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

Jesus Bojorquez[1,1,1], Angelina Martinez-Yrizar[2,2,2], Juan Alvarez-Yepiz[3], and Juan Alvarez-Yepiz[3,3]

[1]Universidad Nacional Autonoma de Mexico
[2]Universidad Nacional Autónoma de México
[3]Instituto Tecnológico de Sonora

November 30, 2022

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.

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

***Adrián Bojórquez[1-2], Angelina Martínez-Yrízar[1] and Juan C. Álvarez-Yépiz[2]**

[1]Laboratorio de Ecología de Zonas Áridas y Semiáridas, Instituto de Ecología, UNAM, Unidad Hermosillo. [2]Laboratorio de Ecología Integrativa, Instituto Tecnológico de Sonora, Cd. Obregón, Sonora

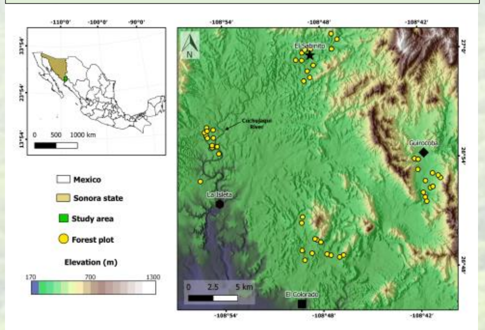
**Corresponding author: jabojorquezv@gmail.com*

Introduction

- Extreme climatic events are inducing episodes of tree mortality worldwide[1,2], causing changes in the aboveground biomass stocks in natural ecosystems[5].
- 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 stands[6]. 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 pastures[6].

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.

Forest without damage

Forest with damage

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

Application of allometric models in the forest stands:

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

Average WSD per species was obtained from regional[10] and global data bases[11].

Results

Density of individuals and aboveground biomass (AGB) estimated in the tropical dry forest of Álamos, Sonora, México. n = 48 sites.

	Individuals per ha	AGB (Mg ha^{-1})
Dead	258	12
Live	1418	45.1

Fig. 1 Tree mortality

2.3 and 3.6 times higher than background mortality

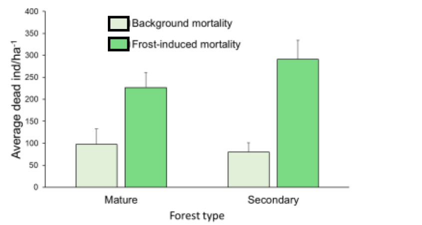
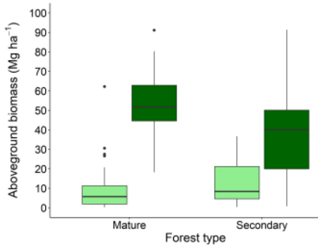


Fig. 2 Post-frost aboveground biomass



Dead AGB
- Was similar between forest types
- Represent 17 (mature) and 33% (secondary) of the total AGB

n = 24 sites per forest type

Fig. 3 Dead aboveground biomass: high variability across the landscape, but higher % in secondary forests stands

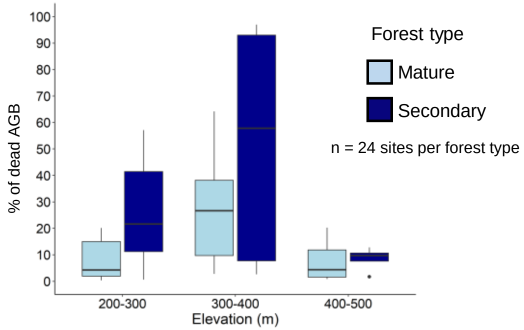
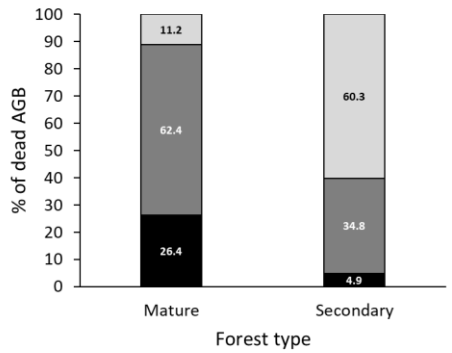


Fig. 4 Two legume species were the most severely affected



Both species contribute with

73 and 95% in mature and secondary forests of the total dead AGB

Conclusions

- The extreme February 2011 frost caused abrupt changes from live to dead AGB stocks in the northmost Neotropical dry forest.
- Magnitude of TDF dead AGB varied across the landscape, severely affecting two of the most abundant legume species in mature and secondary forests.
- High frost–induced tree mortality may have consequences in the TDF community composition and the successional pathway of the 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

1.-IPCC, 2014. Climate Change 2014: Synthesis Report. **2**.-Allen, C.D., et al., 2015. Ecosphere 6, art129. **3**.-Allen, C.D., et al., 2010. For. Ecol. Manage. 259, 660–684. **4**.-Greenwood, et al., 2017. Ecol. Lett. 20, 539–553. **5**. Frank et al. 2015. Glob Change Biol. 2861-2888. **6**.-Bojórquez et al. 2019. Glob Change Biol. 25:3817–3828. **7**.- Álvarez-Yépiz et al., 2008. For. Ecol. Manage. 256, 355-366. **8**.- Chave et al. 2014. Glob Change Biol. 3177-3190; **9**.- Návar 2009. For. Ecol. Manage. 427-434. **10**.- Bojórquez et al. 2020. For. Ecol. Manage.; **11**.- Zanne et al. 2009. Dryad, Data set.

Acknowledgements: To PAPIIT DGAPA/UNAM (IN207315), CB-CONACYT (#36971) and PROFAPI-ITSON (#2021-0082) grants and CONACYT PhD. Scholarship (#270082) to Jesús Adrián Bojórquez Valdez. Thanks to all field