Visual and quantitative characterization of ironwood tree (*Casuarina equisetifolia*) decline on Guam

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INTRODUCTION

Ironwood trees (*Casuarina equisetifolia*), locally known as "gago", have been in the midst of a decline on Guam for nearly a decade. The chronology of decline began in 2002 with the realization that the health of the trees was deteriorating for no apparent reason. In 2008, with funding secured from WSARE, a concerted effort was made to find the cause or causes of ironwood tree decline (IWTD). Decline is now believed to be from multiple stress factors, both biotic and abiotic. Based on the high prevalence of conks on declined trees and their examination by Dr. C. M. Aime of Louisiana State University, *Phellinus* and *Ganoderma* are emerging as likely biotic factors. The most prevalent *Ganoderma* being within the species complex of *G. australe*. The major typhoons (Chataan and Pongsona) and the intervening drought in 2002 are considered likely abiotic factors since they coincide with the first reports of IWTD.

Loss of vigor, thinning of branches (starting in the tree crown) and complete dieback (death) of the tree comprised the progression of symptoms observed. In the past few years the rate and amount of IWTD appears to be increasing as many trees had to be removed from various sites across the island. Due to the fact that detection of IWTD is nearly impossible at onset, attempts were made to devise both destructive as well as more sensitive visual methods to characterize IWTD.

METHODS

Visual monitoring: non-destructive

- Photographs of 44 solitary trees were visually catalogued into a five-scale decline severity (**DS**) rating (**Fig. 1**).
- Based on site visits, these trees were visually evaluated for percent decline (**PD**) (**Fig. 1**).
- Based on the examination of the tree photographs, percent bare branches (**PBB**) was determined (**Fig. 1**).

Quantitative: destructive samplng

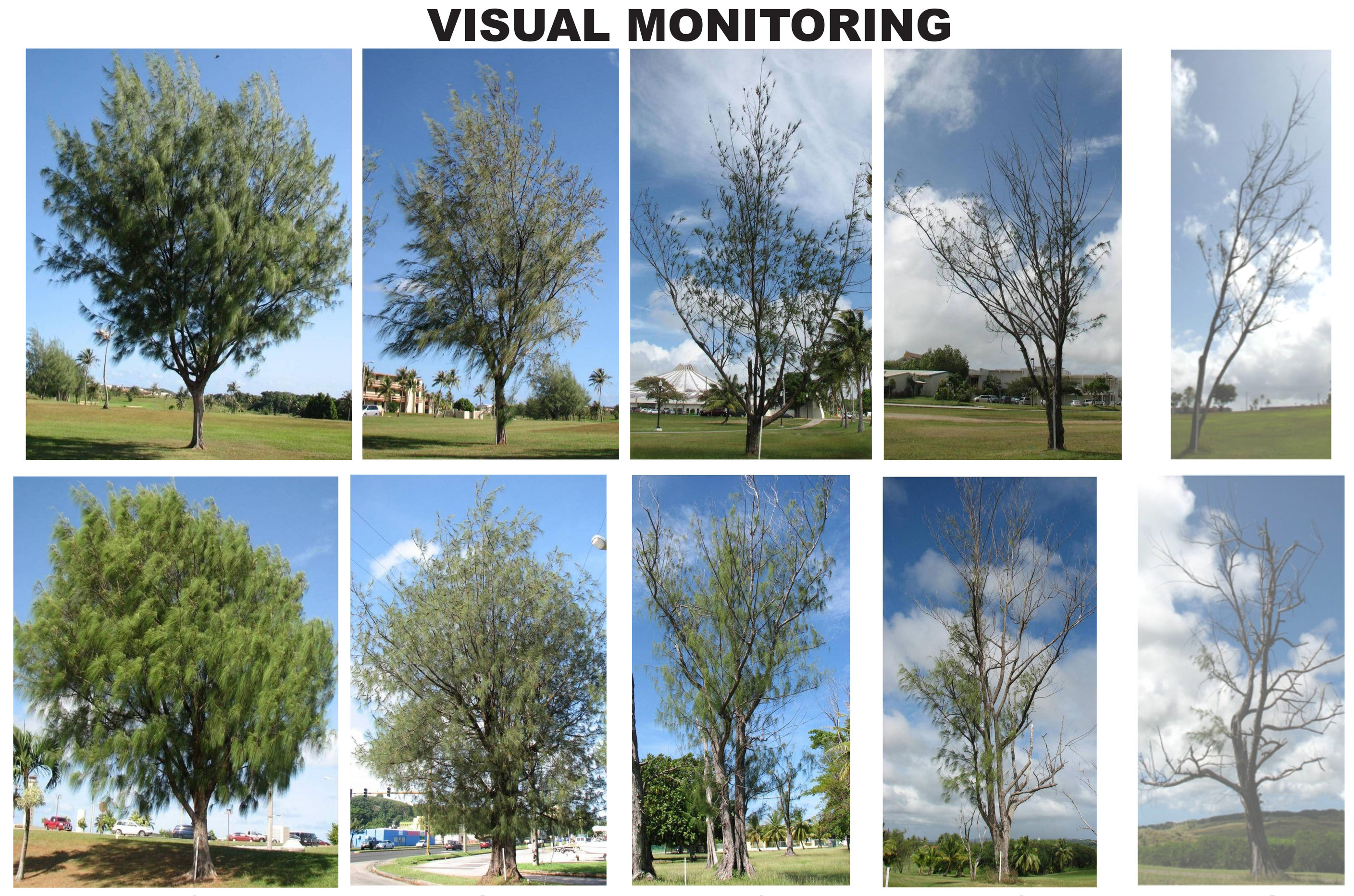
- Measurements of branchlet weight of trees under different states of decline were determined (**Fig. 2**).
- Cross-sections of the longest tree branch easily accessible from ground level were taken at the trunk juncture (**Fig. 5**) and 2 m from the juncture, for evidence of discoloration or wood rot.
- Cross-sections of trunks were examined for evidence of discoloration or wood rot (**Fig. 6**).

