

Frost-induced changes in aboveground biomass stocks in the northmost Neotropical dry forest

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Abstract

Climate-induced episodes of extensive tree mortality worldwide are leading to abrupt changes in forest carbon stocks. A severe frost in early February 2011 triggered widespread tree mortality in the lowland tropical dry forest (TDF) of northwestern Mexico. The studied landscape in southern Sonora is composed by a patchy matrix dominated by mature, secondary (originated in abandoned fields), and active agricultural fields. In this forest, we used allometric equations to assessed frost-induced changes in aboveground biomass (AGB) stocks in mature and secondary tropical dry forests. For AGB estimations we used 48 1-ha plots (24 plots per forest type) distributed within four distant subareas in our 83 230 ha study area. On each plot, we recorded all live/dead individuals, and a total of 11 205 woody plants were registered, of which 7 137 (with at least a stem DBH > 2.5 cm) were likely present before the frost, and the remaining smaller ones were considered as new recruits regenerated from seeds (4,068 individuals). From those plants present before the frost, 26 842 and 8 059 were live and dead stems, and 1 222 were dead individuals. All registered live and dead stems accounted for a total of 273.4 Mg of AGB in our study plots (4.8 ha). From this amount, 57.3 Mg was necromass (dead stems). Interestingly, only two out of a total of 74 registered species contributed with ca. 80% of this necromass. These highly sensitive species are the tree legumes *Lysioma divaricatum* and *Acacia cochliacantha*. On average, AGB in the studied mature and secondary TDF was 64.3 and 49.6 Mg ha⁻¹, respectively. The corresponding necromass for these forests was 10.9 and 13 Mg ha, respectively. The 2011 frost induced a greater change from live biomass to necromass in secondary than mature forests, 26.2% and 16.9%, respectively, which can be explained by the higher abundance of individuals from sensitive species in secondary forests. Our results suggest that climate-induced shifts in carbon stocks are linked to previous land-use changes in tropical dry forests. Restoration plans of these degraded lands should consider the vulnerability of tropical dry forest species to climate extremes.



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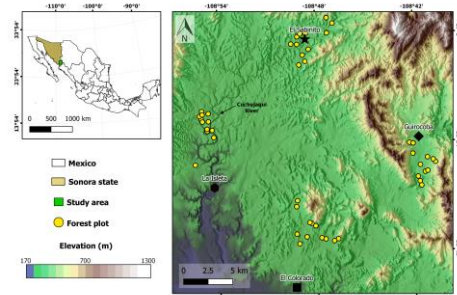


Introduction

- Extreme climatic events are inducing episodes of tree mortality worldwide^{1,2}, causing changes in the aboveground biomass stocks in natural ecosystems⁵.
- An extreme frost affected most of North America in early February 2011 triggering extensive tree mortality in the lowland tropical dry forest of northwestern Mexico.
- This event was likely the most severe since 1949 in the region, where freezing temperatures lasted for nine consecutive days, but there are no reports about widespread tree mortality.
- Extensive tree mortality was observed across the landscape after the 2011 frost reaching up to ca. 90% (secondary) and 50% (mature) forests stands⁶. Tree mortality was highly heterogeneous across the landscape.
- Allometric equations (local and foreign) were used to estimate changes in live and dead aboveground biomass in the TDF lowland after the extreme frost.

Methodology

Study area



Study area (29 × 29 km) in the Alamos municipality, southern Sonora, Mexico.

Landscape is a matrix of mature and secondary tropical dry forests, annual crops and pastures⁶.

Dots represent the 48 mature and secondary forest (24 per forest type) surveyed sites with different degrees of frost-induced vegetation damage. Map was generated with QGIS 3.16.5.

Vegetation sampling

In 48 200 × 50 study sites (10 50 × 2 m Gentry transects per site)

Field surveys:

- Diameter at breast height (D) of all individuals and stems ≥ 1 cm
- Total tree height (H)
- Condition of individuals and stems:
 - Live or dead

For each site, we obtained elevation (EI) from a Digital Elevation Model (15 × 15 m resolution)

Aboveground biomass (AGB in kg/m²) estimation in the 48 forest study sites

Allometric equations used for AGB (kg) estimations in the tropical dry forest in the northwestern of México. WSD = average wood specific density.

