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Contrasting Net Ecosystem Production Across Ecological Succession at Subtropical Dry Forest of Northwestern Mexico

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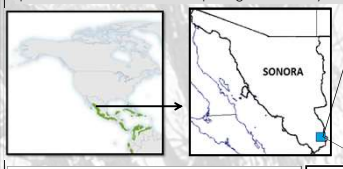
ABSTRACT

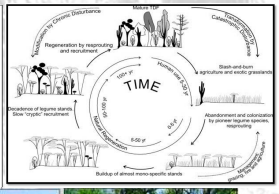
Forests are under major pressures due to contemporary land-use, which creates mosaics of stand-stage development that follow different successional paths, that imply ecosystem complexity. The interplay of carbon and water dynamics across succession involves physical and biological interactions that shape net ecosystem production (NEP) and water use efficiency. Here we present 13 years-site of eddy covariance data (2016-2020) from a seasonally dry tropical forest in Northwestern Mexico to elucidate the environmental controls on ecosystem fluxes and explore the interactions with changes in resource availability. Across a successional gradient, an early (9 years since abandonment) and a mid-successional (about 45 years with natural recruitment and regrowth) sites were net carbon sinks (in the order of 100 to 500 g C m^{-2} y^{-1}) while an old- growth forest was a chronic net source over the 5 years studied (losing between 100 and 300 g C m^{-2} y^{-1}). In contrast evapotranspiration was alike at sites and close to the precipitation input. Ecosystem water use efficiency tended to be higher at the old-growth forest site (ca. 3.0 g C m^{-2} /mm H_2O vs. ca. 2.0 g C m^{-2} / mm H_2O at the secondary sites). Water availability and radiation where clearly dominant environmental controls across sites. Surface characteristics, canopy structure and species composition may explain differences in NEP across succession in TDF at its northernmost extent.

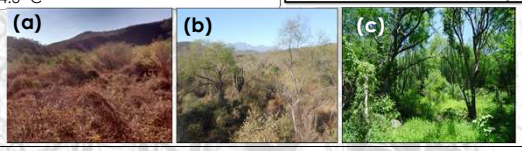
Our goal is to investigate the patterns of NEP, GEP, Reco and ET during succession in TDF and explored what biological and environmental drivers control ecosystem fluxes across succession, to ultimately understand how ecosystem function behaves after disturbance

The study site is within the natural protected area "Reserva monte mojino", within the protected area "Area natural protegida de flora y fauna sierra de Alamos-Río Cuchujaqui"

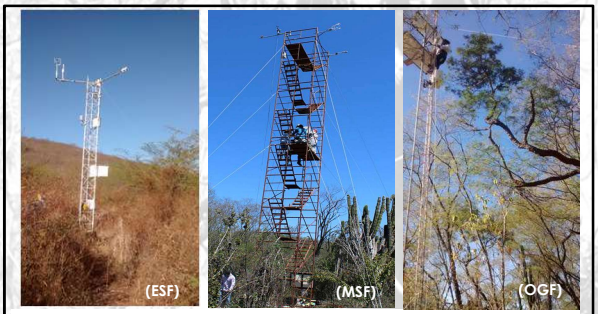


The successional gradient of TDF consist in: (a) An early-succession site (ESF) 11-year abandonment, (b) A secondary forest (MSF) ~ 40 to 45 years of recovery and (c) an old-growth forest (OGF). All sites are within in a range of 2 km among each other. The mean annual precipitation is 710 mm and the mean annual temperature 24.3 °C





Flux measurements across succession



Ecosystem flux measurements at all sites were performed using Eddy covariance (EC) technique and complete meteorological arrangements. The high frequency (10Hz) water vapor and CO_2 concentrations and air temperature measurements were used with the turbulent wind velocities to obtain latent heat flux (LE) or evapotranspiration (ET), sensible heat (H) and net ecosystem exchange (NEE) generally equal to net ecosystem production (-NEP).