IWTD island-wide survey

- A total of 1,427 trees at 44 sites were surveyed for decline from July to December 2009 and compared to survey results from October 2008 to June 2009 (**Fig. 3**).
- Correlation of conk prevalence to DS was determined using 1,398 sampled trees at 38 sites (**Fig. 4**).

RESULTS

VISUAL MONITORING



DS	0	1	2	3	4
PD	0	10.5	49.9	72.8	97.8
PBB	0	16.3	47.3	69.4	93.8

Fig. 1. Representative tree photographs depicting a five-scale decline severity (**DS**) ranking, percent decline (**PD**), and percent bare branches (**PBB**) from forty-two small (top) and large (bottom) solitary trees from across Guam.

BRANCHLET ("NEEDLE") WEIGHT

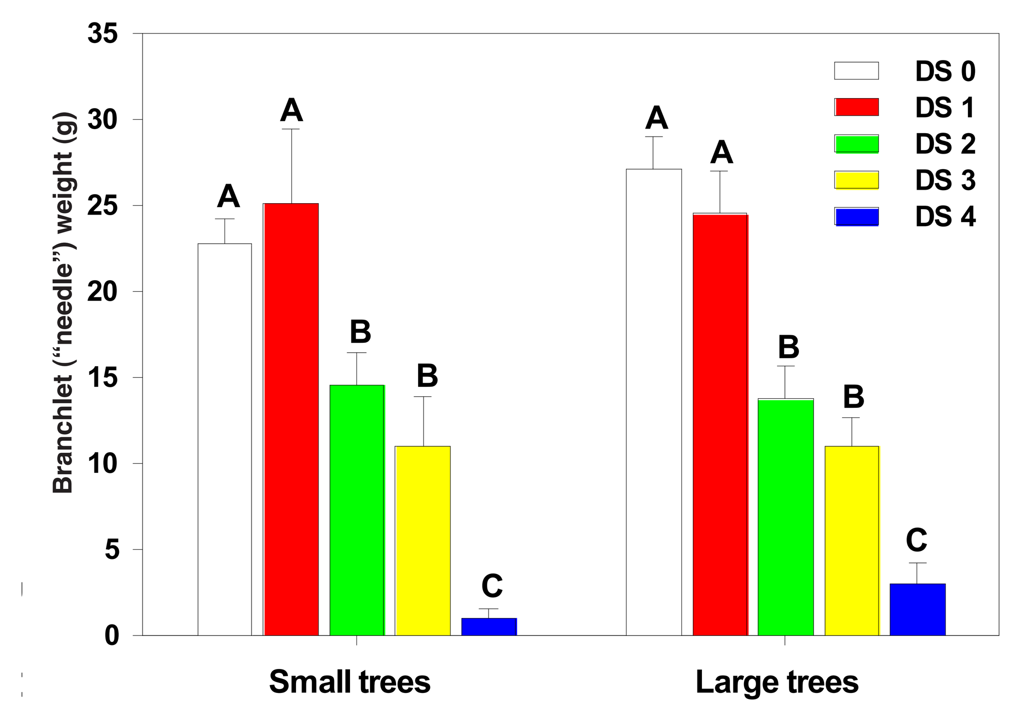


Fig. 2. Average weight of branchlets from 30-cm terminal branch sections from small and large ironwood trees with decline ranging from 0 (healthy) to 4 (nearly dead).

ISLAND-WIDE SURVEY

Table 1. Means for decline severity (DS) and conk prevalence for explanatory variables latitude, stand, and levels of management with ± 95% confidence limits $\bar{x} + (S_E \cdot 1.96)$.

Explanatory variables	DS	Conk prevalence
Latitude		
Northern	0.80 ± 0.31	0.08 ± 0.03
Central	1.95 ± 0.41	0.35 ± 0.13
Southern	0.83 ± 0.36	0.06 ± 0.03
Stand		
Natural	0.08 ± 0.05	0.01 ± 0.00
Planted	1.60 ± 0.26	0.19 ± 0.05
Management		
Slight (0)	0.16 ± 0.11	0.00 ± 0.00
Moderate (1)	1.44 ± 0.51	0.22 ± 0.13
High (2)	2.15 ± 0.30	0.21 ± 0.05

