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Economic value of carbon storage in U.S. National Wildlife Refuge wetland ecosystems ☆

Douglas Patton [a], John C. Bergstrom [b,*], Rebecca Moore [c], Alan P. Covich [d]

[a] Athens Technical College, Athens, GA, USA
[b] University of Georgia, Department of Agricultural and Applied Economics, 208 Conner Hall, Athens, GA, USA
[c] U.S. Department of the Interior, Bureau of Land Management, Fort Collins, CO, USA
[d] University of Georgia, Odum School of Ecology, Athens, GA, USA

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ABSTRACT

The *Third National Climate Assessment* released in 2014 provides further evidence of global warming and mitigation options including carbon sequestration or storage. In this paper, we report on the quantity and economic value of carbon stored in wetlands ecosystems found in four U.S. National Wildlife Refuges. Our results suggest that wetlands in National Wildlife Refuges provide substantial carbon storage benefits to the U.S. and world.

1. Introduction

The recently released *Third National Climate Assessment* provides further evidence that the earth's climate is in a long-term warming trend which has been accelerated during the past several decades by increased atmospheric carbon in the form of carbon dioxide (CO_2). Human-induced sources of increased atmospheric carbon are primarily activities that burn fossil fuels (e.g., generating electricity, manufacturing goods, driving automobiles). The *Assessment* describes many negative economic, social and ecological impacts stemming from a warming global climate, and presents response options including carbon sequestration or storage (hereafter, carbon storage). For example, plants and soils can help mitigate increased human-induced atmospheric carbon by absorbing CO_2 from the atmosphere and storing the associated carbon in natural “carbon sinks” (Houghton, 1996; Jacoby et al., 2014; Mitra et al., 2005; Mitsch et al., 2013).

Ecosystem services, in general, are contributions to human well-being provided by ecosystems which are generally not accounted for in market economies (Boyd and Banzhaf, 2007; Fisher et al., 2009; Heal et al., 2005; Wallace, 2007). For example, if the U.S. government preserves wetlands in a park, national seashore or wildlife refuge, the protected wetlands provide carbon storage and global climate regulating benefits. In recent years, there has been a growing interest in developing and applying methods for estimating the economic value of carbon storage and other ecosystem services (Bateman et al., 2010; Brander et al., 2013; Brown et al., 2007; Heal et al., 2005; Farber et al., 2006).

Laurans et al. (2013) describe three primary ways empirical measures of ecosystem service values might be used in policy and management: (1) *decisive use* where estimated values are meant to inform a specific decision such as whether or not to implement a particular wetlands restoration project; (2) *technical use* where estimated values are used after a policy or management decision has been made to adjust the implementation mechanisms such as the amount of payment to private landowners for protecting a wetland area; and (3) *informative use* where estimated values provide information intended to better inform *exante* and *expost* policy and management decisions. Our study was commissioned by the U.S. Fish and Wildlife Service for reasons consistent primarily with the informative use of estimated ecosystem service values described by Laurans et al. (2013). For example, federal agencies within the U.S. government have been facing austere budget allocations set by the U.S. Congress and Presidential

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* Corresponding author.
E-mail address: jberg@uga.edu (J.C. Bergstrom).

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administration (executive branch). As a result, federal agencies including the U.S. Fish and Wildlife Service are interested in providing the U.S. Congress and Presidential administration with information on the benefits of their programs to the general public, including provision of ecosystem services (e.g., see Heal et al. (2005), Tazik et al. (2013)).

In the case of our study, the U.S. Fish and Wildlife Service desired information on the economic value of ecosystem services supported by wetlands in National Wildlife Refuges which are managed by this agency. Examples were requested to help support budget allocations for their agency and management such as possible expansion of the National Wildlife Refuge System. This use of economic value information to influence wetlands conservation funding decisions can essentially be considered a form of "advocacy" (Daily et al., 2009; Laurans et al., 2013; Pearce and Seccombe-Hett, 2000). For example, economic value information can help garner funding support by informing citizens of the additional benefits of wetlands in National Wildlife Refuges. Individuals and support groups (e.g., the National Wildlife Refuge Association) can also use this information together with other data to lobby their elected representatives to vote in favor of wetlands conservation funding. Economic value information may also help garner support for wetlands conservation funding by influencing how federal agencies distribute limited budgets to different programs and projects.

Following the request from the U.S. Fish and Wildlife Service to have more information about the economic value of ecosystem services supported by wetlands in National Wildlife Refuges, the overall purpose of our study was to estimate the value of selected ecosystem services as a case study (Patton et al., 2012, 2013). Valuation of economic goods and services provided by wetlands has been the subject of extensive research over the past few decades (Brander et al., 2006, 2013; Brouwer et al., 1999; Ghermandi et al., 2010, Moeltner and Woodward, 2009; Woodward and Wui, 2001). Many of the early wetlands valuation studies focused on commercial fishing, recreational fishing and hunting, and avoiding property damages from storms and floods. Only relatively recently have economists, often in collaboration with ecologists, attempted to measure the economic value of complex ecosystem services supported by wetlands such as carbon storage and climate regulation.

