Exploring the Interactions between Land Use, Climate Change and Carbon Cycle using Satellite Measurements

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November 22, 2022

Abstract

Most climate change impacts are linked to terrestrial vegetation productivity, carbon stocks and land use change. Changes in land use and climate drive the dynamics of terrestrial carbon cycle. These carbon cycle dynamics operate at different spatial and temporal scales. Quantification of the spatial and temporal variability of carbon flux has been challenging because land-atmosphere-carbon exchange is influenced by many factors, including but not limited to, land use change and climate change and variability. The study of terrestrial carbon cycle, mainly gross primary product (GPP), net ecosystem exchange (NEE), soil organic carbon (SOC) and ecosystem respiration (Re) and their interactions with land use and climate change, are critical to understanding the terrestrial ecosystem. The main objective of this study was to examine the interactions among land use, climate change and terrestrial carbon cycling in the state of Texas using satellite measurements. We studied GPP, NEE, Re and SOC distributions for five selected major land covers and all ten climate zones in Texas using Soil Moisture Active Passive (SMAP) carbon products. SMAP Carbon products (Res=9 km) were compared with observed CO2 flux data measured at EC flux site on Prairie View A&M University Research Farm. Results showed the same land cover in different climate zones has significantly different carbon sequestration potentials. For example, cropland of the humid climate zone has higher (-228 g C/m2) carbon sequestration potentials than the semiarid climate zone (-36 g C/m2). Also, shrub land in the humid zone and in the semiarid zone showed high (-120 g C/m2) and low (-36 g C/m2) potentials of carbon sequestration, respectively, in the state. Overall, the analyses indicate CO2 storage and exchange respond differently to various land covers, and environments due to differences in water availability, root distribution and soil properties.

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Most climate change impacts are linked to terrestrial vegetation productivity, carbon stocks and land use change. Changes in land use and climate drive the dynamics of terrestrial carbon cycle. These carbon cycle dynamics operate at different spatial and temporal scales. Quantification of the spatial and temporal variability of carbon flux has been challenging because land-atmosphere-carbon exchange is influenced by many factors, including but not limited to, land use change and climate change and variability. The study of terrestrial carbon cycle, mainly gross primary product (GPP), net ecosystem exchange (NEE), soil organic carbon (SOC) and ecosystem respiration (Re) and their interactions with land use and climate change, are critical to understanding the terrestrial ecosystem. The main objective of this study was to examine the interactions among land use, climate change and terrestrial carbon cycling in the state of Texas using satellite measurements. We studied GPP, NEE, Re and SOC distributions for five selected major land covers and all ten climate zones in Texas using Soil Moisture Active Passive (SMAP) carbon products. SMAP Carbon products (Res=9 km) were compared with observed CO_2 flux data measured at EC flux site on Prairie View A&M University Research Farm. Results showed the same land cover in different climate zones has significantly different carbon sequestration potentials. For example, cropland of the humid climate zone has higher (-228 g C/m^2) carbon sequestration potentials than the semiarid climate zone (-36 g C/m^2). Also, shrub land in the humid zone and in the semiarid zone showed high (-120 g C/m^2) and low (-36 g C/m^2) potentials of carbon sequestration, respectively, in the state. Overall, the analyses indicate CO_2 storage and exchange respond differently to various land covers, and environments due to differences in water availability, root distribution and soil properties.

