Value of soil inorganic carbon in the U.S. based on liming replacement costs

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ABSTRACT

Soil inorganic carbon (SIC) is a naturally occurring liming material that regulates soil pH. One simple means to determine the value of SIC is based on the replacement cost approach, whereby commercial limestone would be needed to replace SIC. The objective of this study is to assess the replacement cost of SIC in the contiguous United States (U.S.) by depth, state, region, and land resource region (LRR) using State Soil Geographic database (STATSGO)-derived SIC information reported by Guo et al. (2006). An average 2014 U.S. price of $10.42 per ton of commercial limestone was used in all calculations. Over the depth 0-200 cm, replacement costs of SIC were valued at $5.17T and $0.70 m^{-2}, respectively, for the contiguous U.S. with a trend of SIC value increasing with depth. States having the highest nominal SIC replacement costs were ranked: 1) Texas ($1.84T), 2) New Mexico ($0.36T), and 3) Montana ($0.33T). Normalized by area, the rankings were: 1) Texas ($2.78 m^{-2}), 2) Utah ($1.72 m^{-2}), and 3) Minnesota ($1.35 m^{-2}). Regions with the highest nominal SIC replacement costs were: 1) South Central ($1.95T), 2) West ($1.23T), and 3) Northern Plains ($1.01T), while area-averaged rankings were: 1) South Central ($1.80 m^{-2}), 2) Midwest ($0.82 m^{-2}), and 3) West ($0.63 m^{-2}). Land resource regions (LRR) with the highest SIC value were: 1) D ($1.10T), 2) H ($0.93T), and 3) M ($0.64T), while nominal area-averaged rankings were: 1) I ($3.33 m^{-2}), 2) J ($2.83 m^{-2}), and 3) H ($1.59 m^{-2}).

INTRODUCTION

- Soil inorganic carbon (SIC) has value as a natural liming material. For example, SIC contributes to soil pH buffering, thus affecting the range of nutrient availability.

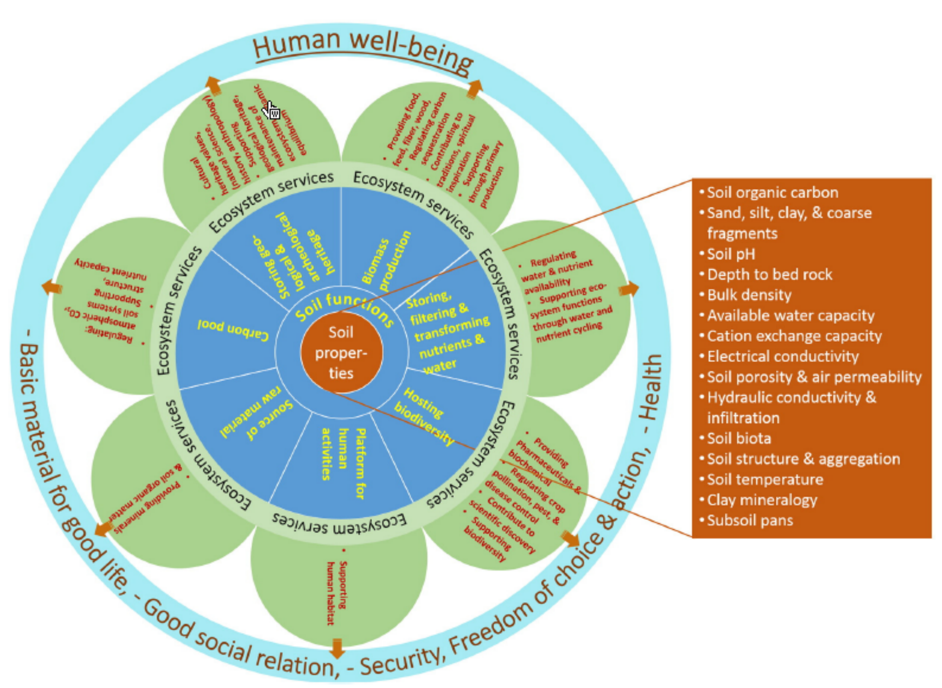

Figure 1. Soil ecosystem services and soil properties (Adhikari and Hartemink, 2016).

OBJECTIVES

- The objective of this study is to assess the replacement cost of SIC in the contiguous United States (U.S.) by depth, state, region, and land resource region (LRR) using data that Guo et al. (2006) derived from the STATSGO (State Soil Geographic) database.

