Opportunity Costs of Supplying Soil C: Sensitivity to Estimated Soil C Rates

John Antle,[a] Susan Capalbo,[b] Siân Mooney,[c] Edward Elliott,[d] and Keith Paustian[e]

[a, b,c] *Department of Agricultural Economics and Economics, Montana State University*

[d] *School of Natural Resource Sciences, University of Nebraska*

[e] *Department of Soil and Crop Sciences and Natural Resource Ecology Laboratory*
Colorado State University

June 2002

Poster presented at the AAEA Annual Meetings, Long Beach, CA, July 28–31, 2002.

http://www.climate.montana.edu/pdf/poster.pdf

MONTANA STATE UNIVERSITY BOZEMAN

John Antle
Susan Capalbo
Siân Mooney
Montana State University

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Edward Elliot
University of Nebraska
Keith Paustian
Colorado State University

Introduction

In a market for greenhouse gases, the competitiveness of US agricultural producers as suppliers of carbon-credits depends on the marginal costs and quantities of soil carbon (C) that can be sequestered. Economic and ecosystem models can be used together to estimate the marginal costs of soil C sequestration and the quantity of C credits that can be sequestered within a given region[1, 2]. The objective of this study is to examine the sensitivity of estimated marginal cost functions to changes in the predicted rates of C sequestration. We consider 3 soil C scenarios – a base scenario that uses estimates of soil C sequestration developed in previous work[2]; scenario 1 in which soil C rates are increased by 50 percent and scenario 2 in which soil C rates are decreased by 50 percent. The results of this project are important for C measurement considerations within the emerging market for GHG mitigation credits.

Models and Methods

An economic production model is coupled to Century, a biophysical crop ecosystem model. These models are used to quantify producer responses to economic incentives for sequestering soil C (Fig. 1). Century provides estimates of the levels of soil C and productivity (yields) associated with each production system using soil and climate data. The economic production model uses economic data including prices and costs of production. These economic parameters are joined with yields from the biophysical model and used to estimate site specific expected returns from alternative production systems in response to policies that pay producers to change land use or management practices. These expected returns are used to simulate the farmer's choice of production systems.

Incentive Design

Producers are encouraged to change their management practices to those that sequester additional soil C through a policy that pays producers for each hectare of land they switch to a management practice thought to increase soil C. Payment levels that range from $5/hectare to $50/hectare are used as inputs into the economic production model (Fig. 1). The integrated model then calculates the implied marginal cost per tonne of soil C.

Study Area and Data

Statistically representative data on field level inputs and production practices were collected from three grain producing regions of Montana (Fig. 2). In addition, soils and climate data were collected as inputs to Century and used to model the processes controlling crop growth, water, nutrient, and organic matter dynamics that determine the productivity of agricultural ecosystems[3].

Acknowledgements

We would like to thank Leslie Jones for producing this poster. This research is funded by USDA/NRICGP Grant # 00-35400-9144 and NSF/MMIA Grant # BCS-9980225.

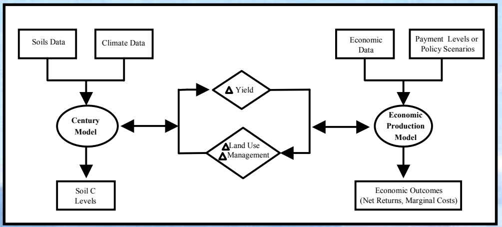

Figure 1. Linkage between Century Model and Economic Production Model

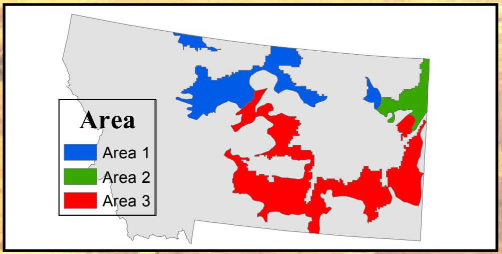

Figure 2. Three Resource Areas in Central and Eastern Montana

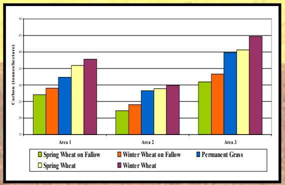

Figure 3. Soil Levels Predicted by the Century Model for Cropping Systems in Montana

