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Research Article

Estimating Soil Carbon Reservoir of the Yellow River Basin in China

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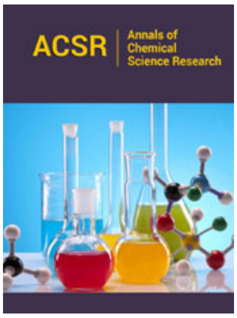

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Abstract

Soil carbon bank of the Yellow River basin in China was estimated, by using the total carbon concentration and organic carbon content in the top and deep soil, and soil type and bulk density data. The results show that, from 2010 to 2018, the organic carbon reserves and the total carbon reserves of surface soil in the Yellow River basin increased by 581×106t and 692×106t. And the total carbon reserves and the total carbon reserves of deep soil in the Yellow River basin increased by 803×106t and 596×106t. It is indicated that the soil carbon reserves in the Yellow River basin have a large increasing trend between 2010 and 2018. This result can provide reference for the study of ecological environment change in China and the world.

Introduction

The issue of global environmental change has attracted increasing attention from more and more countries, due to implementation of the International Geosphere-Biosphere Program (IGBP) initiated in 1980. The study of global change has aroused the attention of many scientists on the carbon balance, carbon storage and distribution in the terrestrial ecosystem, because the carbon stored in soil is about 2.5~3 times that in vegetation [1,2]. The carbon construction is an extremely important ecological factor in the global biogeochemical cycle, which has been well used in environment-ology, ecology, soil science, geography, etc. Therefore, the characteristic of distribution and transformation of soil carbon has become a research hotspot and one of the core contents of international global change research now [3]. This paper depicts a successful example for estimating soil carbon reservoir for study of global environmental change, which can be used as a reference for future environmental conservation studies.

The Yellow River is the second longest river in China with a basin area of about 894,000 square kilometers. The average elevation is over 4000 meters in the western area, which consists of a series of alpine mountains and glacial landform development. The elevation is between 1000 meters and 2000 meters in the central loess region. Due to serious land erosion, degradation and desertification, the carbon and biomass stored in the soil has been reduced obviously.

This paper aims to reveal the formation mechanism of change degree and trend of soil carbon reserves in the Yellow River Basin through the comparative study of carbon storage in 2010 and 2018 and to provide scientific basis for the study of ecological environment change in the Yellow River Basin.

Materials

The data used in this study is from the China Geochemical Benchmark Program [4]. One top-soil sample and one deep soil sample were collected from two catchment basins in each sampling grid (about 80km×80km) at the same time. In order to improve the representation of the samples, all sampling points were deployed according to watershed, with the area of each catchment basins ranging from 1000 square kilometers to 5000 square kilometers, and most of them ranging from 2000 square kilometres to 3000 square kilometres. The surface samples were collected from soil layer A (0-25cm), and the deep samples were collected from the soil layer below 100cm or the soil layer C. Each top sample was gathered from six sub-sites within 100 m of the designed sampling point. Samples were collected twice in 2010 and 2018 respectively, with a total of 455 sampling points in this area (Figure 1) and 910 samples were collected. Flood plain sediment or alluvial plain soil was collected in the eastern hilly and plain areas. Floodplain sediments were collected in the southwest alpine cutting area. The low-lying sediments of the basin were collected in the northern arid Gobi Desert area. Seasonal dry lake (quagmire) deposits were collected in the inner river basin of semi-arid grassland.

