# The effect of wind on forest structure and condition in a lowland tropical dry forest

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*Abstract:* Wind is a climatic factor that influences the ecology and condition of forest ecosystems. East-facing slopes in Palo Verde National Park, Costa Rica experience high wind speeds during the dry season. We evaluated the effect of high winds on the lowland tropical dry forest by comparing trees on neighboring east- and west-facing slopes. While tree size did not significantly differ between slopes, we found that windward slopes had less canopy cover, less leaf litter, more coarse woody debris, and more damaged trees. Our results indicate that eastern trade winds may influence spatial variation in productivity within tropical dry forests, depending on wind exposure.

*Key Words: deciduous, desiccation, trade winds, tropical forest structure*

## Introduction

Wind is a potentially physically damaging and desiccating mechanism that can stress trees and alter forest ecosystem processes. The lowland tropical dry forest of Guanacaste Province in northwestern Costa Rica experiences a pronounced dry season from November through April (Janzen 1986) that is characterized by high temperatures, low humidity, and strong eastern trade winds, ranging from 5 to 60 mph (Janzen 1983). Most trees on east-facing slopes of Guanacaste are deciduous during the dry season, while those on west-facing slopes retain much of their leaf cover (Janzen 1983). The deciduous forests of this area are unique, considering that other forests worldwide at the same elevation, latitude, and rainfall patterns are evergreen. Trees may lose their leaves in response to high wind speeds, either as a strategy to reduce water loss or as a result of physical removal. Strong winds may also break branches, blow away leaf litter, and stress trees, reducing tree growth.

We hypothesized that the aspect of a hill slope in relation to the east-west trade winds would influence the factors that contribute to overall forest condition. We first determined whether east-facing slopes experienced higher wind speeds. Then we tested the predictions that east-facing slopes would have more coarse woody debris and less accumulated leaf litter and that trees on the east-facing slope would be smaller, have more broken branches, and have less canopy cover than the same species on west-facing slopes.

## Methods

Palo Verde National Park, Guanacaste Province, Costa Rica, is dominated by deciduous forest amid isolated limestone hills. Our study was conducted on Mirador la Roca ridge, approximately 400 m southeast of the Palo Verde OTS field station. The ridge had predominantly east (45° east of magnetic north) and west (45° west of magnetic south) facing slopes. At approximately 11:00 on 13 January 2003, we measured wind speed with an anemometer held at arm's length at five points along both slopes between 120 and 130 m elevation. We kept our sampling altitude relatively constant by altimeter readings at each measurement point. We walked transects within this altitude range on both slopes and measured each canopy-level tree we encountered. On the eastern slope we encountered and measured five *Lysiloma divaricatum* (Fabaceae) and five *Astronium gravicolens* (Anacardiaceae). On the western slope we encountered and measured five *Lysiloma divaricatum*, two *Tabebuia ochracca* (Bignoniaceae), and one each of *Tabebuia*





*rosea* (Bignoniaceae) and *Simaruba glauca* (Simaroubaceae).

On each tree we measured canopy cover, height, and diameter at breast height (DBH). We measured canopy cover using a spherical densiometer at the downslope base of each tree to approximate the amount of total canopy occupied by leaves. We determined the height of each tree with a clinometer. Within a 2 m radius of each tree, we counted the amount of coarse woody debris in size classes 5 – 10 cm, 10 – 20 cm, and > 20 cm and estimated the percentage of ground covered by leaf litter. We generated an index of coarse woody debris around each tree by summing the products of the size class (5, 10, or 20 cm) and the number in each class. Lastly, we counted the number of broken tree branches in the entire canopy of each tree > 5 cm in diameter. We used all 10 trees on each side to compare litter accumulation and coarse woody debris. Data were analyzed with a one-way ANOVA.