Many previous studies conducted by ecologists and other physical scientists have estimated carbon storage by wetlands in physical units (for an overview and reviews of this literature, see Bridgham et al. (2006), Chmura (2003), Kayranli et al. (2010), Mitra et al. (2005), and Mitsch et al. (2013)). However, as indicated in the next section, studies which have taken the next step of assigning dollar values to carbon storage are relatively few in number. This paper helps to fill this literature gap.

The next section of this paper presents the study methodology for estimating the economic value of carbon storage provided by National Wildlife Refuge wetlands. This section is followed by a reporting of results for each refuge. Limitations of the empirical methodology and results are then discussed. We then compare, contrast and comment on valuation results across our four case-study refuges. Finally, implications and conclusions are presented.

2. Methodology

Given the limited time frame and research project budget, it was not possible for us to randomly select National Wildlife Refuges to include in our case study. In consultation with our U.S. Fish and Wildlife Service cooperators, including both economists and biologists, we picked four case-study refuges selected for their geographical, climatic, and ecological diversity. Policy and management issues of current interest to the U.S. Fish and Wildlife Service was another selection consideration. For example, one of the reasons the Blackwater National Wildlife Refuge in Maryland was selected is because of current threats to marshes in the refuge from global climate change and sea level rise. One of the reasons the Sevilleta & Bosque del Apache National Wildlife Refuges in New Mexico were selected was because in combination they represent a connected warm, dry ecosystem with relatively few wetlands (thus, leading to an interest in protecting and potentially adding to existing wetlands in these refuges). The other two refuges selected for our study are the Arrowwood National Wildlife Refuge in North Dakota, a cold, wet ecosystem, and the Okefenokee National Wildlife Refuge in Georgia, a warm, wet inland swamp ecosystem.

Ideally, a wetland carbon storage valuation study would use primary data for both economic value and quantity (Plummer, 2009). For example, the quantity of carbon stored in a particular wetland area (say, Wetland Area A) would be estimated by field studies conducted in Wetland Area A which measure the amount of carbon stored above and below ground by plants and soil in this area. The measured quantity of stored carbon would then be multiplied by an economic value per unit of carbon stored estimated from primary data specific to Wetland Area A (e.g., carbon market prices or social costs of carbon estimated using data specific to Wetland Area A and affected human populations). No carbon storage valuation studies we are aware of have followed this ideal approach.

Another carbon storage valuation approach is to use primary data for either economic value or quantity, and secondary data for the other. The Jenkins et al. (2010) and Ibarra et al. (2013) studies are examples of this type of study. In the Jenkins et al. (2010) study, primary carbon storage data were collected on multiple plots to measure and scale up carbon stored by wetlands on agricultural lands in the overall study area. Secondary data on carbon storage value obtained from the IPCC Fourth Assessment Report (IPCC, 2007) were used to monetize the aggregate carbon stored. In the Ibarra et al. (2013) study, primary carbon storage data were collected on one experimental plot to measure and scale up carbon stored by urban wetlands in the overall study area. The spot price of carbon under the Clean Development Mechanism under the Kyoto Protocol (IPCC, 2007) was used to monetize the aggregate carbon stored.

In empirical situations, funds and/or time are often not sufficient to permit collection of primary data on both economic value and quantity. In such cases, carbon storage valuation follows a third approach of using secondary data for both economic value and quantity. Gascoigne et al. (2011), Hansen (2009), Ingraham and Foster (2008), Pandey et al. (2004), and Zhang and Lu (2010) followed this third approach.

As discussed above, the U.S. Fish and Wildlife Service has a desire and need for information on the economic value of ecosystem services supported by National Wildlife Refuges including carbon storage. Also as discussed above, the preferred approaches for estimating the economic value of carbon storage would involve the use of primary data for estimating units of carbon stored in an ecosystem and/or the value per unit of carbon stored. However, in our study, the U.S. Fish and Wildlife Service did not have the funds or time needed for primary data collection. Consequently, we used the third carbon storage valuation approach discussed above.

Our study represents a unique and improved application of the third carbon storage valuation approach in a number of ways. For their quantity measure, Gascoigne et al. (2011), Hansen (2009), Pandey et al. (2004), and Zhang and Lu (2010) used acres (or hectares) of generic wetland land-use types Ingraham and Foster (2008) used generic wetland land-use types adjusted with a primary productivity parameter for their quantity measure. To