Equation	Reference
1 $AGB = 0.673 \times (WSD \cdot D^2 \cdot H)^{0.976}$	Chave et al. 2014
2 $AGB = 0.3700 \times (D)^{1.9600}$	Návar et al. 2009
3 $AGB = 0.187634 \times (D \cdot H)^{1.213918}$	Bojórquez et al. 2020

Application of allometric models in the forest stands:

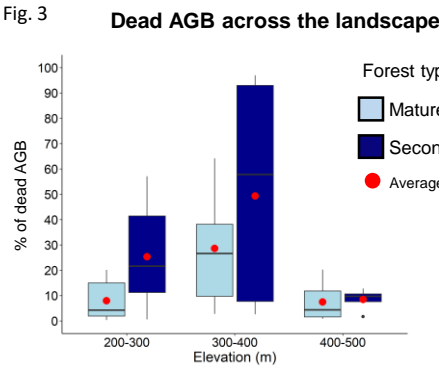
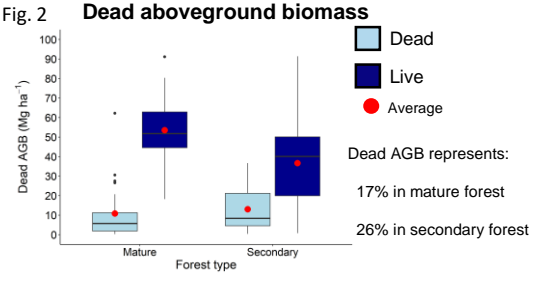
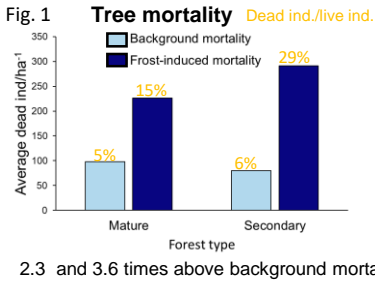
DAP	Forest type	Predictor variables	Equation
≥ 5.2 cm	Mature and secondary	DAP, WSD, H	1
≥ 5.2 cm	Mature	DAP	2
1 and < 5.2 cm	Mature and secondary	DAP, H	3

Average WSD per specie was obtained from regional¹⁰ and global data bases¹¹.

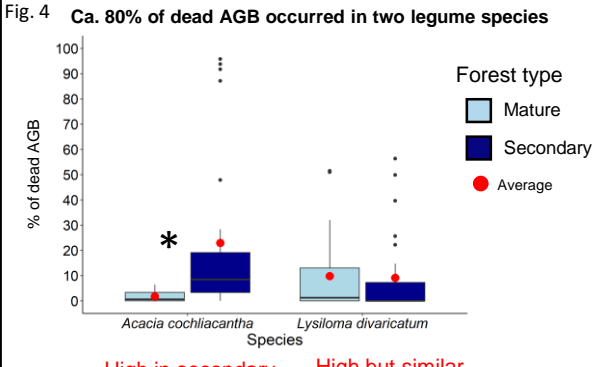
Results

Density of individuals and aboveground biomass estimated in the tropical dry forest of Álamos, Sonora, México. Average in the 48 sites.

	Individuals per ha	Mg ha ⁻¹
Dead	285	12
Live	1418	45.1



High dead AGB in lower and middle elevations (300-400 m a.s.l.) but higher in secondary forests



High in secondary forest stands

High but similar between forests

Conclusions

- ❖ The extreme February 2011 frost induced extensive tree mortality and caused abrupt changes from live to dead AGB stocks in the northmost Neotropical dry forest.
- ❖ Magnitude of TDF dead AGB varied across the landscape, affecting severely two of the most abundant legume species in mature and secondary forests.
- ❖ High frost-induced tree mortality may have consequences in the successional pathway regeneration process.
- ❖ Our results demonstrate the high vulnerability of the tropical dry forest to extreme frost events, and the importance of accurate AGB estimations to understand its effects on the regional and global carbon cycle under future extreme climatic events.

Literature cited

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