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Importance of landscape heterogeneity for sustaining hydrologic ecosystem services in an urbanizing agricultural watershed

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Background/Question/Methods

Human activities alter landscape patterns that can affect processes that underlie production of ecosystem services. Understanding of the ecological basis of many services has improved, but the spatial ecology of ecosystem services remains a significant knowledge gap. In particular, the explicit role of landscape heterogeneity in sustaining ecosystem service provision is not well understood. Studies have investigated effects of landscape composition and configuration on single services (e.g., primarily pollination and pest regulation), but few have considered multiple hydrologic ecosystem services (freshwater benefits to people generated by terrestrial ecosystems). We analyzed supply of three hydrologic services (freshwater supply, ground- and surface-water quality) in the 1,336-km^2 Yahara Watershed (Wisconsin, USA) for 2006 and asked: (1) How do landscape composition and configuration affect delivery of hydrologic services (i.e., does spatial pattern matter)? (2) Are there opportunities for small changes in landscape pattern to produce large gains in hydrologic services? We expected strong effects of landscape composition, with landscape configuration mediating services dependent on lateral transfers of water and nutrients. We quantified landscape metrics and hydrologic services at 30-m resolution for 100 subwatersheds using empirical estimates and spatial models. We tested our hypotheses using multi-model inference.

Results/Conclusions

Landscape composition and configuration affected delivery of hydrologic services in subwatersheds and explained more variation in surface-water quality than in freshwater supply or groundwater quality (Nagelkerke R^2: 86%, 64% and 39%, respectively). Surface-water quality was positively correlated with percent forest, grassland and wetland, and negatively correlated with cropland. Relationships between surface-water quality and percent cropland and wetland were nonlinear. Spatial configuration also influenced surface-water quality—subwatersheds with high wetland patch density, disaggregated forest patches and low contagion had greater surface-water quality. Freshwater supply was negatively correlated with percent urban cover and wetland, and positively correlated with urban edge density. Groundwater quality was negatively correlated with percent cropland and grassland, and configuration variables were unimportant. Further analyses revealed that surface-water quality may be substantially enhanced if percent cropland within a subwatershed declines from 80% to 60% or percent wetland increases from 0% to 10%. Overall, landscape composition had a stronger influence on hydrologic services than landscape configuration, suggesting that altering spatial arrangement of land cover alone will offer little opportunity to enhance hydrologic services. Rather, the relative abundances of land-cover classes may need to change to improve hydrologic ecosystem services in some subwatersheds.