Spatiotemporal patterns of primary production across different land covers in Central-Arizona Phoenix LTER

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ABSTRACT

The prevalence of impervious surfaces and the destruction of native vegetation in urban environments can have profound effects on native biodiversity and ecosystem functioning. Urbanization generally has been thought of as a process that decreases primary production, but for desert cities this may not be the case because of highly productive patches of irrigated green spaces and croplands. While the growth of native desert communities depends strongly on the amount and timing of precipitation, the growth of urban vegetation is decoupled with precipitation due to human ameliorations. To better understand this issue, we attempted to quantify the overall losses and gains of primary productivity due to urbanization in the Phoenix metropolitan region. We used satellite data (250m MODIS NDVI) to assess the spatiotemporal patterns of primary production (as defined here) and vegetation responses to interpolated climate variables that were correlated with NDVI on different time scales, with several urban and non-urban land cover classes considered. Our results show that native desert at lower elevations is less productive than upland communities, and that riparian ecosystems encompassing perennial streams are the most productive. Cultivated grass that occupies less than 0.5 percent of the area has a productivity level comparable to that of riparian vegetation. Urban vegetation and agricultural lands have intermediate levels of primary production. Unlike desert communities, urban vegetation and croplands are least affected by climatic fluctuations. As expected, the primary production of native desert vegetation is tightly coupled with precipitation, but with a time delay of a few months. Our work provides insights into the interactions among vegetation growth, climate variability, and urbanization.

Figure 1. Central Arizona – Phoenix LTER land cover

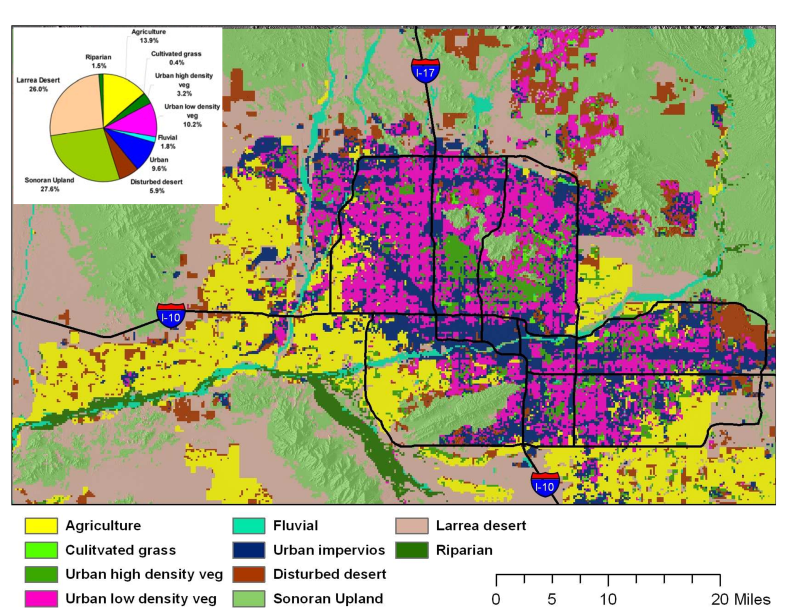
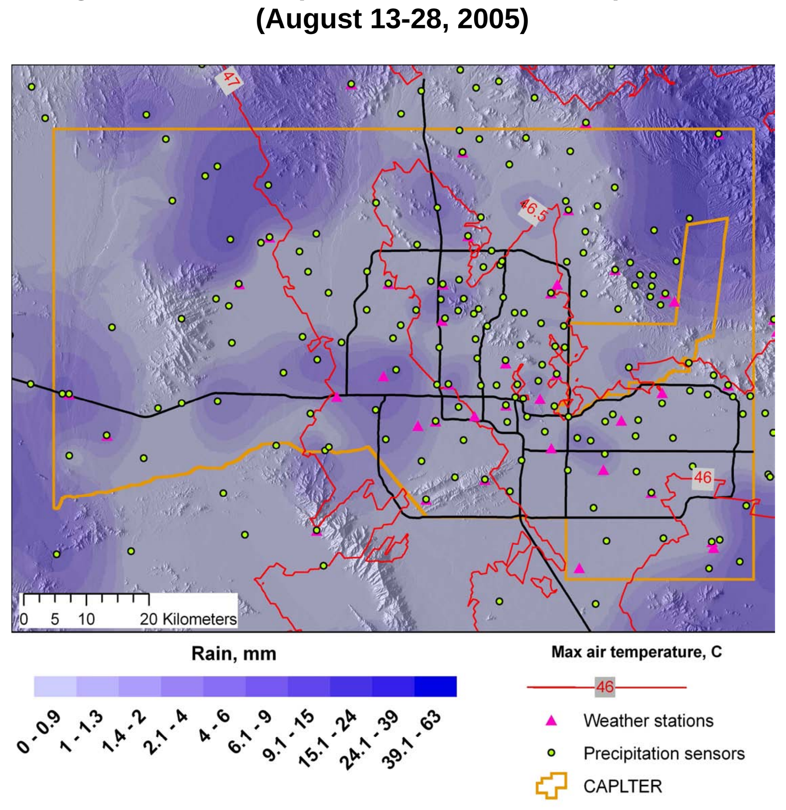