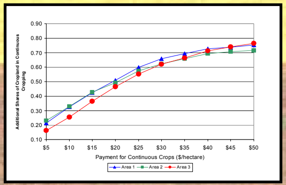

Figure 4. Additions to the Share of Cropland in Continuous Cropping by Area: Base Scenario

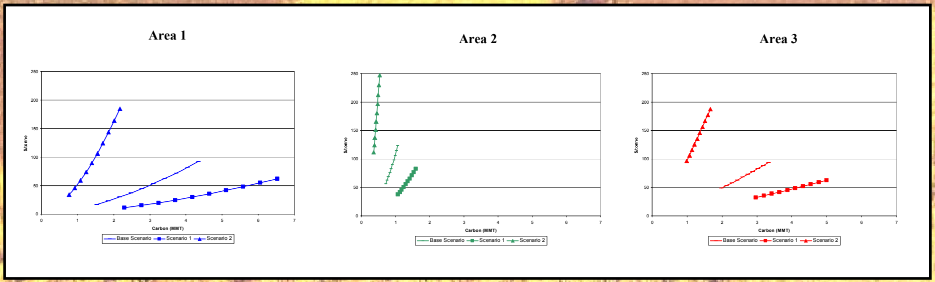

Figure 5. Marginal Cost Curves for Soil C – All Scenarios

Biophysical Results

Simulations of seven crop fallow, continuous cropping, and permanent grass production systems by Century show that the equilibrium levels of soil C under a crop fallow rotation are about 3–6 tonnes per hectare less than continuous grass over a twenty year period (Fig. 3). In addition, soil C levels under permanent grass are 3–5 tonnes per hectare less than under continuous cropping. Fig. 4 shows the simulated changes in land use shares for each area as per-hectare payments for C credits increase. All areas exhibit a similar pattern of land use change under the per hectare policy, reflecting the fact that the opportunity cost of switching from crop fallow or grass to a continuous cropping system is fairly similar. The total amount of soil C sequestered varies depending upon the size of the area, land use, and the ability of each cropping system to sequester soil C.

Economic Results

The marginal cost of sequestering soil C for scenarios 1 and 2 for each area are shown in Fig. 5 and can be used to infer information about the cost and quantity of soil C that could be sequestered under the per hectare policy.

Area 1: At a marginal cost of approximately $50 per tonne C, the quantity of soil C sequestered over 20 years varies from just under 3.0 million tonnes in the base scenario to over 6.0 million tonnes in scenario 1 and less than 1.0 million in scenario 2.

Area 2: Under the base scenario and scenario 2, producers would not participate in a C market unless the price per tonne C exceeds $50. Thus the variation in the amount of soil C that would be sequestered at this price is zero to 1.0 million tonnes over the twenty year period.

Area 3: The amount of C sequestered at a marginal cost of $50 per tonne under the base scenario doubles to 4.0 million tonnes under scenario 1, while a comparable percentage decrease in estimates of soil C rates results in zero participation from producers and zero levels of soil C under scenario 2.

Conclusions

Changing the soil C rates used in the economic production model changes the quantity of soil C sequestered per unit of land placed in a per hectare program, and changes the marginal cost per tonne of soil C. Marginal costs increase in proportion to the square of the increase in soil C rates. Thus, the accuracy of soil C estimates could play a critical role in the emerging market for C credits because this affects both the competitiveness of the agricultural sector as a mitigator of GHG, and the estimates of the total amount of C that could be sequestered. This argues for better measurement of soil C rates as well as an increased focus on frameworks that integrate economic and biophysical models.

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