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Predicted soil organic carbon stocks and changes in Jordan between 2000 and 2030 made using the GEFSOC Modelling System

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Abstract

Estimates of soil organic carbon (SOC) stocks and changes under different land use systems can help determine vulnerability to land degradation. Such information is important for countries in arid areas with high susceptibility to desertification. SOC stocks, and predicted changes between 2000 and 2030, were determined at the national scale for Jordan using The Global Environment Facility Soil Organic Carbon (GEFSOC) Modelling System. For the purpose of this study, Jordan was divided into three natural regions (The Jordan Valley, the Uplands and the Badia) and three developmental regions (North, Middle and South). Based on this division, Jordan was divided into five zones (based on the dominant land use): the Jordan Valley, the North Uplands, the Middle Uplands, the South Uplands and the Badia. This information was merged using GIS, along with a map of rainfall isohyets, to produce a map with 498 polygons. Each of these was given a unique ID, a land management unit identifier and was characterized in terms of its dominant soil type. Historical land use data, current land use and future land use change scenarios were also assembled, forming major inputs of the modelling system.

The GEFSOC Modelling System was then run to produce C stocks in Jordan for the years 1990, 2000 and 2030. The results were compared with conventional methods of estimating carbon stocks, such as the mapping based SOTER method. The results of these comparisons showed that the model runs are acceptable, taking into consideration the limited availability of long-term experimental soil data that can be used to validate them. The main findings of this research show that between 2000 and 2030, SOC may increase in heavily used areas under irrigation and will likely decrease in grazed rangelands that cover most of Jordan giving an overall decrease in total SOC over time if the land is indeed used under the estimated forms of land use.

Keywords: Jordan; Century; Roth-C; Soil organic carbon; Soil; Modelling

1. Introduction

Regional and global C budget quantifications need to include an understanding of SOC dynamics and SOC distribution at a regional level (Paustian et al., 1997). C sequestration can be indirectly assessed through the modelling of SOC content, which may complement direct measurements (Ardö and Olsson, 2003). Modelling helps in identifying areas with large potential for C sequestration. It also helps in predicting and understanding future changes due to climate change, land use change and different land management scenarios (Ardö and Olsson, 2003).

Roth-C (Jenkinson and Rayner, 1977) and Century (Parton et al., 1987) are the most widely used SOC simulation models. They have been tested against a variety

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of long-term agricultural field trials in a variety of climate zones, including arid and semi-arid regions. Roth-C requires fewer data inputs than Century and is, therefore, easier to parameterize. However, Roth-C only models soil processes and, consequently, plant residue C is a required input. Century is an ecosystem model that simulates biogeochemical fluxes of C, N, P and S, primary production and water balance on a monthly time step (Parton et al., 1988). The model supplies a tool for ecosystem analysis that enables an evaluation of changes in climate and the management of ecosystems (Ardö and Olsson, 2003). Both models have been used in many parts of the world as tools to predict C stocks and changes (Hill, 2003; Falloon and Smith, 2002; Ardö and Olsson, 2003; Jenkinson et al., 1999).

Past studies have used different approaches to integrate Century and Roth-C with spatially explicit databases via geographical information systems (GIS). Fallon et al. (1998) integrated the Roth-C model with GIS to illustrate the effect on SOM through an afforestation scenario in Hungary. Ardö and Olsson (2003) integrated GIS with the Century model to assess SOC in semi-arid Sudan. Refined estimates of potential SOC sources and sinks, including their variation in space and time, are possible through the linkage of dynamic simulation models and spatially explicit data (Ardö and Olsson, 2003). Lal (2002) emphasized that any assessment of soil C at different scales requires GIS and modelling.

This paper presents predicted SOC stocks and stock changes (for the years 2000–2030) made for Jordan at the national scale using the GEFSOC Modelling System. This newly developed system links spatially explicit data with two soil C models (Century and Roth-C) and an empirical method for estimating SOC stock changes (the IPCC method) in a GIS environment. Further details of the development and utilisation of the system are given by Easter et al. (2007).

2. Background information on the study area

The study area comprised the whole of Jordan. Jordan is a relatively small country (89,342 km^2) located in the eastern Mediterranean region between 29°–32°N latitude and 34°–39°E longitude (Fig. 1). The country is bordered on the north by Syria, to the east by Iraq and by Saudi Arabia on the east and south. To the west is Israel and the occupied West Bank, while Jordan's only outlet to the sea, the Gulf of Aqaba, is to the south. However, Jordan's diverse terrain and landscape belie its actual size, demonstrating a variety of landscapes and agro-ecologies, usually found only in large countries.

For the purpose of this study, Jordan has been divided into three main geographic and climatic areas:

1. The Jordan Valley, which extends down the entire western flank of Jordan, is the country's most distinctive natural feature. The Jordan Valley forms part of the Great Rift Valley of Africa, which extends from southern Turkey through Lebanon and Syria to the salty depression of the Dead Sea, where it continues south through Aqaba and the Red Sea to eastern Africa. This fissure was created 20 million years ago by shifting tectonic plates.
2. The Uplands, which separate the Jordan Valley and its margins from the plains of the eastern desert. This region extends the entire length of the western part of the country. The highlands of Jordan host most of Jordan's

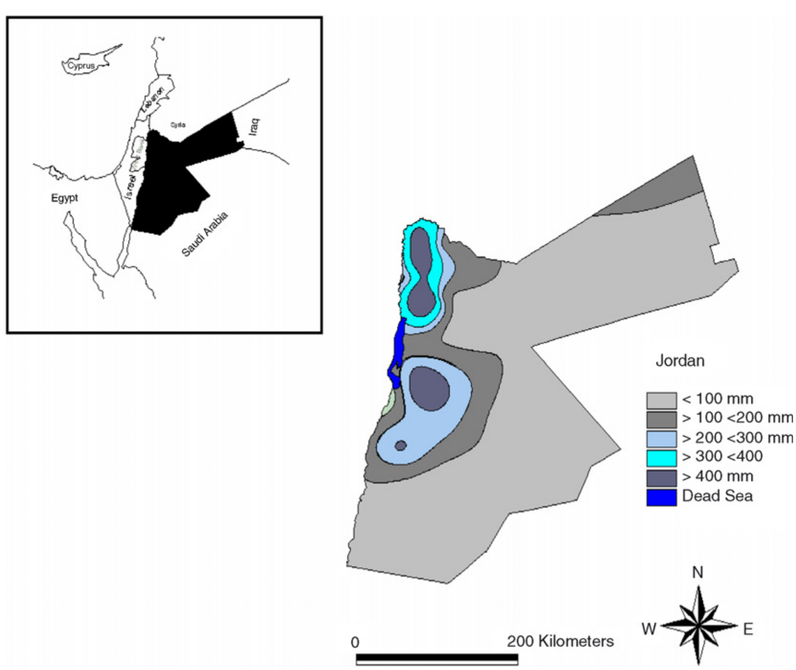

Fig. 1. The location of Jordan in relation to neighbouring countries and rainfall distribution.