MATERIALS AND METHODS

Calculating the value of SIC content and storage

- Data reported by Guo et al. (2006) for midpoint SIC content and storage were converted to U.S. dollars to represent the cost of replacing the naturally-occurring SIC with commercial agricultural limestone, $CaCO_3$, at the average 2014 U.S. price of $10.42 per ton.

$$\$ = (SIC\ Storage,\ g) \times \frac{100\,g\,CaCO_3}{12\,g\,SIC} \times \frac{1\,lb_m}{453.59\,g} \times \frac{1\,U.S.ton}{2000\,lb_m} \times \frac{\$\,price}{U.S.ton\,CaCO_3} \quad (1)$$

$$\$/m^2 = (price\ from\ eqn.\ 1) \times \frac{1}{area\ in\ km^2} \times \frac{1\,km^2}{10^6\,m^2} \quad (2)$$

RESULTS AND DISCUSSION

Value of SIC in the regions and states

- Total and area-averaged nominal values of SIC in the U.S. are highest in the West and mid-regions of the country. In contrast, Eastern U.S. regions have the lowest values of SIC (Figure 2).

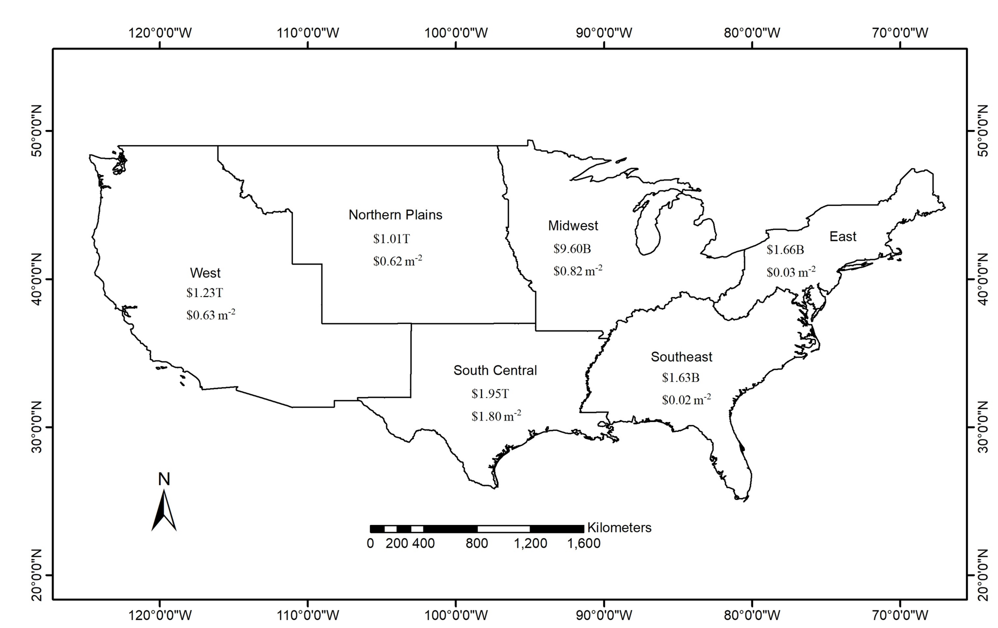

Figure 2. Replacement costs of soil inorganic carbon in different regions of the United States. For each region, the top number is total cost and the bottom number is cost per area.

- States with high nominal SIC replacement costs on an area-averaged basis are: Texas, Utah, New Mexico (Figure 3).

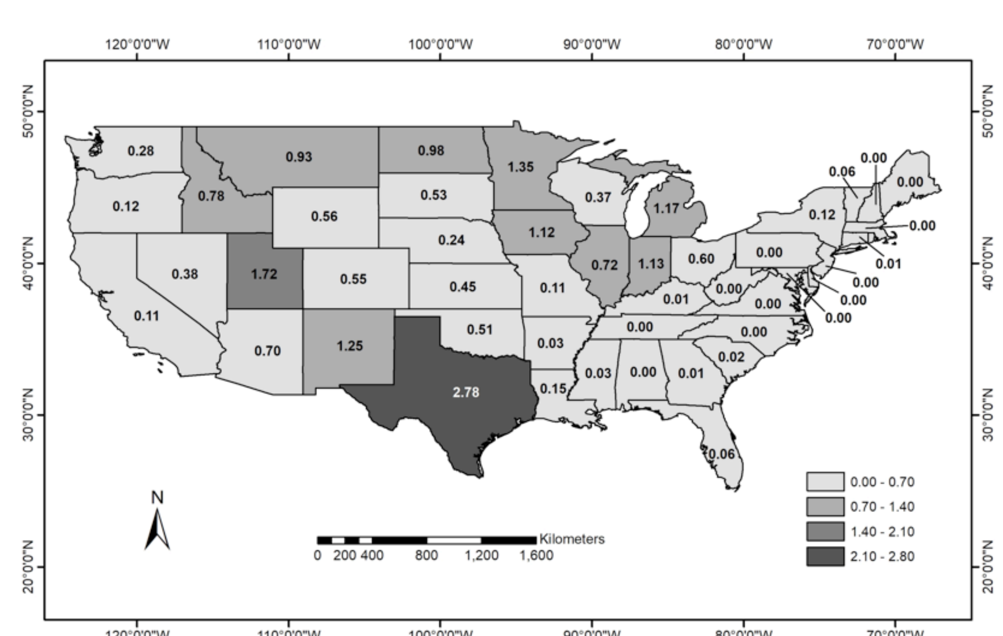

Figure 3. Nominal area-averaged replacement cost values ($ m^{-2}) for soil inorganic carbon in the different states.