## Results

As predicted, east-facing slopes experienced higher wind speeds ($F = 306.44$, $df = 4$, $P < 0.001$). Wind speed averaged 9.6 ± 0.32 mph (mean ± SE) and 1.7 ± 0.32 mph for east and west slopes, respectively. Eastern slopes had significantly less litter and more dead wood than western slopes (Table 1). One species (*Lysiloma divaricatum)* that occurred on both slopes had significantly less canopy cover and more broken branches on the eastern side (Table 1). Tree height and DBH of the trees were not statistically different, but were slightly higher on the western slope (Table 1).

## Discussion

Our results supported the hypothesis that wind influences forest condition. The eastern slope experienced significantly higher wind speeds than its neighboring western slope. Trees on the eastern side had less leaf litter and more woody debris than trees on the western side. The increase in coarse woody debris on the eastern slope indicated that trees lost more branches and/or that the fallen wood did not rapidly decompose there. The reduction in leaf litter may deplete the source of organic matter in the soil. However, an accumulation of dead wood may provide a habitat for small invertebrates and help to stabilize soil.

There was a marked difference in canopy cover between *Lysiloma divaricatum* on the eastern and western slopes. Individuals on the eastern slope had lost most of

TABLE 1. Attributes of trees (mean ± SE) on the east and west sides of Mirador la Roca ridge, Palo Verde National Park, Costa Rica. All measurements were taken at an altitude range of 120 – 130 m, as determined by an altimeter. Statistical analyses for P- values were done with a one-way ANOVA.

| Tree attribute | East | West | n / slope | F | P | |
|---|---|---|---|---|---|---|
| Litter cover (%) | 29.5 ± 6.10 | 71.5 ± 6.10 | 10 | 23.6 | 0.0001 | *** |
| Coarse woody debris | 65.0 ± 0.10 | 16.5 ± 0.10 | 10 | 11.7 | 0.0031 | ** |
| Canopy cover (%)+ | 3.5 ± 1.40 | 14.9 ± 1.40 | 5 | 31.7 | 0.0005 | *** |
| Breakage+ | 5.4 ± 0.88 | 2.0 ± 0.88 | 5 | 7.4 | 0.026 | * |
| Height (m)+ | 6.3 ± 0.47 | 6.9 ± 0.47 | 5 | 0.94 | 0.359 | ns |
| DBH (m)+ | 0.8 ± 0.16 | 1.0 ± 0.16 | 5 | 0.84 | 0.386 | ns |

+ = measurements taken only on *Lysiloma divaricatum*, present in high abundance on both slopes.
*** = $P < 0.001$
** = $P < 0.01$
* = $P < 0.05$
ns = not significant

their leaves, while those on the western slope still retained most of their canopy cover. High wind speeds increase air movement above the canopy, increasing evapotranspiration rates (Leigh 1999). As a result, it is possible that trees on windy slopes lose their leaves more readily or earlier in the dry season as a strategy to decrease water loss. Additionally, wind may physically remove leaves. A reduction in total leaf area may reduce tree productivity. For example, gross annual photosynthesis is higher in evergreen forests than deciduous forests (Leigh 1999). However, net production, while lower overall in dry forest (Leigh 1999), may not differ with leaf loss, because it is also influenced by the amount of forest respiration.

High winds may have additional consequences for ecosystem dynamics. We noted, but did not measure, an increase in temperature and humidity on the western slope. Desiccation on wind-exposed slopes lowers humidity and makes forests more susceptible to fire (E. Gonzalez, pers. comm.). Lowered humidity may also decrease soil decomposition rates (Begon et al. 1990). This may slow rates of nutrient cycling and in turn limit forest growth. As another gauge of forest growth, we observed a large number of vines, especially *Arrabidaea* spp. (Bignoniaceae) and understory plants on the western slope. These were conspicuously absent on the eastern slope. While our measurements of forest growth (height and DBH) did not show a significant difference between sides, a larger sample size might reveal a stronger trend towards smaller trees on east-facing slopes. We speculate that the water loss and physical stress of a high wind environment, such as an east-facing slope in Guanacaste, may limit forest growth in the long term.

## Literature Cited

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