Objectives

- Quantify the spatial patterns and temporal distributions of terrestrial carbon cycle in Texas using SMAP level 4 carbon products
- Examine the interactions among land-use, climate change and terrestrial carbon cycle in Texas

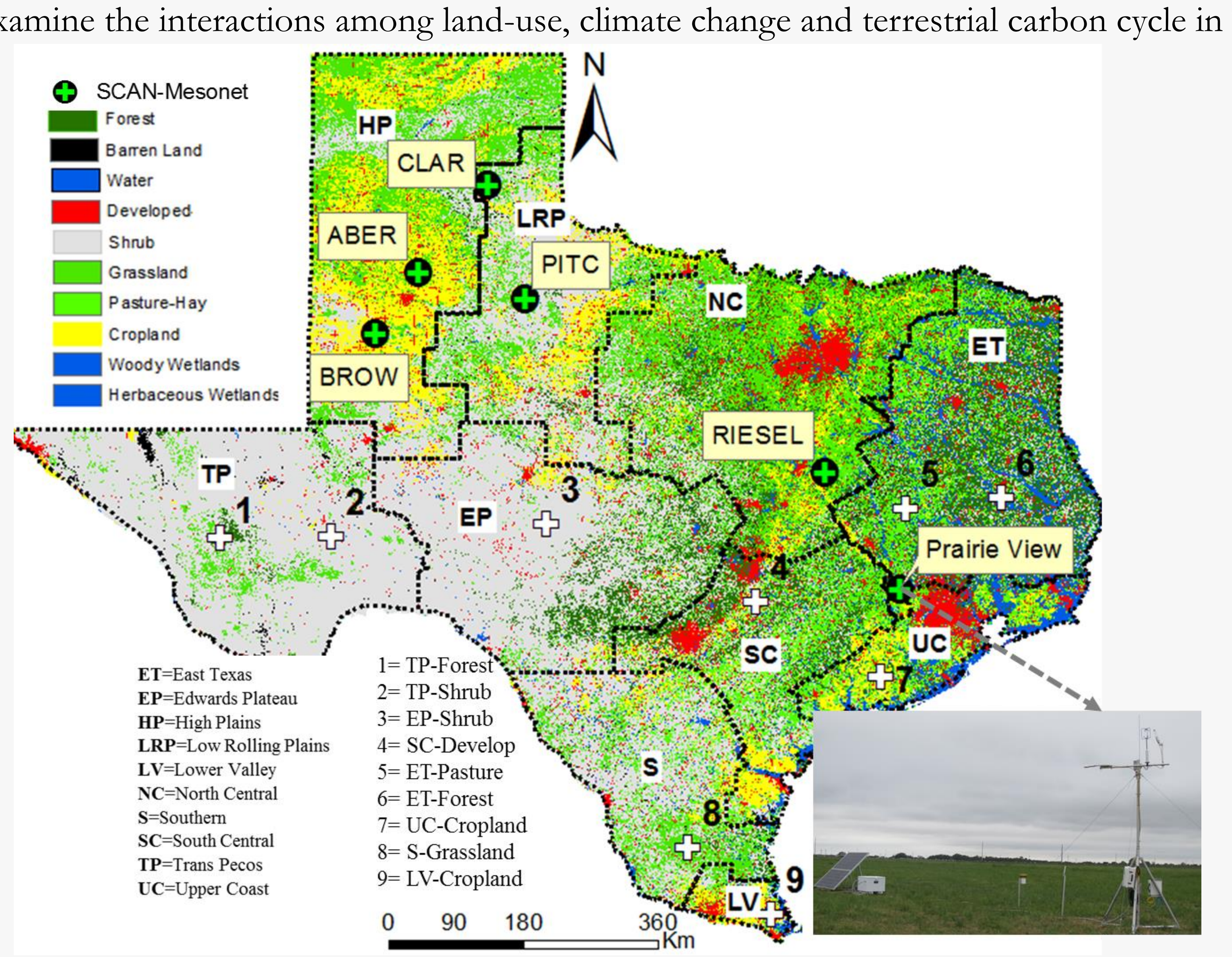

Fig. 1: Study Area

Methods

This study used SMAP level-4 (provides daily estimates of NEE) products to determine the spatial pattern and temporal changes on GPP, NEE, SOC and heterotrophic respiration (RH) for different climate zones and impacts of land covers on them. The key ecosystem types in the conterminous US including: Forest, shrub land, developed, pasture, cropland and grassland for 13 different stations were selected for study (**Fig. 1 and Table 1**). Analysis was conducted at five Soil Climate Analysis Network stations, one flux tower and seven selected pixel at different climate zones of the study area. Eddy Covariance (EC) flux tower's NEE data were used to validate SMAP NEE data. Since, SMAP data was available from Mar 31, 2015, this study analyzed satellite data from Apr 2015 to present. Spatial maps of GPP, RH, and NEE were developed for selected dry and wet days (before and after Hurricane Harvey). Time series graphs were developed to compare GPP, RH, NEE and SOC for different land covers to observe their seasonal distributions from April 2015 through Nov 2017.

Results and Discussion

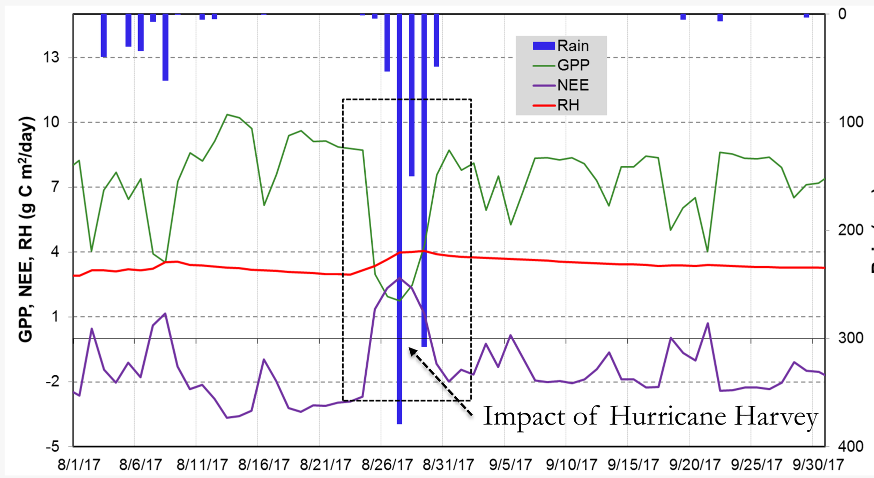

Fig. 2: Comparing in-situ rain with SMAP's GPP, NEE and RH during the Hurricane Harvey in Houston, Texas (Aug. 1 to Sep. 30, 2017). The NEE increased significantly on 27th of August.

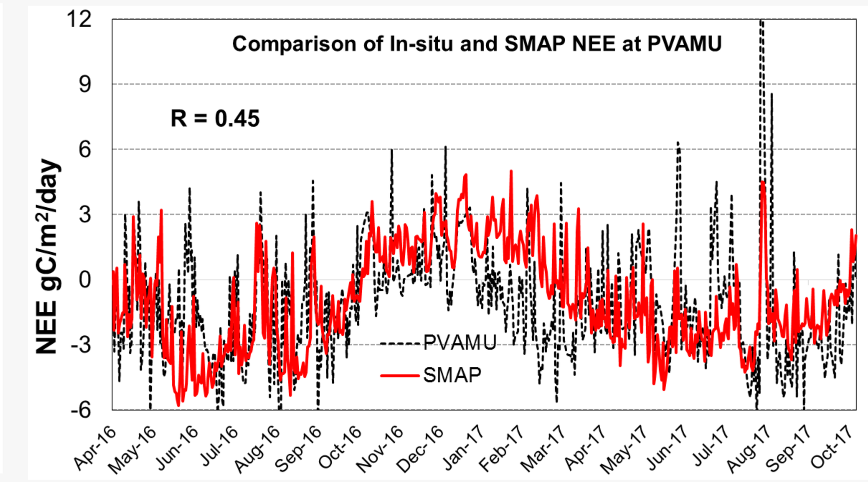

Fig. 3: Comparing in-situ and SMAP NEE measurements on PVAMU Flux Tower site at Prairie View Texas. There is good agreement between satellite and in situ NEE measurements.

