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Analysis

Valuing ecosystem and economic services across land-use scenarios in the Prairie Pothole Region of the Dakotas, USA

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ABSTRACT

This study uses biophysical values derived for the Prairie Pothole Region (PPR) of North and South Dakota, in conjunction with value transfer methods, to assess environmental and economic tradeoffs under different policy-relevant land-use scenarios over a 20-year period. The ecosystem service valuation is carried out by comparing the biophysical and economic values of three focal services (i.e. carbon sequestration, reduction in sedimentation, and waterfowl production) across three focal land uses in the region [i.e. native prairie grasslands, lands enrolled in the Conservation Reserve and Wetlands Reserve Programs (CRP/WRP), and cropland]. This study finds that CRP/WRP lands cannot mitigate (hectare for hectare) the loss of native prairie from a social welfare standpoint. Land use scenarios where native prairie loss was minimized, and CRP/WRP lands were increased, provided the most societal benefit. The scenario modeling projected native prairie conversion to cropland over the next 20 years would result in a social welfare loss valued at over $4 billion when considering the study's three ecosystem services, and a net loss of about $3.4 billion when reductions in commodity production are accounted for.

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1. Introduction

Increases in domestic and international demands for food, fiber, and fuel have led to increased land conversion for agricultural production across the U.S. In the last few decades, conservation provisions have been introduced into U.S. agricultural policy to mitigate conversions and restore once native habitats and the respective ecosystem services they provide. Two of the most prominent conservation programs within the U.S. Farm Bill are the Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP). These programs were engineered to establish long-term, resource-conserving covers on marginally productive farmland, and have conserved more than 12 million hectares nationwide each year since 1990 (Hart, 2006).

Ecosystem services have been described as the direct and indirect benefits people obtain from ecological systems (Millennium Ecosystem Assessment, 2003). This anthropocentric view has led to increased efforts to identify, quantify, and value ecosystem services. An economic perspective on ecosystems portrays them as natural assets providing a flow of goods and services (Daily et al., 2000; Turner et al., 2008). Once these goods and services are identified and quantified, they can be monetized to complete the valuation process (Murray et al., 2009). Complicating this last step is the fact that most of these goods and services are public and non-market. Identifying the economic value of these services is essential in revealing their societal value because this provides a common metric to facilitate comparisons across attributes and differing ecological scenarios in policy assessments (NRC, 2005). Programs such as the CRP and WRP are geared towards increasing the amount of ecosystem services provided through public investment. To foster ecosystem service markets the U.S. Department of Agriculture (USDA) announced the establishment of a new Office of Ecosystem Services and Markets (USDA, 2008; News Release No. 0307.08), now called "Office of Environmental Markets."

The objectives of this study are to (1) model and analyze the primary ecosystem and economic services across prominent land uses within the Prairie Pothole Region (PPR) of North and South Dakota, (2) illustrate and compare the societal values of agricultural products and ecosystem services produced under policy-relevant land-use change scenarios, and (3) explore the effectiveness of mitigating native prairie loss with conservation program lands. Conservation and natural resource managers have been criticized for focusing on a single economic sector, while trying to maximize a narrow set of objectives (Tallis and Polasky, 2009). By quantifying both ecosystem and economic services in the PPR and analyzing the tradeoffs between them, natural resource managers and policy makers can make more efficient, knowledgeable, and defensible decisions in a region described as

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"North America's most endangered ecosystem (Samson and Knopf, 1996)."

Numerous studies have been conducted to estimate the value of a range of ecosystem services using both stated and revealed preference techniques, as well as benefit transfer methodology. However, the integration of both biophysical and ecosystem service valuation data is a relatively new phenomenon (NRC, 2005; Troy and Wilson, 2006). Past integrated research has usually incorporated a descriptive spatial component [ex. Geographic Information Systems (GIS)] within the models used (Bockstael et al., 1995; Eade and Moran, 1996; Kreuter et al., 2001; Lant et al., 2004; Troy and Wilson, 2006; Zhao et al., 2003); whereby changes in ecosystem services and relative economic valuation are compared across various land uses and spatial patterns. However, few of these studies attempt to model future land-use predictions, and subsequent changes in ecosystem service values produced (see Nelson et al., 2009 for uncommon example).

Due to the complexity of both the ecological and economic valuation processes, most integrated research has been either broad-scale assessments of multiple services (Costanza et al., 1997; Troy and Wilson, 2006), or highly detailed functional analysis of a single ecosystem service at small geographical scales (Polasky et al., 2008; Smith, 2007). The broader approach is often criticized for its generality across habitat types, while the other is noted for lacking both the scope and scale for it to be relevant and applicable to policy scenarios (Nelson et al., 2009). Furthermore, few authors have compared the ecosystem service values generated to the opportunity costs of alternative land uses, such as agricultural production or urban development (see Jenkins et al., 2010; Nelson et al., 2009, and Polasky et al., 2008 for initial attempts).