Figure 2. An example of climate data interpolations (August 13-28, 2005)



RESEARCH METHODOLOGY FLOWCHART DIAGRAM

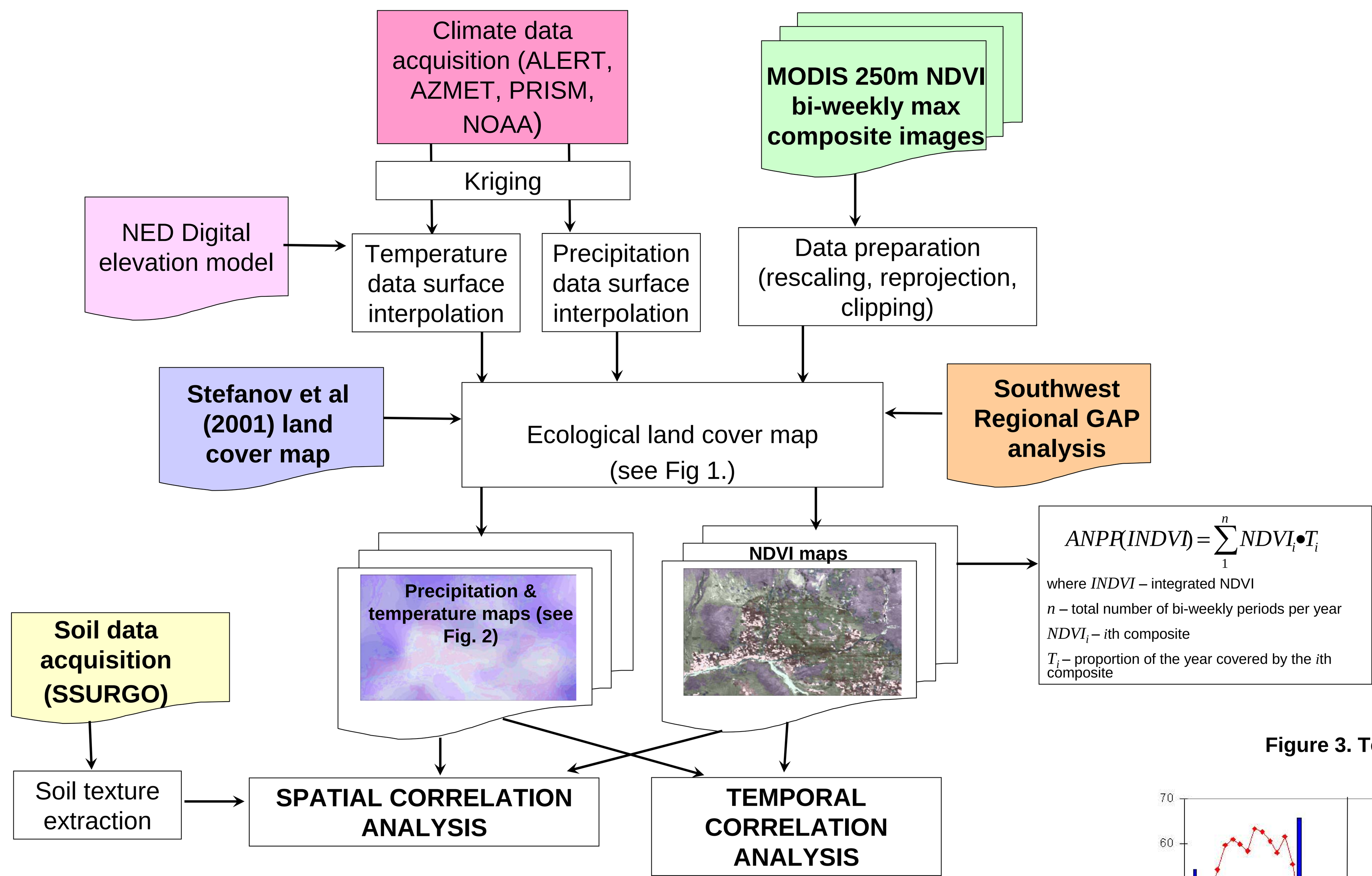