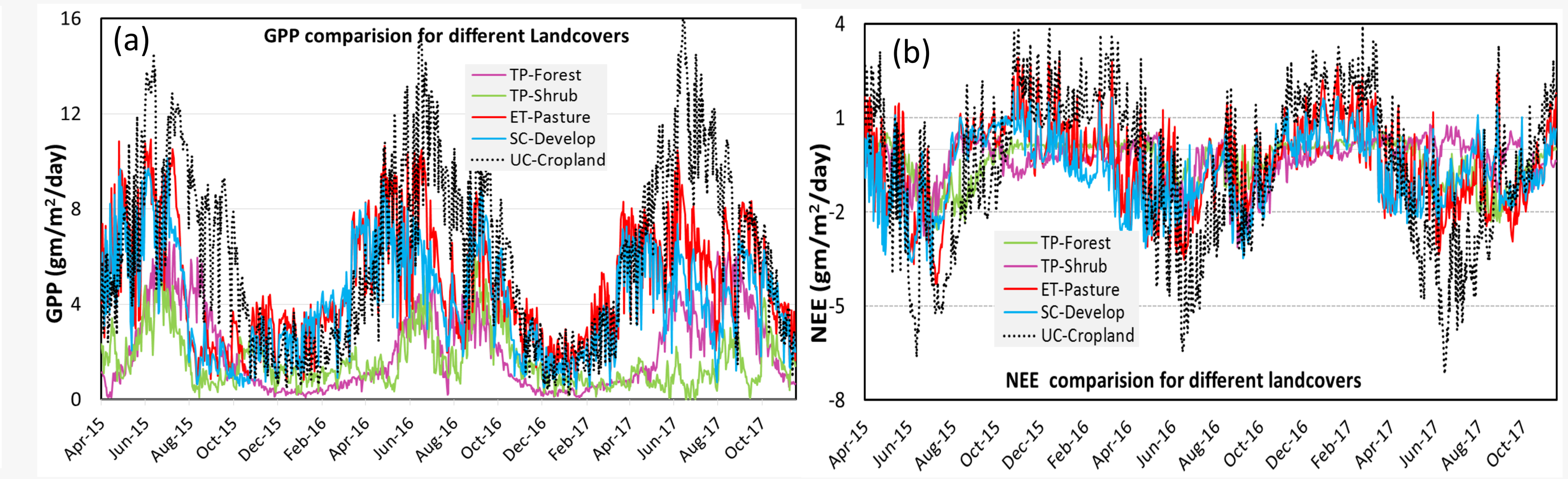

Fig. 4: Figures 4a and 4b compare GPP and NEE at five different land cover in Texas. Results show variations in GPP and NEE for cropland are different than all four other vegetation. As expected, because crop uses lot of carbon to produce food, cropland has high carbon NEE sink and low source. Also, carbon sink occurs during the crop growing season which is from April to October of each year.

