Environmental Science & Policy 60 (2016) 28–37

Contents lists available at ScienceDirect

Environmental Science & Policy

journal homepage: www.elsevier.com/locate/envsci

A distributional analysis of the socio-ecological and economic determinants of forest carbon stocks

José R. Soto[a,*], Francisco J. Escobedo[b], Damian C. Adams[a], German Blanco[c]

[a] School of Forest Resources and Conservation, University of Florida, P.O. Box 110410, Gainesville, FL 32611, USA
[b] Functional and Ecosystem Ecology Unit – Biology Program, Faculty of Natural Sciences and Mathematics, Universidad del Rosario, Kr 26 No 63B-48, Bogotá D.C., Colombia
[c] Economics Department, Illinois State University, Campus Box 4200, Normal, IL 61790, USA

ARTICLE INFO

Article history:
Received 24 July 2015
Received in revised form 24 February 2016
Accepted 24 February 2016
Available online xxx

Keywords:
Carbon sequestration
Distributional impacts
Quantile regression
Forest inventory and analysis
Ecosystem services

ABSTRACT

Forest carbon (C) sequestration is being actively considered by several states as a way to cost-effectively comply with the forthcoming United States (US) Environmental Protection Agency's rule that will reduce power plant C emissions by 32% of 2005 levels by 2030. However, little is known about the socio-ecological and distributional effects of such a policy. Given that C is heterogeneous across the landscape, understanding how social, economic, and ecological changes affect forest C stocks and sequestration is key for developing forest management policies that offset C emissions. Using Florida US as a case study, we use US National Forest Inventory Analysis and Census Bureau data in both linear regression and quantile regression analyses to examine the socio-ecological and economic determinants of forest C stocks and its relationship with differing communities. Quantile regression findings demonstrate nonlinearity in the effects of key determinants, which highlight the limitations of regularly used mean-based regression analyses. We also found that forest basal area, site quality, stand size, and stand age are significant ecological predictors of carbon stocks, with a positive and increasing effect on upper quantiles where C stocks are greater. The effect of education was generally positive and mostly significant at upper quantiles, while the effects of income and locations with predominantly minority residents (as compared to whites) were negative. Upper quantiles were also affected by population age. Our findings underscore the importance of considering the broader socio-ecological and economic implications of compliance strategies that target the management of forests for carbon sequestration and other ecosystem services.

1. Introduction and background

Under the 2014 Clean Power Plant (CPP) rule proposed by the United States (US) Environmental Protection Agency (EPA), states must collectively reduce carbon (C) emissions from coal-fired power plants by 32% of 2005 levels by 2030, with state-specific targets defined by historic emissions and other factors (EPA, 2015). As part of these emissions reduction targets, the EPA has indicated that states will have flexibility in developing emissions compliance portfolios that best fit their needs. Importantly for forest landowners, the EPA has explicitly stated that C sequestration from forestry and agriculture may be included in these portfolios, and that the new policy will reinforce existing regional greenhouse gas programs such as the Regional Greenhouse Gas Initiative (RGGI), California's "Global Warming Solutions Act" (AB32), and Colorado's "Clean Air, Clean Jobs Act"—all of which include forest C offsets.

Collectively, US forests have tremendous potential to offset C emissions, likely accounting for 15% (979.3 $TgCO_2$) of total US emissions reductions (EPA, 2014). Several regional and national studies have found that using forests to capture Greenhouse Gas (GHG) emissions merits serious consideration from both policy makers and landowners (e.g., Adams et al., 1999; Lubowski et al., 2006; Qureshi et al., 2012) given the expected marginal costs of forest C sequestration relative to other C emissions reduction approaches (Charnley et al., 2010). Indeed, forest-based C sequestration is considered an important, relatively low cost approach to mitigating C emissions (Pacala and Socolow, 2004;

* Corresponding author. Fax: +1 3528461277.
E-mail addresses: josesoto@ufl.edu, nogalitos@hotmail.com (J.R. Soto), franciscoj.escobedo@urosario.edu.co (F.J. Escobedo), dcadams@ufl.edu (D.C. Adams), gblanco@ilstu.edu (G. Blanco).

http://dx.doi.org/10.1016/j.envsci.2016.02.015
1462-9011/

Parks and Hardie, 1995; Adams et al., 1999; Nielsen et al., 2014; Markowski-Lindsay et al., 2011; Stavins, 1999; Richards and Stokes, 2004; Escobedo et al., 2010).

Currently, forests cover approximately one third of all U.S. land area (Smith et al., 2009), largely concentrated in several southern, northeastern, and northwestern states. Given their share of total land area in these states, even small changes in forest policy or forest product markets can affect regional economies and community dynamics. Forests in the southeastern US are being lost due to urban development, socio-economic changes, increasing land values, and other disturbances such as climate change (Brown and Nowak, 2012).

