane.

5. ACKNOWLEDGEMENTS

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