Comparison of GPP, RH, NEE and SOC for different Land covers

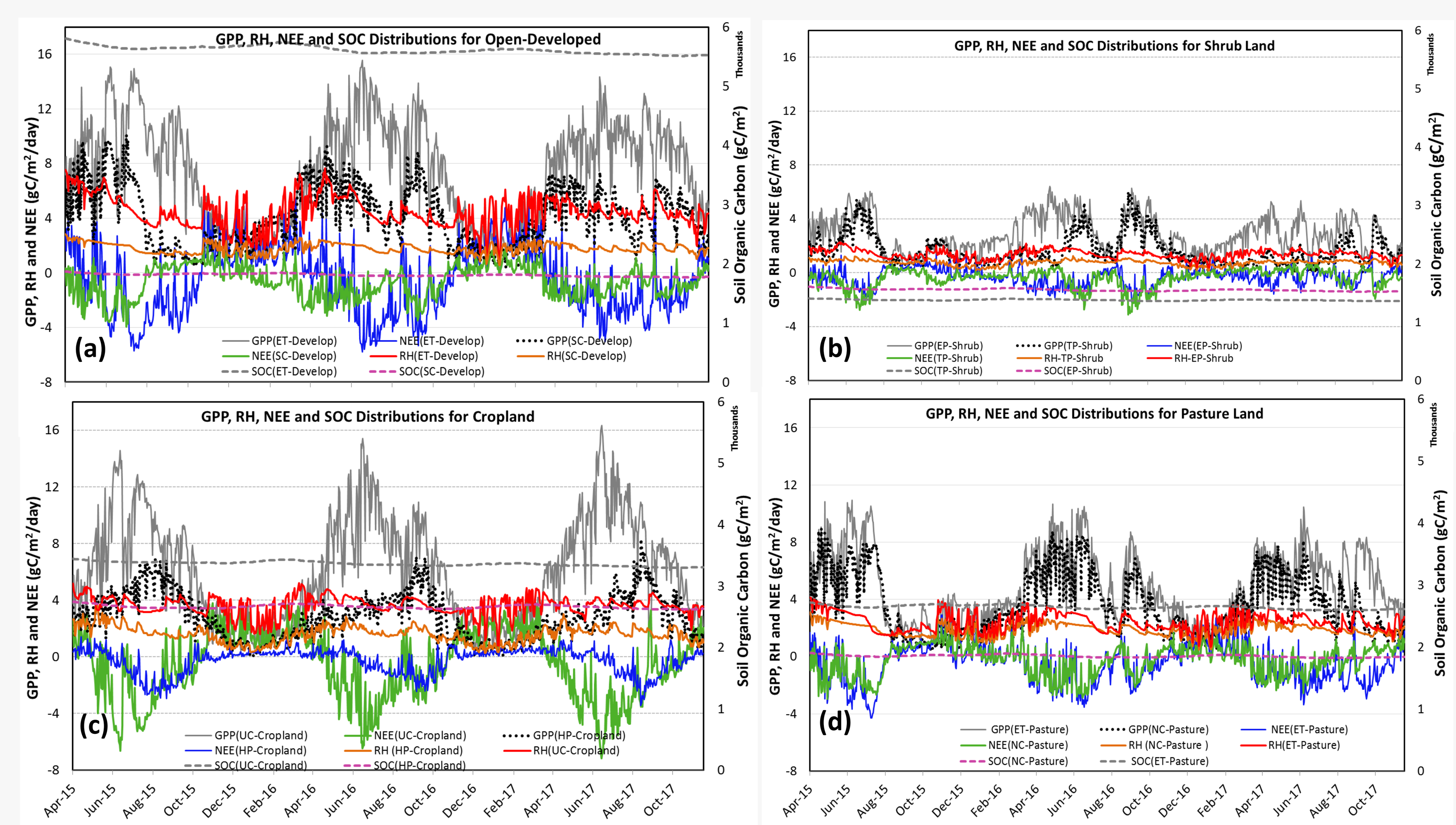

Table 1: Selected 13 SMAP grid locations in study domain

SN	Station Name	Landcover	Climate Zone	GPP (g/m²/d)	NEE (g/m²/d) Source	NEE (g/m²/d) Sink	SOC (g/m²)
1	Prairie View	Developed	East Texas	7.20	1.65	-3.00	4533
2	SC-Developed	Developed	South Central	3.96	0.93	-1.48	1760
3	TP-Shrub	Shrub	Trans Pecos	1.59	0.31	-0.45	1650
4	EP-Shrub	Shrub	Edwards Plateau	3.14	0.57	-0.98	1607
5	Brownfield	Cropland	High Plains	3.02	0.71	-1.38	2515
6	UC-Cropland	Cropland	Upper Coast	6.60	1.70	-3.19	3166
7	RISEL	Pasture	North Central	3.57	0.92	-1.46	1709
8	ET-Pasture	Pasture	East Texas	4.16	1.12	-1.54	2393
9	TP-Forest	Forest	Trans Pecos	2.46	0.50	-0.57	2692
10	ET-Forest	Forest	East Texas	5.40	1.47	-1.11	5270
11	Clarendon	Shrub	Low Rolling Plain	2.41	0.53	-0.76	2085
12	Pitchfork	Grassland	Low Rolling Plain	2.70	0.52	-1.00	1903
13	Abernathy	Grassland	High Plains	3.24	0.66	-1.61	2078

