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Land use, land use change and soil carbon sequestration in the St. Johns River Basin, Florida, USA

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ABSTRACT

Land use change is widely recognized as a net source of greenhouse gas emissions at the global scale. Most of these emissions are attributed to losses from aboveground terrestrial pools such as deforestation. However, much less is known about the effects of land use change on soil carbon pools at regional scales. To address this problem, relationships between soil organic carbon (SOC), land use/land cover (LULC) classes, and LULC change were investigated at the regional scale. A legacy soil survey was used in conjunction with a new, contemporary sampling campaign to determine SOC change through time. Together, the two datasets cover an approximate 40-year time period (1965 to 2009). The greatest densities of SOC were documented in wetland classes. Specifically, soils of Hardwood Swamp, Cypress Swamp, and Mixed Urban consisted of both residential Wetland Forest contained 9.8, 9.5, and 7.8 g C m^{-2}. In regard to absolute storage, or SOC stocks, Hardwood Swamp, Pineland, and Urban ranked highest and contained 14.4, 13.3, and 9.9 Tg C, respectively. The effect of LULC change was mixed, and resulted in both gains and losses of SOC at the field scale. At the regional scale, median SOC increased by 16.9 g C m^{-2} yr^{-1}. Urbanization of natural landscapes resulted in the largest rate of sequestration, which increased SOC by 37.1 g C m^{-2} yr^{-1}. The largest losses were documented in LULC classes converted from Improved Pasture to Rangeland, which decreased SOC by 8.5 g m^{-2} yr^{-1}.

1. Introduction

Anthropogenic activities have led to a dramatic increase in the concentration of atmospheric carbon-dioxide (CO_2) and other greenhouse gases (GHGs), which in turn has increased radiative forcing and contributed to global warming (Prentice et al., 2001; Shine and de Forster, 1999). As a result, many countries have begun developing policies to mitigate anthropogenically induced global warming and subsequent changes to climate (Fischer and Newell, 2008). One such strategy aims to mitigate anthropogenic emissions by increasing the carbon sink and storage capacity of the terrestrial biosphere through proper land use management (Lal, 2014; Schimel, 1995). However, the amount and rate at which carbon can be transferred from the atmosphere to the terrestrial biosphere is not yet fully understood. Despite this uncertainty, it is clear that the terrestrial biosphere plays a critical role in the carbon cycle by actively exchanging carbon with the atmosphere, serving as both a sink and a source for carbon.

Globally, the terrestrial biosphere serves as a net carbon sink (−1.6 Pg C yr^{-1}) (Ciais et al., 2014). However, emissions from land use change represent a significant source of carbon (0.9 Pg C yr^{-1}), accounting for approximately 17% of anthropogenic GHG emissions (Ciais et al., 2014). Since the 1980s, the majority of these emissions have been attributed to deforestation in the tropics and the subtropics, a trend that is expected to continue in order to keep up with the growing demand for food as the world's population is expected to surpass 9 billion by mid-century (Godfray et al., 2010). This is an important consideration, as tropical and subtropical ecosystems have been estimated to store more carbon in vegetation and soils (combined) than any other ecosystem (Eglin et al., 2010). The majority of this carbon is stored below ground as soil organic carbon (SOC), with turnover times ranging from years to thousands of years (Parton et al., 1987).

In undisturbed conditions, the soil carbon pool is considered to be in a state of equilibrium as sources and sinks balance one another over relatively short time scales (Fearnside and Barbosa, 1998). Across large geographic regions, this equilibrium depends primarily on vegetation type and productivity, which in turn is governed by climate and the soil forming factors first described by Dokuchaev (Glinka, 1927) and popularized by Jenny (1941). Additional factors, such as genoform (McBratney et al., 2003) and anthropogenic activities (Grunwald et al., 2011b) also influence SOC. Land use change, which often results in changes to land cover, has the potential to disrupt this equilibrium, causing soils to act as a source or sink of carbon until a new equilibrium is reached (Watson et al., 2000).

Identifying relationships between SOC, land use and land cover (LULC) can provide important information for predicting the effects of

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LULC change on SOC pools. Additionally, this information can be used for developing policy and management guidelines that mitigate anthropogenic GHG emissions. The tropics and sub-tropics represent one of the largest areas of uncertainty in regard to carbon dynamics, as it is not yet clear if these soils serve as a net sink or source for carbon (Baker et al., 2004; Clark, 2004). The state of Florida provides an excellent opportunity to study these relationships due to its unique environmental, climatic, and socio-economic conditions. Florida ranks highest in terms of SOC storage among conterminous U.S. (Guo et al., 2006). Much of this carbon is at risk of being transferred to the atmosphere via deforestation, land clearing, and other forms of LULC change driven largely by an increasing population, which is expected to increase 80% by 2030, surpassing 28 million people (U. S. Census Bureau, 2005).