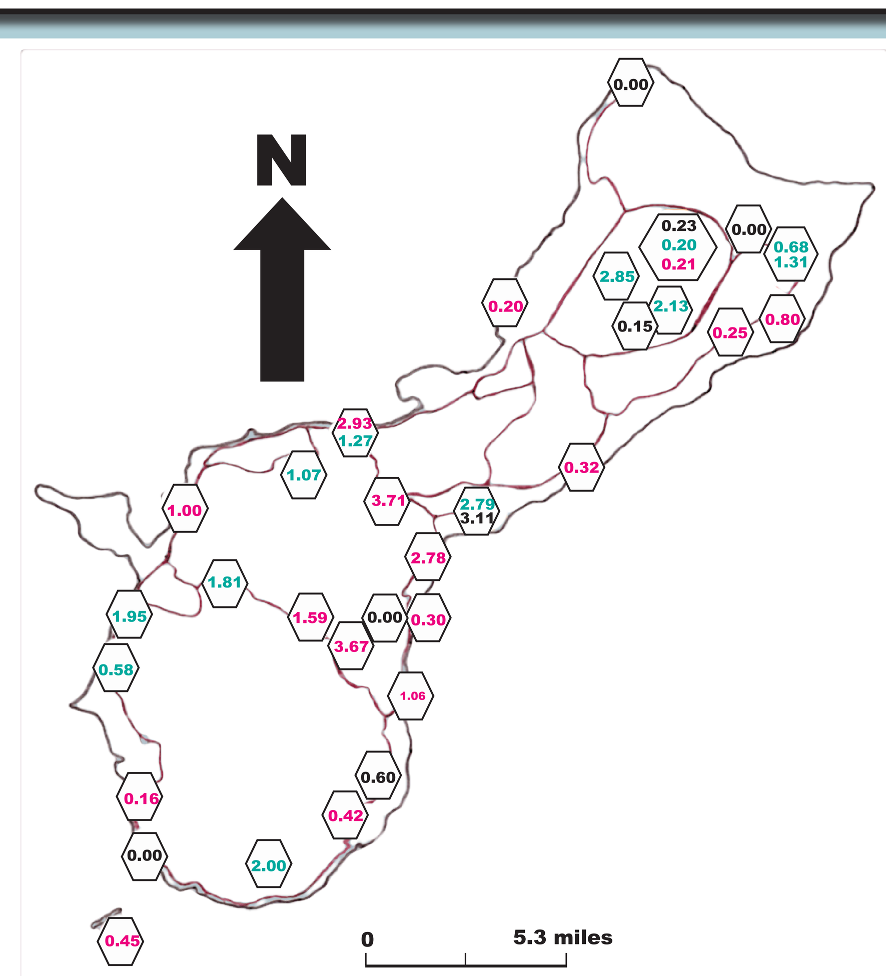


Fig. 3. Means of decline severity (DS) found at sites during Survey II (July to December 2009) either remained nearly the same (**black**), increased (**red**), or decreased (green) in comparison to Survey I (October 2008 to June 2009).

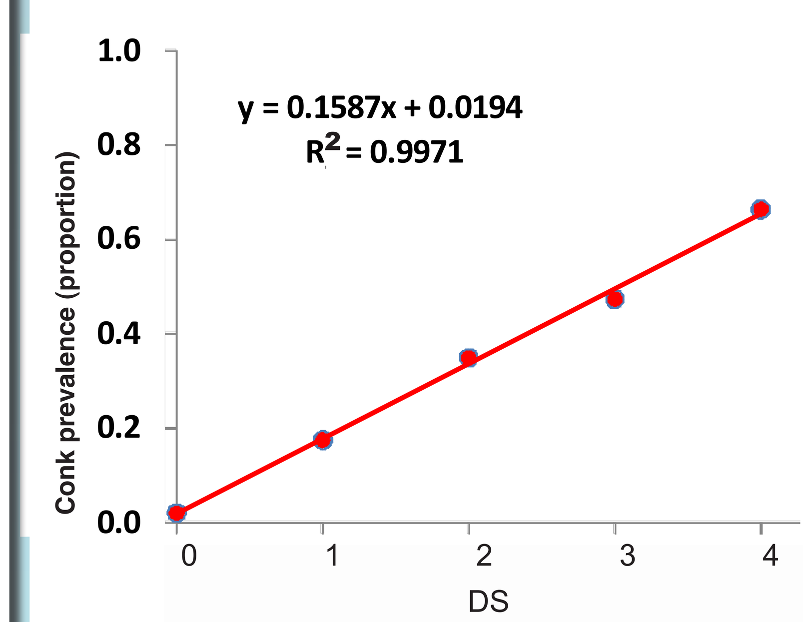


