**ESA 2012 ABSTRACT—Draft 2 (Feb. 22, 2012)**

# Spatial interactions among ecosystem services in an urbanizing agricultural landscape in the Upper Midwest

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## Background/Question/Methods

Spatially explicit understanding of the delivery of multiple ecosystem services is essential to inform landscape management that attempts to sustain the benefits people derive from ecosystems. Despite increasing attention focused on ecosystem services, few studies have investigated the kind, amount, distribution and spatial interactions among multiple ecosystem services across landscapes. Such information is critical for evaluating tradeoffs and synergies of ecosystem services and may help to reveal mechanisms underpinning these interactions. We analyzed the production of multiple ecosystem services in the 1330-$km^2$ Yahara Watershed (Wisconsin, USA) for the year 2006 to address two questions: (1) Given current land-use patterns, where are the "hot" and "cold" spots of multiple ecosystem services delivery, and what distinguishes there areas? (2) Where in the landscape might the strongest tradeoffs and synergies among ecosystem services occur? We quantified and mapped spatial patterns of major provisioning and regulating services at 30-m spatial resolution using empirical data and spatial models. Interactions among ecosystem services were identified by Spearman pairwise correlations among ecosystem services based on 1000 randomly generated points. The spatial patterns of synergies and tradeoffs were identified by overlaying multiple services to map the locations of positive and negative interactions.

## Results/Conclusions

The production of individual ecosystem services in 2006 showed substantial spatial heterogeneity across the Yahara Watershed. Some ecosystem services (e.g., soil retention, surface runoff, freshwater supply) were spatially aggregated in the landscape whereas others (e.g., pasture production) were spatially dispersed (Moran's I, $P < 0.001$). When multiple ecosystem services were overlain, hot spots (locations in the upper $20^{th}$ percentile for production of a given service) occupied less of the landscape than cold spots (e.g., 4% vs. 20%, respectively, for five key services). Hot spots were primarily located in forest and cultivated land covers, whereas cold spots occurred largely in developed land-cover classes. Spatially, hot spots were more fragmented than cold spots, which were clumped in areas where human activities were highly concentrated. Our results indicated landscape tradeoffs (negative correlations) between provisioning and regulating ecosystem services and landscape synergies (positive relationships) among all regulating services. From these interactions, we identified locations that might have the most pronounced tradeoffs and synergies across the landscape. Knowledge of the spatial interactions among multiple services can help to identify areas where conflicts over different ecosystem services are likely and areas that are critical for the sustained provision of multiple services.