Figure 6. Interannual variability of ANPP = NDVI annual integral

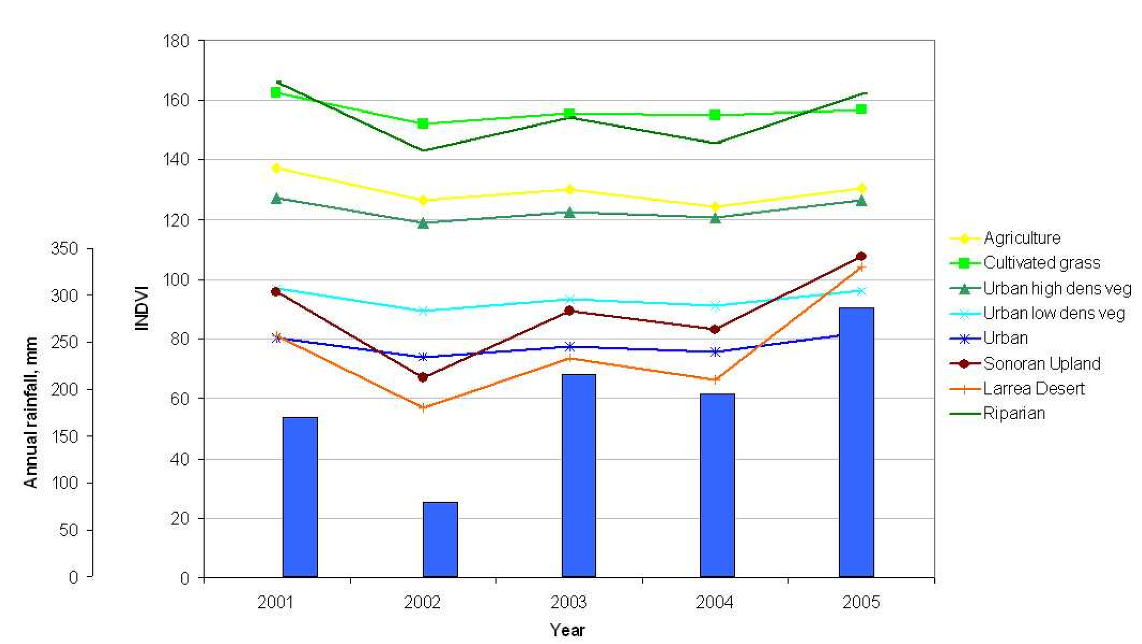
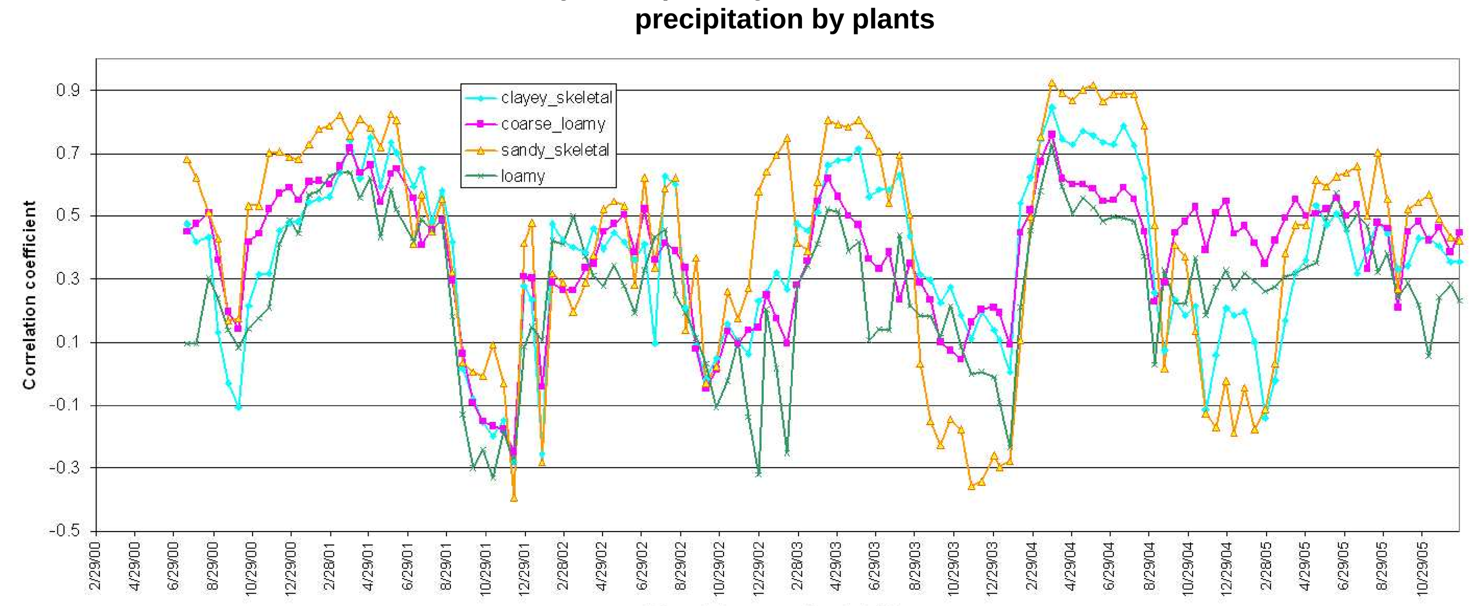