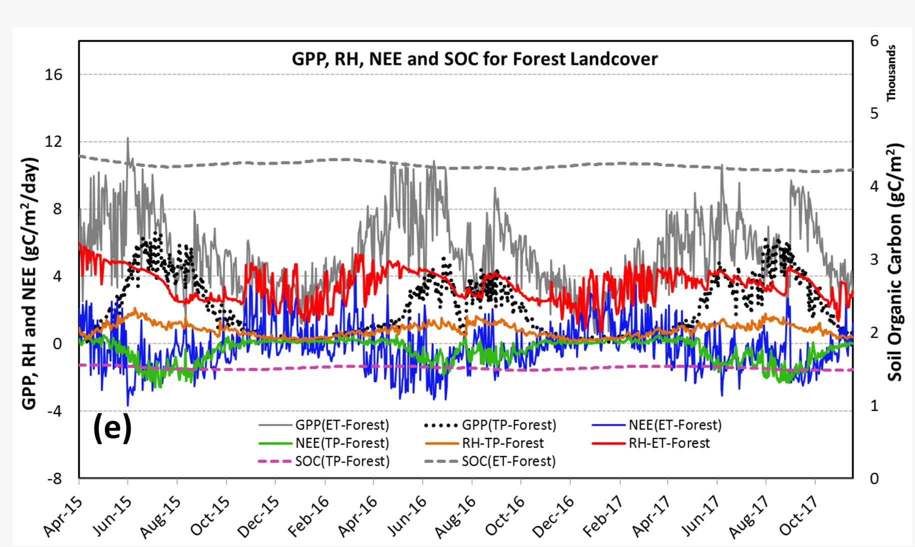

Fig. 5: Figures 5a to 5c represent daily GPP, RH, NEE and SOC distributions for the selected five different land covers in Texas. GPP started to increase during the summer reaching peak in mid June started to decrease from fall to early spring each year. The GPP and NEE variations clearly states the growing season of crops and observed higher and lower carbon sources and sinks in the state of Texas. Also, analysis shows low carbon exchanges from mid October to mid March for developed, pasture and cropland and comparatively high carbon exchange during the same period for forest and shrub land covers.

Table 1 presents the average GPP, NEE and SOC for different land covers during the study period. The highest and lowest GPP were observed at PVAMU and TP-Shrub sites, respectively. Climate has significant impact on carbon exchange. Forest land cover in East Texas climate zone has almost two times more carbon exchange than the forest land cover in Trans Pecos climate zone. **Fig. 6** shows significant increase of NEE, RH and decrease of GPP in southern Texas before and during the Hurricane Harvey in 2017. The highest amount of carbon exchange was observed on 27th of August 2017 when total daily rainfall was 350 mm.