Fig. 4. Linear regression of the proportion of conks present on trees under different levels of decline severity (DS).

DISCOLORATION: DESTRUCTIVE SAMPLING AND QUANTIFICATION

Fig. 5. Branch cross-section samples from the juncture of the main trunk from declined (left) and healthy (right) trees.

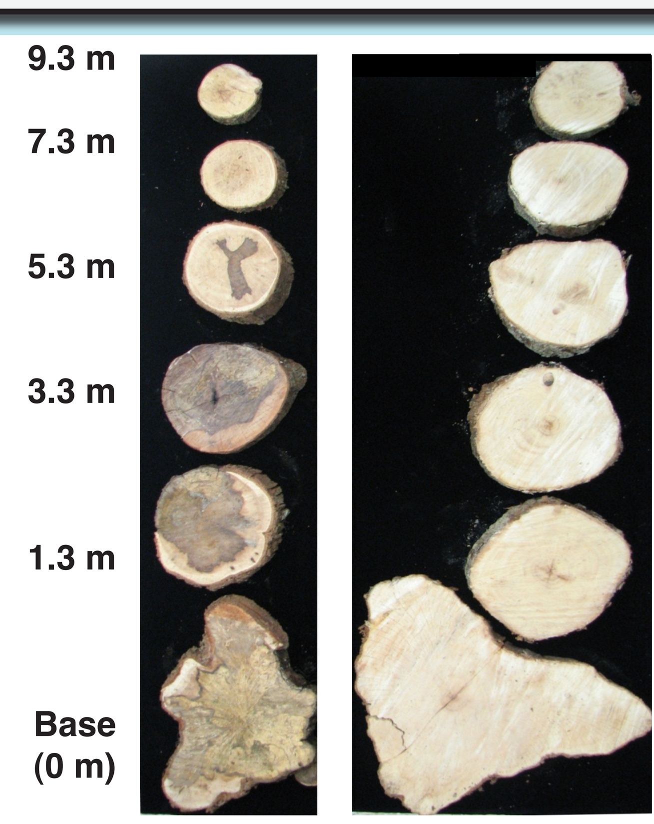


Fig. 6. Trunk cross-sections from a declined (left) and healthy (right) tree.