Considering the amount of carbon stored in Florida's soils in addition to its risk of being transferred to the atmosphere via LULC change, it is imperative to gain a better understanding of relationships between soils and LULC, as well as the effects of LULC change on soil carbon pools in this region. The primary objectives of this study were to i) identify relationships between SOC and LULC classes across a large subtropical region in Florida based on contemporary soil survey and ii) assess the effects of LULC change on SOC dynamics over a 40-year time period by utilizing legacy data.

2. Materials and methods

2.1. Study area

This study was conducted in the Lower, Middle and Upper St. Johns River Basins as well as the Ocklawaha River Basin of Florida, located between latitudes 30.48° to 27.51°N and longitudes −82.43° to −80.74°W (Fig. 1). The region has a subtropical climate, receiving approximately 1224 mm of precipitation annually with a mean annual temperature of 20.5 °C (National Climatic Data Center, 2011). Elevation within the study area is flat to mildly undulating and ranges from below

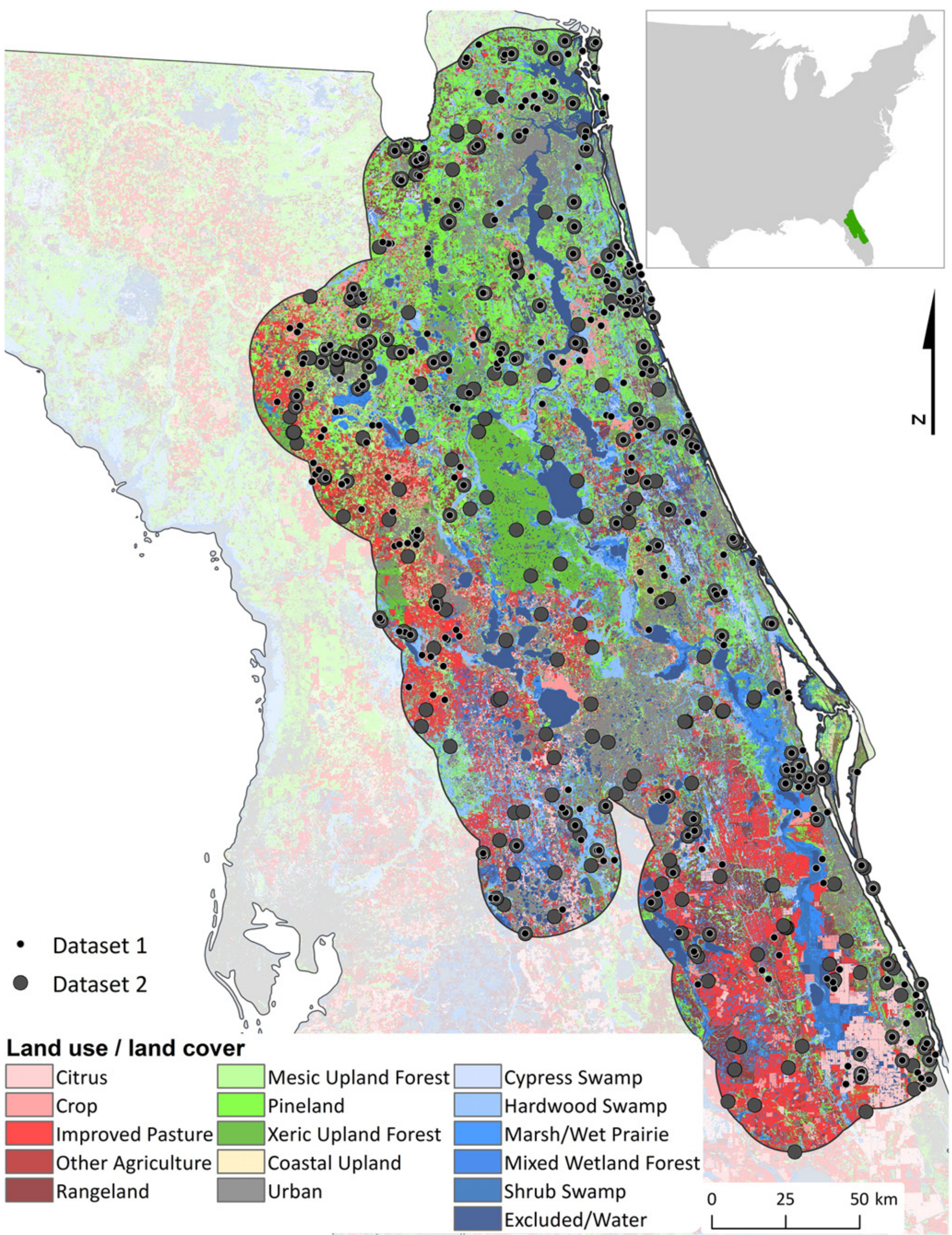

Fig. 1. The study area displaying the spatial distribution of legacy (Dataset 1) and current (Dataset 2) soil survey overlying the land use/land cover classes adapted from Stys et al., 2004.