Figure 5. Temporal variation of spatial correlation coefficients between Sonoran Upland NDVI and precipitation aggregated for 5 months prior to the bi-weekly period preceding each NDVI image. Areas of different soils are analyzed separately to assess the effects of soil texture on the use of precipitation by plants



RESULTS

- Unlike urban areas and croplands natural land covers follow predictable seasonal cycles of vegetation growth which is mostly driven by amount and timing of precipitation (Fig. 3). Most significant growth peaks at the community level seem to respond to substantial winter months' rainfall and relatively low springtime air temperatures.
- Urban and agricultural lands exhibit the least inter- and intra-annual fluctuations in NDVI confirming that urban vegetation is highly maintained by humans (Fig. 3)
- Most land covers are positively correlated with rainfall both spatially (Fig. 3 and 4) and temporally (Table 1) with best relationships observed during spring growing season in Sonoral Upland vegetation communities
- The strongest and most consistent spatial correlations are observed between NDVI and the 5-month rainfall accumulated prior to one bi-weekly period that precedes NDVI imagery (Fig. 4)
- All land covers except riparian are on average negatively correlated with maximum air temperature confirming that the rise in temperature in this arid environment inhibits vegetation growth.
- Temporally most land covers respond strongly to cumulative precipitation summed over 3-4 months prior the dates of NDVI imagery (Table 1, lags 0-6 and 0-8).
- Spatial variations in correlations between 5-month rainfall and desert vegetation growing on soils of different texture elucidate the role soil texture in rainfall water usage by plants (Fig. 5). Sandy substrates appear to promote the strongest correlations between winter and early spring rainfall with springtime vegetation patterns while resulting in late fall negative correlations during wet years.
- Primary productivity (as defined here) can double between drought and wet years (Fig. 6) in the least productive desert shrublands. The most productive riparian ecosystems are less affected by immediate rainfall. They are more strongly associated with rainfall at larger time lags and rainfall accumulation periods (Table 1). Urban and agricultural vegetation in general have intermediate levels of primary production which is not affected by climatic fluctuations (Fig. 6). Golf courses and lawns have productivity levels comparable to that of riparian communities. During droughts their productivity can even exceed ANPP of any natural vegetation community. Grasses, however, occupy only a small fraction of the entire region and do not contribute significantly to regional photosynthesis.