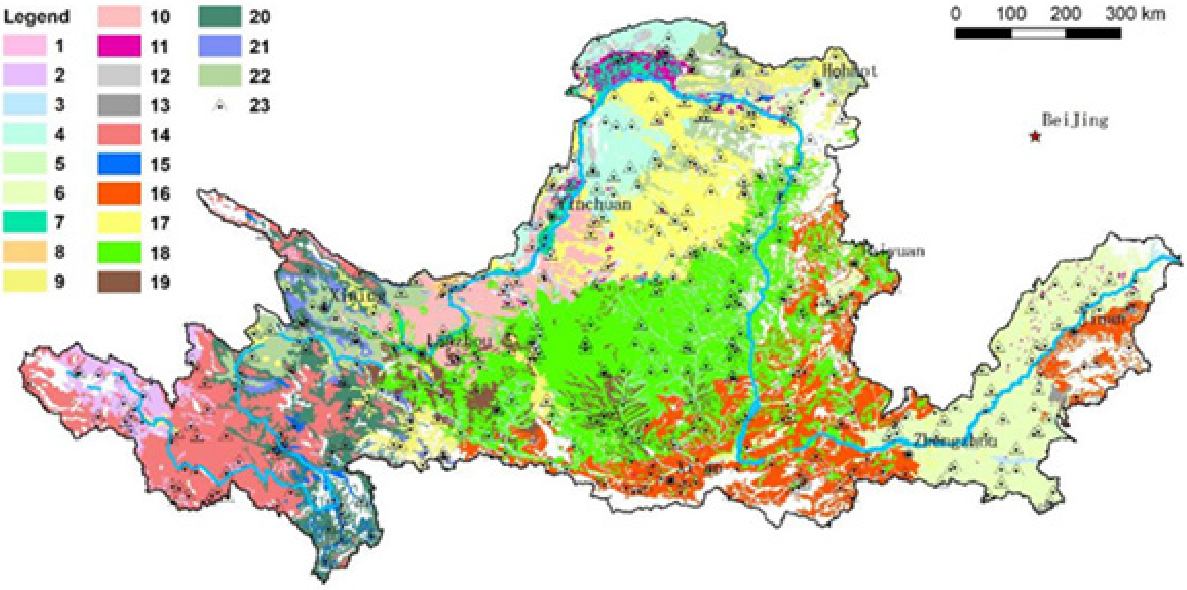

Figure 1: Map of sampling sites
1.Frigid plateau solonchaks; 2.Frigid calcic soils; 3.Alluvial soils; 4.Brown pedocals; 5.Paddy soils; 6.Fluvo-aquic soils; 7.Cumulated irrigated soils; 8.Gray-browndesrt soils; 9.Grey-cinnamon soils; 10.Sierozem; 11.Solonchaks; 12.Litho soils; 13.Lime concretion black soils; 14.Felty soils; 15. Meadow soils; 16. Cinnamon soils; 17. Aeolian soils; 18. Cultivated loessial soils; 19. Dark loessial soils; 20. Dark felty soils; 21. Chernozems; 22 Castanozems; 23.CGB sampling site.

All the samples were first air-dried at room temperature. After drying, the samples were sieved and gathered the size fraction of <2mm. Then, each of the <2mm samples was ground to <0.074mm. The analytical procedures followed those in the RGNR guidelines [5]. Certified reference materials (CRMs) developed by IGGE [6,7], equal to about 8% of the total samples, were inserted randomly into each batch of 50 samples and analyzed along with field samples. Organic carbon was determined by oxidative pyrolysis-potential method (POT). Total carbon was determined by oxidative pyrolysis-gas chromatography method (GC). The detection limits of organic carbon and total carbon are both 1% .

Method of calculation

First, according to the actual survey information of 455 points, the calculated thickness and the soil types involved were determined. The final surface layer thickness was determined to be 0.3m, an deep layer thickness was 1.5m. Secondly, GIS method was used to determine the area of each soil type involved in this work [8]. Soil bulk density at each sampling site was gathered from the Harmonized World Soil Database (HWSD) constructed by Food and Agriculture Organization of the United Nations (FAO) and Vienna International Institute for Applied Systems (IIASA) [9]. When the bulk density contains many different values in a soil type , the arithmetic mean value is taken. Finally, carbon storage in the Yellow River Basin can be calculated as:

$$M_c = \sum \left(Ci \times Si \times Di \times \rho i \times a \right) \qquad (1)$$

where Mc is the calculated carbon reserve value (t), Ci is the carbon content (%) of class i soil type, Si is the area of class i soil type (km^2), Di is the sample's collection depth (m) in class i soil type, ρi is the average soil bulk weight (g/cm^3) in i soil type, and a is the conversion coefficient, the value of a is 104.

