Spatially explicit scenario analysis for hydrologic services in an urbanizing agricultural watershed

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The sustainability of hydrologic services (benefits to people generated by terrestrial ecosystem effects on freshwater) is challenged by changes in climate and land use. Despite the importance of hydrologic services, few studies have investigated how the provision of ecosystem services related to freshwater quantity and quality may vary in magnitude and spatial pattern for alternative future trajectories. Such analyses may provide useful information for sustaining freshwater resources in the face of a complex and uncertain future. We analyzed the supply of multiple hydrologic services from 2010 to 2070 across a large urbanizing agricultural watershed in the Upper Midwest of the United States, and asked the following: (*i*) What are the potential trajectories for the supply of hydrologic services under contrasting but plausible future scenarios? (*ii*) Where on the landscape is the delivery of hydrologic services most vulnerable to future changes? The "Nested Watershed*"* scenario represents extreme climate change (warmer temperatures and more frequent extreme events) and a concerted response from institutions, whereas in the *Investment in Innovation* scenario, climate change is less severe and technological innovations play a major role. Despite more extreme climate in the *Nested Watershed* scenario, all hydrologic services (i.e., freshwater supply, surface water quality, flood regulation) were maintained or enhanced (~30%) compared to the 2010 baseline, by strict government interventions that prioritized freshwater resources. Despite less extreme climate in the *Investment in Innovation* scenario and advances in green technology, only surface water quality and flood regulation were maintained or increased (~80%); freshwater supply declined by 25%, indicating a potential future tradeoff between water quality and quantity. Spatially, the locations of greatest vulnerability (i.e., decline) differed by service and among scenarios. In the *Nested Watershed* scenario, although freshwater supply and surface water quality were sustained or enhanced overall, these hydrologic services declined in ~60% and 20% of the landscape, respectively. The greatest improvement for most hydrologic services corresponded to areas of restored wetland, forest and perennial crops, which were less vulnerable to future degradation. In the *Investment in Innovation* scenario, freshwater supply declined in almost the entire watershed; improvement of surface water quality and flood regulation occurred mainly in urban areas, where highly engineered systems made them less vulnerable. Overall, our results indicated that hydrologic services will respond differently to future climate and land-use change, and sustaining one may involve tradeoffs of another. Technological progress can conserve particular services but might not be the panacea for the future. How society reacts in the face of changes can have an important role in determining the pathways to the future and the provision and spatial patterns of ecosystem services.