Figure 3. Temporal plots showing biweekly precipitation, maximum air temperature and maximum NDVI (2000-2005)

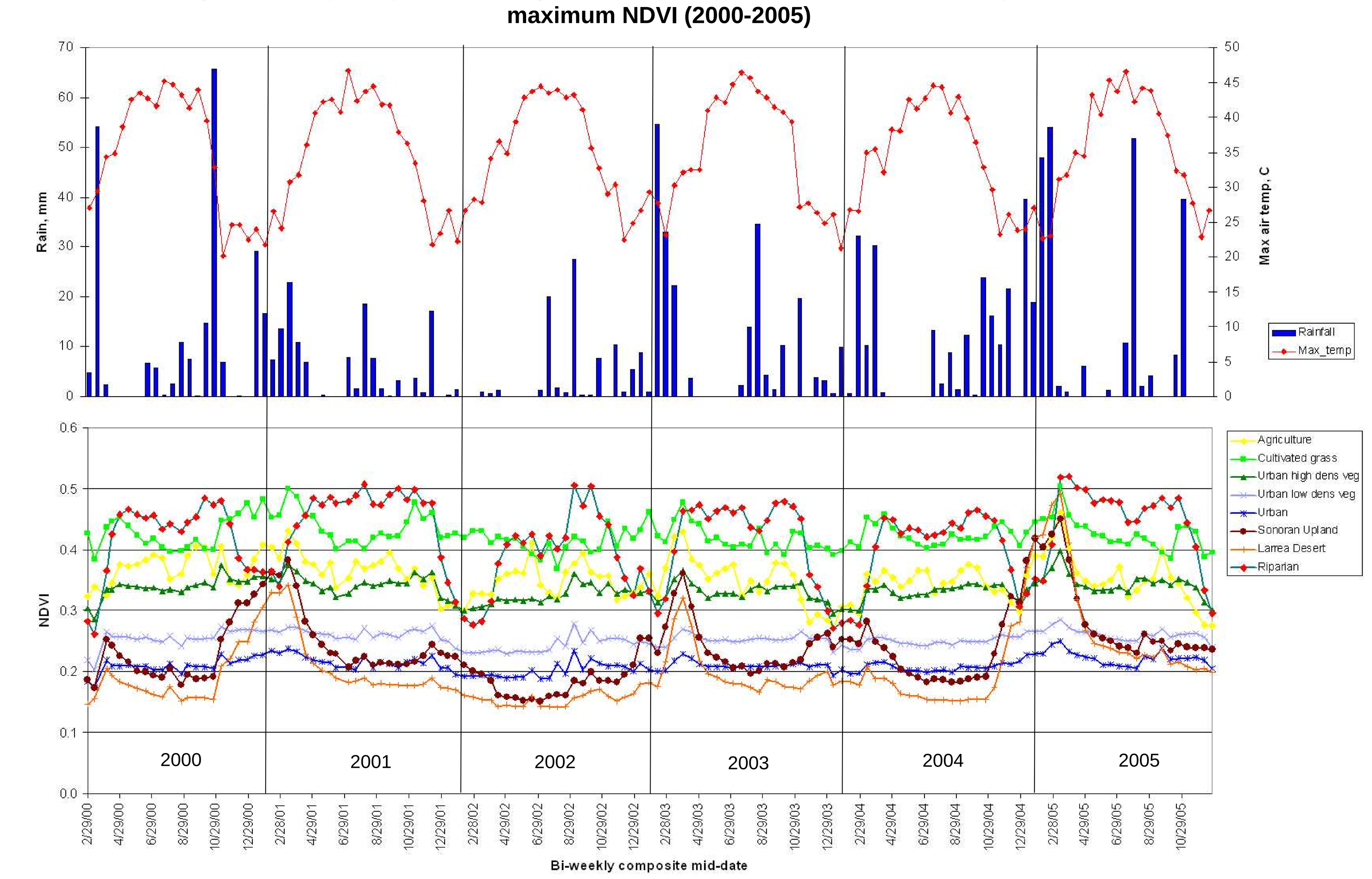


Figure 4. Temporal profiles of spatial correlation coefficients between NDVI and precipitation aggregated for 5 months prior to the bi-weekly period preceding NDVI image (only selected land covers are shown)