Results and Discussion

The results of soil carbon storage estimation in the Yellow River Basin are shown in Table 1. It can be seen that the area of soil types sampled accounts for 88% of the total area of the Yellow River Basin, and a small part of soil types are not covered. The organic carbon reserves of topsoil and deep soil accounted for 49% and 32% of the total carbon reserves respectively in 2018. While the organic carbon reserves of topsoil and deep soil accounted for 45% and 30% of the total carbon reserves respectively in 2010. It indicates that the proportion of organic carbon in this area is smaller than that in other areas of China [10], which is consistent with the results of soil desertification, less vegetation cover on the surface and less organic carbon stored in the Yellow River Basin.

Table 1: Note: CGB: China Geochemical Baselines; T: Top; D:Deep

		CGB2010_T								CGB2010_D					CGB2018_T				CGB2018_D		
Type	N	S	TC	Corg	ρ	Mtc	Morg	D_ TC	Corg	ρ	Mtc	Morg	N	TC	Corg	Mtc	Morg	TC	Corg	Mtc	Morg
		/km2	/%	/%	$/g\cdot cm^{-3}$	106t	/106t	/%	/%	$/g\cdot cm^{-3}$	106t	/106t		/%	/%	/106t	/106t	/%	/%	106t	/106t
meadow soil	1	6868	2.05	0.59	1.38	58.3	16.8	2.05	0.59	1.39	294	84.5	6	2.03	1.49	57.7	42.3	1.52	0.67	218	95.5
Felty soils	22	71480	2.32	1.77	1.58	786	601	1.39	0.79	1.58	2365	1339	7	2.20	1.64	745	557	1.48	0.97	2514	1645
Fluvo-aquic soils	44	10352	1.92	0.89	1.46	873	406	1.51	0.36	1.45	3401	816	26	2.20	1.05	977	464	1.80	0.50	3971	1107
Aeolian soils	18	64042	0.90	0.22	1.64	284	68.4	1.13	0.24	1.65	1791	378	10	0.80	0.30	261	98.8	0.90	0.27	1472	435
Cumulated irrigated	7	9565	1.38	0.56	1.48	58.6	23.8	1.04	0.19	1.48	220	41.2	4	2.32	0.72	110	34.2	1.76	0.27	410	63.1
soils																					
Frigid plateau	1	4874	2.94	1.37	1.61	69.2	32.3	2.57	1.17	1.61	303	138	1	2.79	2.81	65.7	66.2	1.65	1.78	194	210
Frigid calcic soils	8	16371	2.51	1.16	1.58	195	90.0	2.00	0.68	1.58	776	262	6	1.89	0.60	150	47.5	1.58	0.42	626	167
Cinnamon soils	28	87954	2.34	1.14	1.43	880	431	1.62	0.64	1.41	3016	1192	9	1.92	1.19	756	471	1.35	0.62	2531	1170
Chernozems	5	8255	1.89	0.57	1.36	64.0	19.1	1.99	0.52	1.38	340	88.5	2	2.20	0.99	73.7	33.1	2.46	1.11	414	186
Dark loessial soils	11	19446	1.69	0.28	1.41	139	23.0	1.71	0.21	1.37	681	82.8	1	2.36	0.33	192	26.9	2.36	0.33	951	133
Dark felty soils	20	45926	2.52	1.51	1.40	487	291	2.16	1.04	1.40	2093	1009	2	3.63	2.35	753	488	1.88	0.72	1944	742
Cultivated loessial	49	16624	1.91	0.63	1.43	135	450	1.59	0.28	1.39	5520	964	21	1.84	0.56	1331	403	1.53	0.19	5273	658
Sierozem	13	34010	1.15	0.29	1.42	167	41.9	1.11	0.26	1.40	791	184	4	1.87	0.62	268	89.0	1.29	0.24	910	169
Grey-cinnamon soils	12	23834	2.03	0.76	1.50	217	80.8	2.00	0.83	1.37	976	406	4	3.13	1.90	343	208	3.03	1.39	1474	678
Gray-browndesrt	3	1486	1.22	0.29	1.37	7.47	1.75	0.89	0.22	1.35	26.9	6.52	1	0.66	0.02	4.02	0.15	0.72	0.03	21.8	0.78
Castanozems	18	42579	1.12	0.40	1.43	205	73.9	1.00	0.31	1.44	919	280	9	2.47	1.27	466	239	1.34	0.34	1255	319
Lime concretion	1	2555	2.95	0.92	1.55	35.0	10.9	3.99	0.50	1.50	229	28.7	1	1.41	1.51	14.7	15.7	2.54	0.76	128	38.2
black soils																					
Litho soils	6	11640	1.07	0.32	1.38	51.3	15.5	0.82	0.11	1.37	197	26.4	2	1.38	0.29	72.7	15.2	1.90	1.16	501	305
Paddy soils	1	1296	0.84	0.50	1.38	4.51	2.68	0.26	0.10	1.39	7.02	2.70	1	1.07	1.09	5.80	5.91	0.48	0.48	13.0	12.9
Alluvial soils	14	29331	2.13	1.06	1.53	286	142	1.32	0.31	1.52	884	207	28	1.78	0.62	235	81.6	1.42	0.31	932	205
Solonchaks	6	8790	1.03	0.60	1.32	35.7	21.0	1.06	0.35	1.31	182	59.7	2	1.76	0.38	60.9	13.0	1.63	0.28	277	47.4
Brown pedocals	11	28705	0.94	0.22	1.41	115	26.7	1.41	0.21	1.39	844	125	9	1.06	0.42	128	50.9	0.70	0.22	424	135
Total	299	78876	\	\	\	637	2869	\	\	\	25858	7721	15	\	\	7069	3449	\	\	2645	8524