$$NEP = GEP - R_{eco}$$

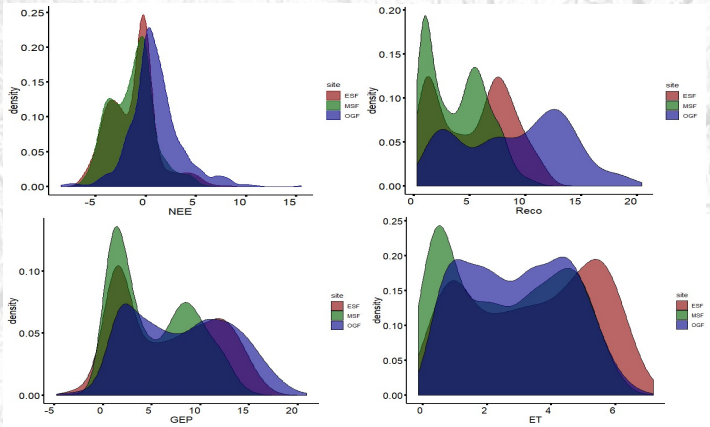
- The flux measurements were corrected for density fluctuations (Webb et al. 1980)
- The Data below a threshold of a critical friction velocity were removed (Papale et al. 2006) The μ* filtering (Table 2), data gaps filled, an flux partitioning were performed using the online tool Reddyproc (http://www.bgc-jena.mpg.de/REddyProc/brew/REddyProc.rhtml)

Site and flux characteristics

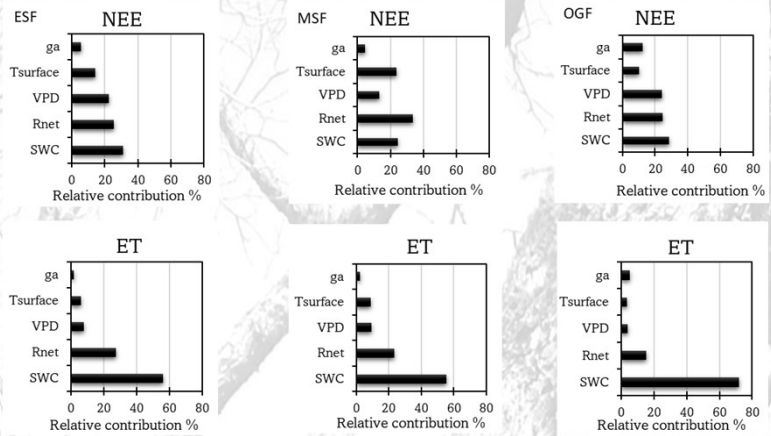
Site Atributes	OGF	MSF	ESF
Canopy height (m)	15	12	5
Above ground biomass (Mg/ha)	33.0 ± 10	18.5 ± 6	18.0 ± 10
Albedo	0.13	0.10	0.20

Data Atributes	OGF	MSF	ESF
Footprint (m)	73	137	120
E.Clous. (r^2)	0.77	0.65	0.77
Fricc. Vel. μ* (m/s)	0.15	0.11	0.059

RESULTS



Probability density curves (PDF) of daily sums of Carbon and water fluxes showed a bimodal behavior across sites, but a marked difference occurs at the OG site, where NEE and Reco depart from the general trend. Despite the slight differences in the density of GEP across the successional gradient, the peaks are similar. The contrast between GEP and Reco points at the significance of Reco to define the C source or sink strength of TDF across succession.



Results from a bootstrap regression tree analysis to asses the relative contribution of environmental variables on ecosystems fluxes. The factors with the higher relative contribution for flux predictability are Surface Temperature (Tsurface), Vapor presure deficit (VPD), Soil Volumetric Water Content (SWC), Net Radiation (Rnet), and aerodynamic conductance (ga). The variables with more influence changed according to the successional stage. For instance, at the ESF and OGF sites SWC and Rnet where the most influential, but for the MSF site Rnet and surface temperature where influential. For ET, Important transitions between Rnet and VWC where noticed.

Cumulative amounts of carbon and water fluxes and annual precipitation

	OGF		MSF		ESF		
YEAR	NEE (g C m^{-2} yr^{-1})	ET (mm yr^{-1})	NEE (g C m^{-2} yr^{-1})	ET (mm yr^{-1})	NEE (g C m^{-2} yr^{-1})	ET (mm yr^{-1})	PPT (mm yr^{-1})
2016	181	752	-428	614	-149	742	725
2017	295	675	-566	548	-195	682	580
2018	208	790	-468	654	-308	816	860
2019	193	638	-267	532	--	--	614
2020	233	669	-197	551	--	--	452

CONCLUSION AND FURTHER HYPOTHESIS

The OGF consistently lost more carbon than gained at a five year-long period following a strong el Niño event and a prior extreme frost, while the secondary forests remained as net C sinks during this same5-year period. In 2011 there was a remarkable frost affecting the TDF at the study site (Bojorquez et al., 2019) and further drought effects in 2015 from El Niño. Therefore, we hypothesize that net C sources to the atmosphere observed during the reported five years at the OGF site, in contrast to the sites in secondary succession, respond to the decomposition of accumulated organic matter from stress and plant mortality following extreme climate events in the region.

AKNOWLEGEMENTS

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