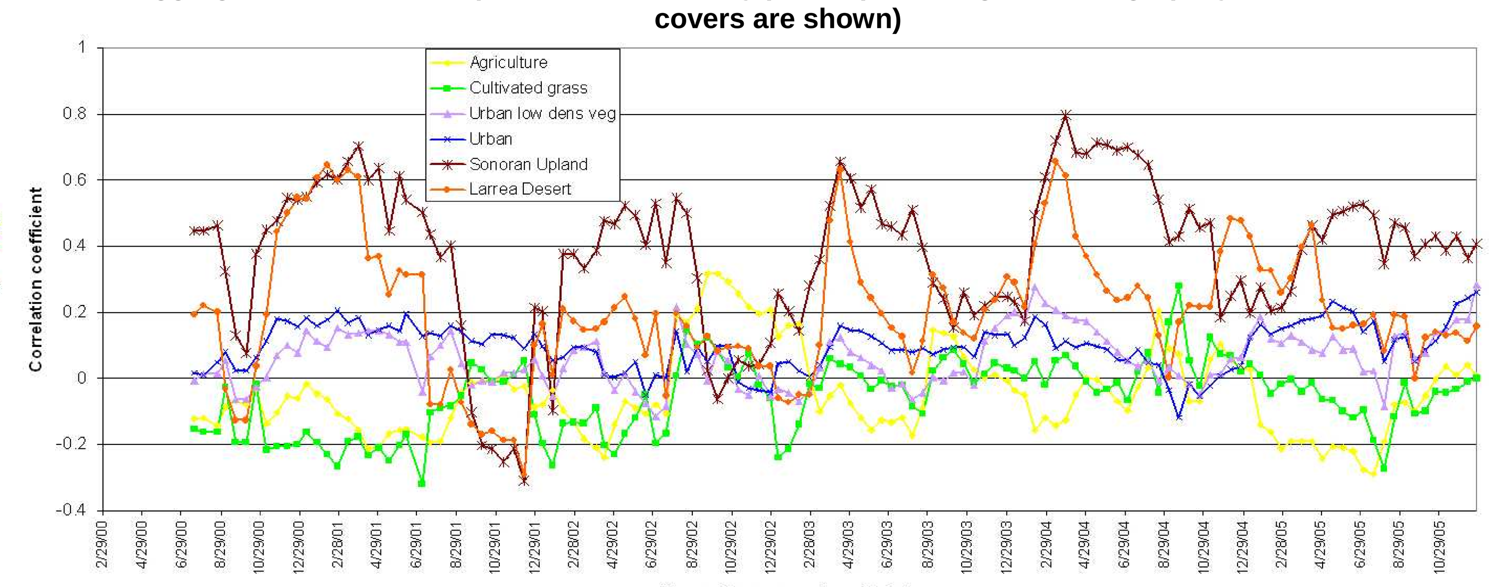


Table 1. Temporal correlation coefficients between mean NDVI and precipitation (per land cover class) in different combinations of time periods. The numbers in the first column indicate time intervals (0 = current biweekly period, 1 = first previous period, 0-1 = rain accumulation over the current and the first previous period, etc.)