There is a building body of literature estimating the non-market benefits of government-sponsored conservation programs. Much of the economic literature focuses on greenhouse gas mitigation and the potential for retired lands or altered agricultural operations to sequester carbon (Antle et al., 2007; Feng et al., 2004; Lal et al., 1999; Marland et al., 2001). Research has found that instituted market mechanisms and/or additional program payments for carbon sequestration have the potential to exceed the cost of land restoration and the opportunity cost of foregone agricultural production in some particular areas (Hansen, 2009; Jenkins et al., 2010; Lewandrowski et al., 2004). Far less research has been done on the economic value of native prairie grasslands and wetlands (see Hovde and Leitch (1994), and Hubbard (1988) for early examples).

In this study, we model changes to ecosystem and associated economic values across policy-relevant land-use change scenarios over the next 20 years within the PPR of North and South Dakota. This is accomplished by way of linking sound ecological field data and economic valuation within a single accounting metric. The study area was selected based on available scientific data and its unique and critical ecological makeup, as well as the region's vulnerability to future land-use change. Our analysis focuses on three ecosystem services; (1) carbon sequestration as it pertains to global climate regulation, (2) reduction in sedimentation relative to soil and water quality, and (3) waterfowl production in relation to the derived benefits associated with increases in duck populations. Biological and associated economic values are compared across three focal land uses found in the study region: (1) native prairie grasslands, (2) land enrolled in the CRP and WRP (CRP/WRP), and (3) cropland. Our study's findings provide insight into the impacts of the CRP/WRP and other conservation provisions that are currently in existence or up for consideration within the U.S. Farm Bill. Such accounting is critical to ensuring the continued funding of Federal conservation programs, as is required by the President's Budget and Performance Integration Initiative (Gleason et al., 2008). Importantly, this study will help determine economic and ecological tradeoffs in the PPR and the substitutability of retired croplands enrolled in conservation programs for native prairie grasslands that have experienced annual conversion rates approaching 3% in recent years (DU-EPF, 2009).

2. Methods

2.1. Study Area

The PPR is found within the Northern Great Plains, and covers approximately 900,000 km^2. The region extends all the way from the north-central United States, incorporating parts of Iowa, Minnesota, North Dakota, South Dakota, and Montana, to the south-central part of Canada, encompassing sections of Alberta, Saskatchewan, and Manitoba (Reference Fig. 1). For this study, we focus specifically on the PPR of North and South Dakota that is roughly defined by the area and state boundaries north and east of the Missouri River, covering approximately 224,000 km^2. The combination of interspersed grassland and wetland ecosystems within this region produces a highly valued bundle of ecosystem services. For example, the PPR has been referred to as the "Duck Factory," as it serves as the most important breeding ground for North American waterfowl, producing 50–80% of the continent's entire dabbling duck population on only 10% of the available nesting habitat (Batt et al., 1989; Ducks Unlimited, 2008). However, this same landscape provides necessary inputs for valuable agricultural production. North and South Dakota are more economically dependent on the agricultural sector than any other states in the country, with their annual agricultural products valued at around $6.5 billion (USDA-NASS, 2007a).

The vast network of agricultural operations interspersed among critical habitats has made the PPR an attractive area for farm conservation investment. The CRP and WRP are voluntary land retirement programs for agricultural landowners. Through the programs, landowners can receive annual rental payments and cost-share assistance to establish long-term, resource-conserving land cover. A majority of newly enrolled CRP hectares have been planted with a native grass and forbs mix over the last three years in the Dakotas (USDA-FSA, 2010). Contract periods for the CRP are typically between 10 and 15 years, whereas the WRP offers perpetual and 30-year conservation easements. At the end of 2008, both North and South Dakota ranked in the top ten states for land enrolled in the CRP, with a combined enrollment of nearly 1.7 million hectares (USDA-FSA). However, in a time of rising commodity prices, renewable energy mandates, and tightening federal allowances, along with the timing of CRP contract expirations, many experts fear that enrolled hectares are in a steep decline. In a recent Congressional report, North and South Dakota were noted as having the largest decreases in CRP lands in the country over the last few years (Cowan, 2009).

Remaining tracts of native prairie also remain vulnerable to the forces threatening CRP/WRP reenrollment. The recent push for renewable energy from biofuels and higher-than-average market prices for corn, with a growing portion of this crop being used as a bioenergy fuel feedstock, appear to be providing economic incentive to convert native prairie lands (Stubbs, 2007). With only a quarter of the original grasslands remaining in South Dakota, elevated conversion rates persist (Reynolds et al., 2006; Stephens et al., 2006). Similarly, previous estimates indicate more than 50 % of PPR wetlands in the U.S. have been drained or altered for purposes of agricultural production (Tiner, 1984).

2.2. Valuation Process

The valuation sequence is composed of four essential steps: (1) identify ecosystem services by land use, (2) quantify the biological values associated with those services down to annualized per-hectare values, (3) monetize those values using economic methods, and (4) track and sum the flux in those values as the number of hectares change in each land use scenario (Murray et al., 2009). By standardizing measurements into per-hectare values, we are able to compare ecosystem services and other land incomes at the regional scale. Once economic values are added, ecosystem service values can be summed and cross-tabulated by service and land use for each scenario (Troy and Wilson, 2006).