The results show that the total carbon reserves and the organic carbon reserves of surface soil in the Yellow River basin increased 692106 tons and 581106 tons from 2010 to 2018 respectively. The total carbon reserves and the organic carbon reserves of deep soil in the Yellow River basin increased 596106 tons and 803106 tons from 2010 to 2018 respectively. It indicates that both topsoil and deep soil carbon reservoir in the Yellow River Basin have an increasing trend during the two working times, which means the Yellow River basin is a carbon sink and organic carbon sink is the main source of total carbon sink.

Organic carbon in soil refers to humus, animal and plant residues and microorganisms formed by microbial action. Surface vegetation can bring a large amount of organic carbon input to soil. Based on the special geographical location and geomorphic type of the Yellow River Basin, soil and water loss in this region is easy and soil carbon storage is continuously lost. However, through the unremitting efforts of human beings, according to China Ecological Governance Development Report (2020-2021) [11], it is believed that the ecosystem of the Yellow River Basin is continuously improving at a high speed. Some scholars have comprehensively evaluated the status of ecosystem quality in the Yellow River Basin from 2000 to 2018 based on the remote sensing ecological index [12] and the results shows that the improvement of ecosystem quality in the Yellow River Basin in recent 20 years is much higher than the degradation, and the ecosystem quality in the Yellow River Basin will be mainly improved in the future, and the continuous improvement will inevitably lead to carbon sink. which has been confirmed in this calculation results. The calculation results in our study is in good agreement with this point also.

Conclusion

In conclusion, the carbon storage in the Yellow River Basin increased from 2010 to 2018. This study directly proves that the regional ecosystem quality in the Yellow River Basin has been improved. This study will provide a scientific basis for explaining and predicting the improvement of ecosystem in the region.

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