Managing forests for C requires information on ecological disturbance regimes, stand characteristics, species diversity, and other influential drivers (Wardle et al., 2003; Luyssaert et al., 2008). Recent studies have identified areas in the state of Florida with high forest C stocks, or hotspots, (Timilsina et al., 2013; Cademus et al., 2014) and several influential determinants including: forest type, site quality, stand age, location in periurban and conservation areas, and silvicultural treatments. Other factors known to drive C stocks include disturbance regimes and species diversity (Wardle et al., 2003; Luyssaert et al., 2008). Changes in forest management can subsequently have significant impacts on the communities where these forests grow (Jindal et al., 2008; Caplow et al., 2011), raising serious concerns about the social, economic, and ecological aspects of forest C sequestration projects (Brown and Corbera, 2003).

Studies have also analyzed landowner and socioeconomic characteristics associated with particular forest management practices and related ecosystem services (Beach et al., 2005; Joshi and Arano, 2009; Fischer and Charnley, 2010; Kaetzel et al., 2012; Miller et al., 2012; Szantoi et al., 2012; Stein et al., 2013). Joshi and Arano (2009) for example identified the demographic, tenure and forest stand characteristics that influence forest management characteristics. In their reviews, Beach et al. (2005) and Fischer and Charnley (2010) found that income, education, age, owner proximity as well as forest site quality, growing stock and plot size have been found to affect forest management behavior.

However, despite the need for such research, very little emphasis has been placed on identifying the socio-ecological and economic factors that affect forest C stocks, or understanding the impacts that C sequestration policy changes will have on communities. As lawmakers develop programs to achieve C emissions reductions, it is important to consider the broad socio-ecological context of increasing forest C sequestration, to ensure that forest C policy choices align with more traditional economic and social development goals (e.g., ecosystem services, environmental justice, voter referendums).

In this study, we econometrically assess the potential distributional effects of important socio-ecological and economic determinants of forest C stocks in Florida US. We employ socio-economic data from the U.S. Census and plot-level ecological data from the USDA Forest Service's National Forest Inventory Analysis program in both linear regression and quantile regression (e.g., Damette and Delacote, 2012) models to predict the social, ecological, and economic determinants of forest C stocks along a C-poor to C-rich gradient.

2. Materials and methods

2.1. Study area

Florida is one of the fastest growing states in the US with a highly urbanized population of 19.9 million residents (Smith et al., 2011). The state grew by nearly 2.8 million residents between 2000 and 2010, with sixteen counties doubling in size during this period. Despite this, Florida is also heavily forested, with forests comprising approximately half of the state's land area and more than half of the counties are over 50% forested, and forest area alone grew by 2.63% from 2007 to 2010 (Brown and Nowak, 2012). Under the proposed EPA Clean Power Plan rule, Florida will need to cut roughly 26% of 2012 power plant CO_2 emissions by 2030 (EPA, 2015). Given the state's forest resources, forest C sequestration can likely play a strong role in the state's emissions reduction portfolio.

Florida has a mean annual temperatures range from 16 to 25 °C and mean annual precipitation ranges of 1000–1600 mm (McNab

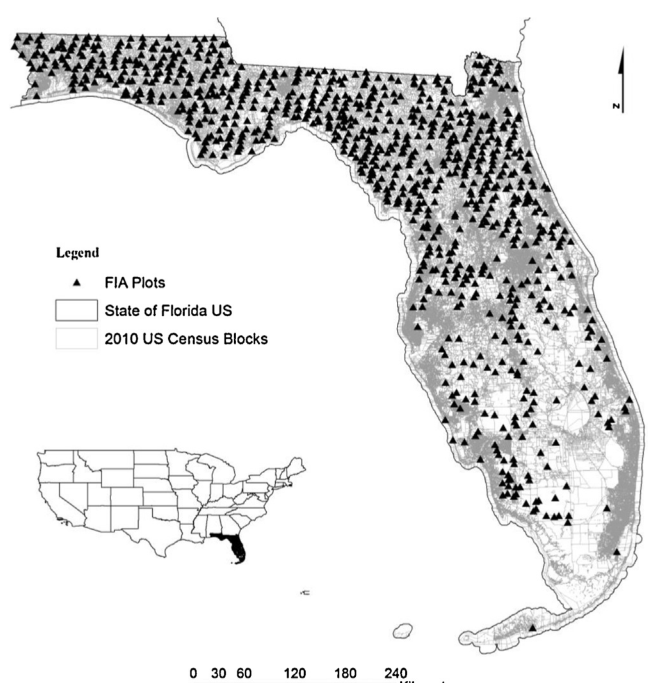

Fig. 1. USDA Forest Service Forest Inventory and Analysis (FIA) plots and US Census blocks in Florida.