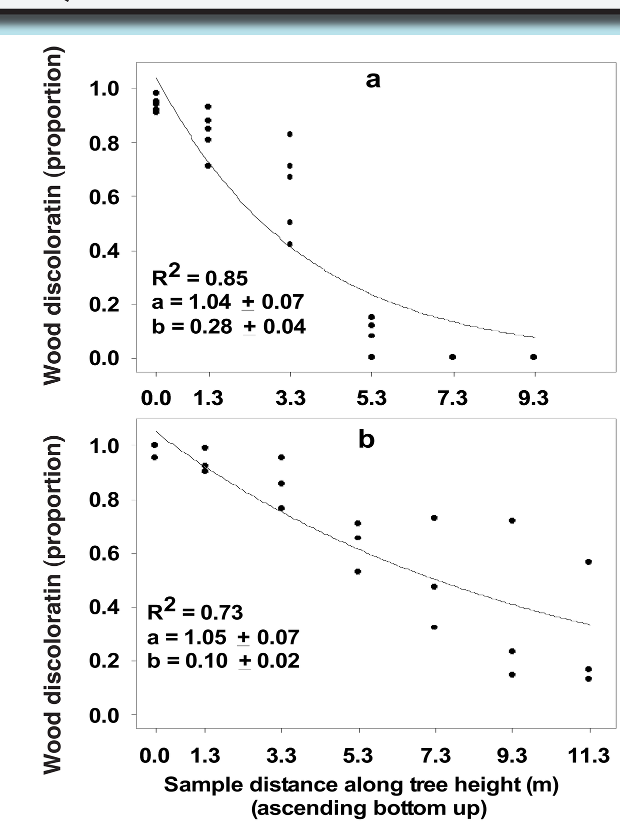


Fig. 7. Non-linear regression analyses of the proportion of wood discoloration in trunk cross-sections fitted to exponential decay function $y(x) = a * exp(b * x)$ for small (a) and large (b) trees.

DISCUSSION

The visual five-scale decline severity (DS) ranking (**Fig. 1**) was helpful in monitoring the spatial and temporal dynamics of IWTD on Guam and could potentially be useful for the neighboring islands. Where possible, visual scales should be developed for ecological and seasonal variations.

The differences between the weight of branchlets ("needles") were not significantly different between DS 0 and 1 or DS 2 and 3 (**Fig. 2**). However, DS 4 trees were the worst with 95.3% fewer branchlets when compared to DS 0 trees.

The presence of discoloration at the branch juncture of declined trees was consistent for all levels of decline (**Fig. 5**).

There was a clear, consistent gradient of discoloration within the trunk of declining trees. In small healthy trees, the cuts were clean and not discolored (**Fig. 6**).

Exponential decay function explained the trend of an acropetal wood discoloration gradient within the tree trunk of small and large trees (**Fig. 7**).

The difference among means for decline severity for explanatory variables (latitude, stand, and management) closely parallel means for conk prevalence (**Table 1**).

IWTD from survey II had remained largely the same at 9 sites, had increased at 17 sites and had decreased at 12 sites (**Fig. 3**). Alarmingly, IWTD is now appearing at previously healthy locations such as Cocos Island.

Conk prevalence was very highly correlated with progressive increments of DS reaching nearly 70% of DS 4 level trees (**Fig. 4**).

CONCLUSIONS

Though visual assessment of a tree's canopy and branchlet biomass are good indicators of decline, they fail to separate the various physiological and environmental factors that may also be responsible for poor growth; whereas, the detection of internal wood discoloration in the trunk and to a lesser extent in the branches does provide such insight. When discoloration does not conform to those of heartwood and other natural causes, then it becomes a good indicator of decline.

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