	Agriculture	Cultivated grass	Urban high dens veg	Urban low dens veg	Fluvial	Urban	Sonoran Upland	Larrea Desert	Riparian
lag 0	0.04	0.08	0.10	0.03	0.17	0.11	0.26	0.23	-0.15
lag 1	**0.24**	**0.32**	**0.36**	0.32	0.42	0.39	0.44	0.39	-0.03
lag 2	0.20	0.30	0.30	0.33	**0.46**	0.37	**0.47**	**0.42**	0.06
lag 3	0.20	0.29	0.26	**0.34**	0.45	**0.41**	0.43	0.40	0.08
lag 4	0.17	0.29	0.20	0.24	0.36	0.26	0.33	0.31	0.12
lag 5	0.10	0.21	0.14	0.25	0.25	0.25	0.25	0.25	0.12
lag 6	0.04	0.17	0.06	0.16	0.20	0.16	0.20	0.22	0.06
0-1	0.19	0.26	0.30	0.22	0.39	0.32	0.45	0.41	-0.13
0-2	0.26	0.39	0.44	0.41	0.56	0.50	0.60	0.55	-0.04
0-3	0.33	0.46	0.50	0.50	0.68	0.61	0.70	0.66	0.01
0-4	0.37	0.53	0.53	0.54	0.75	0.65	0.75	0.72	0.06
0-5	0.37	0.55	0.54	0.58	0.78	0.69	0.77	0.75	0.10
0-6	0.36	**0.57**	0.52	0.59	0.79	0.69	0.78	0.77	0.11
0-7	0.34	0.56	0.49	0.59	0.79	0.69	0.79	0.79	0.11
0-8	0.33	0.52	0.47	**0.60**	**0.80**	**0.70**	**0.80**	**0.82**	0.10
0-12	0.32	0.44	0.45	0.53	0.74	0.61	0.73	0.78	0.13
0-16	0.40	0.34	**0.55**	0.56	0.69	0.62	0.59	0.65	0.38
1-2	0.29	0.41	0.44	0.43	0.58	0.50	0.58	0.54	0.02
1-3	0.35	0.47	0.48	0.51	0.69	0.61	0.67	0.64	0.07
1-4	0.38	0.52	0.51	0.54	0.75	0.64	0.71	0.68	0.11
1-5	0.38	0.55	0.51	0.58	0.77	0.68	0.74	0.72	0.15
1-6	0.37	**0.56**	0.49	**0.59**	**0.78**	0.68	0.74	0.74	0.16
1-7	0.34	0.55	0.46	0.58	0.77	0.67	0.74	0.76	0.16
1-8	0.33	0.50	0.43	0.58	0.77	0.67	**0.75**	**0.78**	0.14
1-12	0.31	0.42	0.41	0.50	0.72	0.58	0.69	0.75	0.17
2-1	0.24	0.39	0.30	0.38	0.52	0.44	0.49	0.47	0.13
2-2	0.24	0.40	0.31	0.43	0.54	0.48	0.51	0.50	0.17
2-3	0.22	**0.41**	0.29	0.43	0.55	0.48	0.51	0.53	0.16
2-4	0.20	0.40	0.26	0.43	0.56	0.48	0.53	0.56	0.16
2-5	0.19	0.35	0.24	0.43	0.57	**0.49**	0.54	0.59	0.13
2-6	0.16	0.32	0.22	0.41	0.57	0.47	0.54	**0.61**	0.12
2-8	0.15	0.29	0.23	0.37	0.54	0.42	0.51	0.59	0.13
2-16	0.10	0.10	**0.34**	**0.47**	0.41	0.43	0.29	0.35	**0.43**
3-1	0.18	0.33	0.22	0.32	0.40	0.34	0.37	0.37	0.16
3-2	0.16	**0.34**	0.20	0.33	0.41	0.35	0.39	0.40	0.15
3-3	0.14	0.32	0.18	0.33	0.43	0.35	0.41	0.44	0.14
3-4	0.12	0.28	0.16	0.34	0.45	**0.37**	0.43	0.48	0.12
3-5	0.10	0.25	0.14	0.32	**0.46**	0.36	**0.45**	0.50	0.10
3-6	0.08	0.24	0.14	0.29	0.45	0.33	0.44	0.50	0.09
3-12	**0.23**	0.11	**0.33**	**0.35**	0.40	0.34	0.28	0.37	**0.43**
4-1	0.10	0.25	0.13	0.27	0.29	0.27	0.28	0.30	0.12
4-2	0.07	0.23	0.11	0.26	0.32	0.27	0.32	0.35	0.10
4-3	0.06	0.19	0.09	0.27	0.34	0.29	0.34	0.39	0.08
4-4	0.04	0.16	0.08	0.26	**0.36**	0.29	**0.37**	0.43	0.06
4-5	0.02	0.15	0.08	0.23	0.35	0.26	0.36	0.43	0.05
4-6	0.04	0.14	0.10	0.22	0.33	0.24	0.34	0.41	0.07
4-12	**0.14**	0.04	**0.31**	**0.34**	0.31	0.31	0.19	0.27	**0.45**

CONCLUSIONS

- Analysis of MODIS NDVI and climate data provides important insights into the interactions between vegetation patterns, climate variability, and urbanization
- Our preliminary analysis suggests that urbanization in Central Arizona creates more land covers with rates of primary production significantly higher those of natural vegetation, especially during droughts.
- Complex NDVI relationships with climatic variables in Sonoran desert are characterized by larger time lags and rainfall aggregation periods. Such relationships are considerably affected by soil texture characteristics.

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