RESULTS AND DISCUSSION

Value of SIC in the soil orders

- Soil orders with the highest nominal values for SIC are located in the Great Plains, Central Midwest and arid regions (Groshans et al., 2018) (Table 1).

Table 1. Value of soil inorganic carbon in the soil orders of the contiguous United States (Groshans et al., 2017).

Orders	Midpoint total storage (10^6 Mg) (Guo et al., 2006)	Value of midpoint total SIC storage* and ranking ($)	Midpoint total SIC content (kg m^{-2}) (Guo et al., 2006)	Value of midpoint total SIC content* and ranking ($ m^{-2})
Alfisols	5461	5.23E+11 (3)	4.3	0.41 (6)
Andisols	2	1.91E+8 (9)	0.0	0.00 (-)
Aridisols	12890	1.23E+12 (2)	15.9	1.52 (2)
Entisols	5112	4.89E+11 (4)	4.8	0.46 (5)
Histosols	260	2.49E+10 (7)	2.4	0.23 (7)
Inceptisols	4006	3.83E+11 (5)	5.1	0.49 (4)
Mollisols	23181	2.22E+12 (1)	11.5	1.10 (3)
Spodosols	149	1.43E+10 (8)	0.6	0.06 (8)
Ultisols	0	0 (-)	0.0	0.00 (-)
Vertisols	3075	2.94E+11 (6)	23.2	2.22 (1)

* Based on national average of $10.42 price per ton of $CaCO_3$ lime in U.S. (2014)

- Aridisols have the highest nominal SIC value within a 0-20 cm depth and second highest within 0-100 cm.
- Vertisols have the highest SIC value within a 0-100 cm depth and second highest within 0-20 cm.
- Mollisols have the third highest SIC value for both the 0-20 cm and 0-100 cm depths.

Table 2. Spatial value of SIC in the soil orders of the contiguous United States.

Orders	Mean SIC in 0-20 cm depth (kg m^{-2}) (Guo et al., 2006)	Value of mean SIC in 0-20 cm depth* and ranking ($ m^{-2})	Mean SIC in 0-100 cm depth (kg m^{-2}) (Guo et al., 2006)	Value of mean SIC in 0-100 cm depth* and rankings ($ m-^{2})
Alfisols	0.03	0.00 (-)	1.36	0.13 (6)
Andisols	0.01	0.00 (-)	0.02	0.00 (-)
Aridisols	1.50	0.14 (1)	9.49	0.91 (2)
Entisols	0.76	0.07 (4)	3.30	0.32 (4)
Histosols	0.01	0.00 (-)	0.91	0.09 (7)
Inceptisols	0.43	0.04 (5)	3.11	0.30 (5)
Mollisols	0.77	0.07 (3)	5.56	0.53 (3)
Spodosols	0.00	0.00 (-)	0.17	0.02 (8)
Ultisols	0.00	0.00 (-)	0.00	0.00 (-)
Vertisols	1.41	0.13 (2)	10.67	1.02 (1)

* Based on national average of $10.42 price per ton of $CaCO_3$ lime in U.S. (2014)

Value of SIC by depth

- Replacement cost values for both total and area-averaged SIC increase with soil depth (Table 3)
- Nominal total and area-averaged values for SIC over the total soil depth reported (0-200 cm) are $5.18E+12 and $0.70 m^{-2}, respectively.

Table 3. Total and area-averaged SIC replacement cost values in the contiguous U.S. by soil depth.

Depth (cm)	Midpoint total SIC storage, 10^8 Mg (Guo et al., 2006)	Value of midpoint total SIC storage and ranking ($)	Midpoint total SIC content, kg m^{-2} (Guo et al., 2006)	Value of midpoint total SIC content and ranking ($ m^{-2})
0-20	41	3.92E+11 (3)	0.56	0.05 (3)
20-100	240	2.30E+12 (2)	3.26	0.31 (2)
100-200	260	2.49E+12 (1)	3.53	0.34 (1)
Total (0-200)	541	5.18E+12	7.34	0.70

* Based on national average of $10.42 price per ton of $CaCO_3$ lime in U.S. (2014)

RESULTS AND DISCUSSION

Value of SIC in the Land Resource Regions (LRR)

- The Land Resource Regions (LRR) with the highest nominal total and area-averaged SIC replacement cost values are in the Southwestern and mid-regions of the U.S. (Tables 4 and 5).