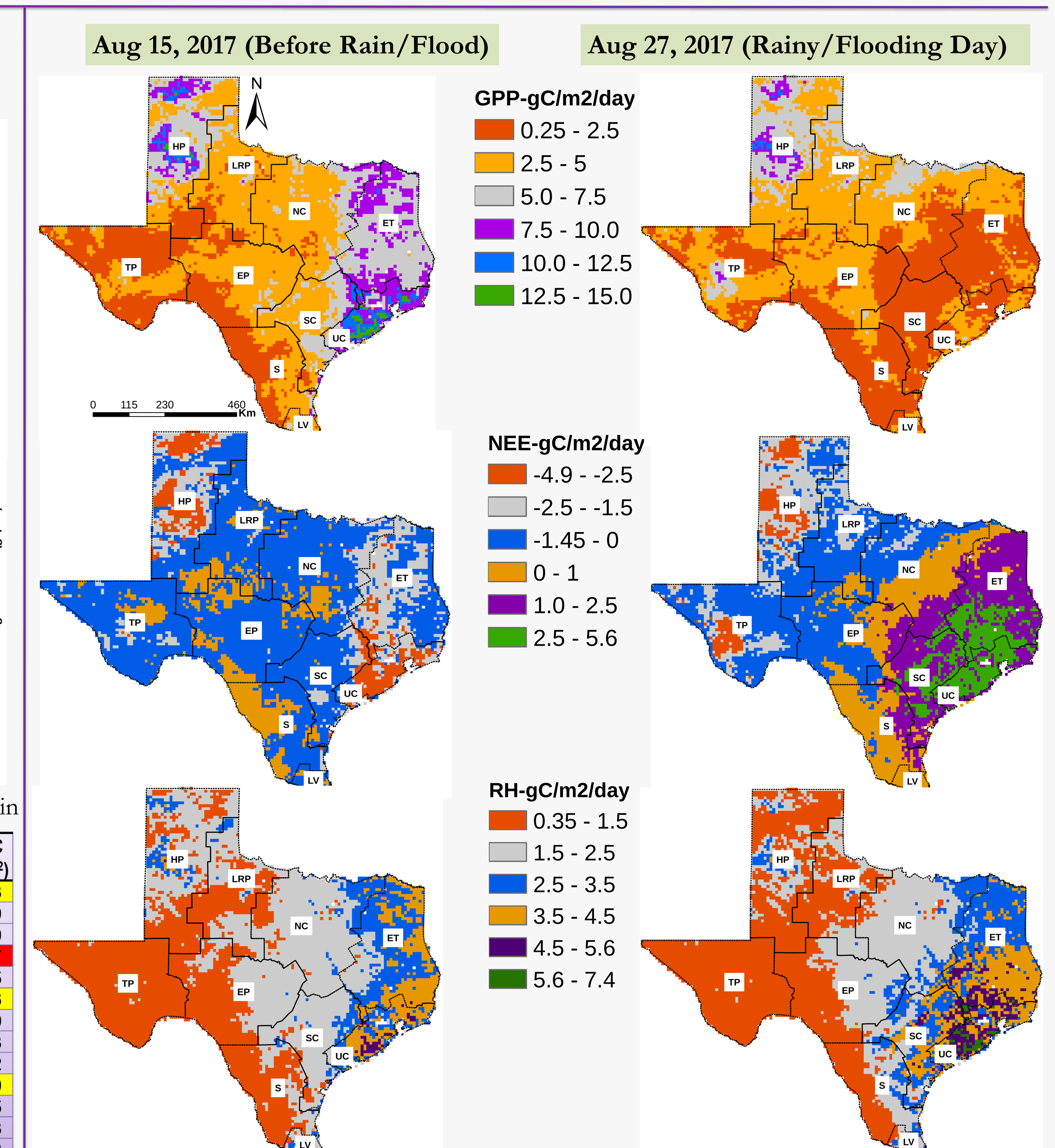

Fig. 6: Spatial distributions of GPP, RH and NEE before and during the Hurricane Harvey

Conclusions

Current observations show the carbon net exchange rate varies with the climate and land cover distributions in the Texas. While the same land cover at two different climate zones have different rate of GPP, RH, NEE and SOC, different land cover within one climate zone has a different carbon exchange and productivity rate. Although, the eddy covariance method makes it possible to measure NEE with precision and contributes to the identification of the characteristics of source/sink activities of various global ecosystems, there are few EC towers active in the state. Therefore, remotely sensed carbon products are very helpful to study the net ecosystem exchange and carbon cycle.

Acknowledgements

This work was supported by the USDA National Institute of Food and Agriculture Evans-Allen 1890 Research Formula Program.