Table 4. Total and area-averaged nominal replacement cost values of soil inorganic carbon in the Land Resource Regions (LRR) of the contiguous United States.

LRR	Area (km^2)	Midpoint total SIC storage (10^4 Mg) (Guo et al., 2006)	Value of midpoint total SIC storage* and ranking ($)	Midpoint total SIC content (kg m^{-2}) (Guo et al., 2006)	Value of midpoint total SIC content* and ranking ($ m^{-2})
A	181,215	166	1.59E+8 (19)	0.0	0.00 (-)
B	259,284	204258	1.96E+11 (8)	7.9	0.76 (8)
C	146,884	5989	5.73E+9 (16)	0.4	0.04 (15)
D	1,268,922	1148860	1.10E+12 (1)	9.1	0.87 (7)
E	521,442	193339	1.85E+11 (10)	3.7	0.35 (11)
F	583,820	418782	4.01E+11 (5)	11.9	1.14 (4)
G	169,689	369138	3.53E+11 (7)	7.1	0.68 (9)
H	139,624	967082	9.26E+11 (2)	16.6	1.59 (3)
I	300,269	590386	5.65E+11 (4)	34.8	3.33 (1)
J	119,997	413207	3.96E+11 (6)	29.6	2.83 (2)
K	717,615	197945	1.89E+11 (9)	6.6	0.63 (10)
L	603,434	140490	1.34E+11 (11)	11.7	1.12 (5)
M	94,652	663473	6.35E+11 (3)	9.2	0.88 (6)
N	677,160	5365	5.14E+9 (17)	0.1	0.01 (17)
O	300,536	19869	1.90E+10 (13)	2.1	0.20 (13)
P	99,147	4862	4.65E+9 (18)	0.1	0.01 (18)
R	231,303	7656	7.33E+9 (15)	0.3	0.03 (16)
S	99,147	65	6.22E+7 (20)	0.0	0.00 (-)
T	231,303	54611	5.23E+10 (12)	2.4	0.23 (12)
U	85,410	8458	8.10E+9 (14)	1.0	0.10 (14)

* Based on national average of $10.42 price per ton of $CaCO_3$ lime in U.S. (2014)

- Land Resource Region 'I' has the highest spatial value for both depths measurements of 0-20 cm and 0-100 cm.
- Land Resource Region 'J' has the second highest value for both depth measurements of 0-20 cm and 0-100 cm.

Table 5. Spatial value of SIC in Land Resource Regions (LRR) of the contiguous United States.

LRR	Number of soil components	Mean SIC in 0-20 cm depth (kg m^{-2}) (Guo et al., 2006)	Value of mean SIC in 0-20 cm depth* ($ m^{-2}) and ranking	Mean SIC in 0-100 cm depth (kg m^{-2}) (Guo et al., 2006)	Value of mean SIC's in 0-100 cm depth* ($ m^{-2}) and ranking
A	3040	0.00	0.00 (-)	0.01	0.00 (-)
B	5465	0.44	0.04 (7)	4.48	0.43 (7)
C	4621	0.03	0.00 (15)	0.24	0.02 (15)
D	17318	1.11	0.11 (3)	5.73	0.55 (5)
E	9142	0.28	0.03 (9)	2.37	0.23 (11)
F	4378	0.53	0.05 (6)	7.28	0.70 (3)
G	6555	0.73	0.07 (5)	4.61	0.44 (6)
H	6613	0.75	0.07 (4)	6.54	0.63 (4)
I	1460	4.46	0.43 (1)	19.47	1.86 (1)
J	1285	2.80	0.27 (2)	15.53	1.49 (2)
K	4608	0.09	0.01 (11)	2.72	0.26 (10)
L	1939	0.07	0.01 (13)	3.75	0.36 (8)
M	9413	0.28	0.03 (10)	3.39	0.32 (9)
N	10048	0.01	0.00 (16)	0.04	0.00 (-)
O	2038	0.05	0.00 (14)	1.1	0.11 (12)
P	9791	0.01	0.00 (17)	0.03	0.00 (-)
R	7708	0.01	0.00 (18)	0.08	0.01 (16)
S	2183	0.00	0.00 (-)	0.00	0.00 (-)
T	3100	0.09	0.01 (12)	0.99	0.09 (13)
U	542	0.32	0.03 (8)	0.87	0.08 (14)
Weighted average within LRR.s		0.56	0.05	3.82	0.37

* Based on national average of $10.42 price per ton of $CaCO_3$ lime in U.S. (2014)

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