INTERPOLATING THE INFORMATION OF SITE-BASED SOIL ORGANIC CARBON STOCKS INTO SURFACE: A CASE STUDY IN THE NORTH CHINA PLAIN

Jinyan Zhan¹, Nana Shi¹, Xiangzheng Deng²,³, Hongbo Su³, Dongsheng Qiu³

¹. Beijing Normal University, No 19, Xinjiekouwai Street, Beijing, 100875, 86-10-59893226, zhanjy@bnu.edu.cn; ². Center for Agricultural Policy, Chinese Academy of Science, No. 11A, Datun Road, Anwai, Beijing, 100101 China; ³. Institute of Geographic Science and Natural Resources Research, Chinese Academy of Science, No. 11A, Datun Road, Anwai, Beijing, 100101, 86-10-64888980, 86-10-64856533, dengxz.ccap@igsnrr.ac.cn, suhb@igsnrr.ac.cn, qiuds@lreis.ac.cn

ABSTRACT

It is of great significance to understand the spatial variability of soil organic carbon (SOC) stocks of North China Plain which is one of the most important grain production bases in China. In this paper, we use Kriging interpolation method to generate a surface using the site-based SOC stocks in North China plain and then analyze the spatial variability of carbon SOC stocks. The surface data on the SOC stocks offers the one of the most important reference information to support the carbon management.

Keywords— SOC stocks, spatial variability, North China Plain, Kriging interpolation method

1. INTRODUCTION

It is of great importance to understand the spatial variability of Soil Organic Carbon (SOC) stocks at the regional scale which affects the ecosystem and agro-ecosystem function by influencing soil fertility, water holding capacity and many other factors in the top soil, and also of global importance due to its role in the global carbon cycle and therefore, the part it plays in the mitigation or worsening of atmospheric levels of green gases. But the exact size and distribution of SOC stock is still difficult to determine quantitatively because the information of the SOC stocks, however, is commonly derived from the site-based soil survey which could not offer a sufficient and detailed database to generate a surface of soil organic matter. Some experts has explore the spatial variability and estimate the SOC stock in many developed nations, for example, USA, etc (Kamoni et al., 2007), while others illustrated more detailed influencing factors and their driving mechanism resulting in the changes of SOC stock over time and space in those fast developing regions, e.g., the China mainland (Huang et al., 1999). A case study conducted in the Amazon region discloses that there are spatial differences on the SOC stock due to the difference of the soil types, land uses, bulk density or other kind of soil information over space (Ney et al., 2008).

Past long-term experimental studies have shown that SOC is highly sensitive to changes in land uses, with changes from native ecosystems such as forest or grassland to agriculture system always resulting in a loss of SOC (Jenkinson 1977, Pau et al., 1997). So, one of the most important purpose of this paper is to supply some information on SOC stock, which is urgently needed for the soil carbon management under the condition that little is known concerning the spatial variability of SOC stock.

The case study area, North China Plain is based on the deposits of the Yellow River and is one of the largest alluvial plain of eastern Asia. The plain is bordered on the north by the Yanshan Mountains and on the west by the Taihang Mountains. To the south, it merges into the Yangtze Plain. From northeast to southeast, it fronts the Bohai Gulf, the highlands of Shandong Peninsula, and the Yellow Sea. The Yellow River flows through the middle of the plain into Bohai Gulf. The plain covers an area of about 409,500 square kilometers, 158,000 square miles, most of which is less than 50 m above sea level. This flat yellow-soil plain is the main area of sorghum, millet, maize, and cotton production in China. Wheat, sesame seed, peanuts and tobacco are also grown here (Huang et al., 2001). The cultivable land in North China Plain is about 1/5 of the total land of the entire China (Figure 1). The plain is one of the most densely populated regions in the world. As an essential indicator of soil quality, SOC and its fractions play an important role in soil chemical, physical, and stability in the North China plain. During the second round of soil survey, information on the SOC stock from 139 soil profile was collected.

Agro-ecological zoning defines zones on the basis of combinations of soil, landform and climatic characteristics. In order to clearly state the spatial variability of SOC stocks in North China Plain, we divided this area into nine agro-ecological zones (Figure 2).

Using the information from the second round soil survey across China, we interpolated the site-base information from the soil profile to get the surface data on SOC stock.
2. DATA AND METHODS

2.1 Data

The information of soil survey of China used in this paper was acquired in early 1980s, and there is no more other information of relative factors but the relative location of the soil profile recorded. Before being interpolated onto the spatial dimension, soil information is being geo-referenced.

2.2 Methodology

Currently, there are a couple of algorithms developed and used for the interpolation of the site-based information of SOC stocks (Deng et al., 2002, Deng et al., 2004). It includes mainly two kinds of methods: empirical or modeling methods. Empirical method is part of the scientific method and generally taken to mean the collection of data on which to base a theory or derive a conclusion in science. This method is characterized by the collection of a large amount of data before much speculation as to their significance, or without many idea of what to expect, and is to be contrasted with more theoretical methods in which the collection of empirical data is guided largely by preliminary theoretical exploration of what to expect. The empirical method is necessary in entering hitherto completely unexplored fields, and becomes less purely empirical as the acquired mastery of the field increases. Using empirical methods, total SOC stocks are estimated by the summation methods of all soil types.

Kriging interpolation method, used here, is one of the most popular and useful methods to predict unknown values from data observed at known locations, especially in geo-statistical. This method produces visually appealing map from irregularly space data and uses variogram to express trends suggested in the data. Take high points as example, they might be connected along a ridge contours rather than an in the type of “bull’s eyes”, one of the most important characteristics of the Inverse Distance to a Power Method, which means the method generate “bull’s eye” surrounding the observation position within the grid area. Specifically, the estimation of the unknown values in ordinary Kriging is based on a weighted linear combination of the available values and the sum of all the weights is just as the inverse distance method. What is different is that the weights using in this linear combination is defined to mostly minimize the variance of error which can be given by using a stationary function. Kriging can also be either an exact or a smoothing interpolator, depending on the user-specified parameters, which means it can not only generate smooth possible surface but also honor the data exactly. It interpolates anisotropy and underlying trends in an efficient and natural manner.

Compared with the Inverse Distance to a Power Method, one of the most popular and easy methods, Kriging interpolation method can control the variance of error, so it is more accurate. While Kriging interpolation method could not generate a possible surface as smooth as the Minimum Curvature Method which is widely used in the earth science, but the advantage is that this method is an exact interpolator, which means that the data are always honored exactly.

3. INTERPOLATION STRATEGIES

3.1 Main steps used to generate the surface data

There are mainly two steps to generate the soil profile information: geo-correcting and defining the parameters of soil profile information and using the arc command in ArcGIS software to generate the surface variables of soil information.

1) Geo-correct the soil profile information and define the project of the point coverage of soil profile in ArcGIS using define project command. All together, 139 soil profiles are geo-corrected. The projection is defined as the Albers projection.

2) Using the Kriging command in the Arc module to generate surface data of all kinds of climatic variables.

Before generating the final output surface, the GRAPH option should be used to help determine the most appropriate options. To interrupt the surface continuity, the barriers options which always significantly extend the processing time required to interpolate the output raster should be used to specify the location of linear feature known. Barrier features should be input in the LINE format and Kriging command will look for the barrier (cover or file) which must have at no less than 2 and no more than 2000 vertices and use it. The output Kriging gives contains the Kriging variance at each output raster cell. Assuming the Kriging errors are normally distributed, after calculation, we find that there is a 95.5 percent probability that the actual z-value at the cell is between the predicted raster value ± two times the square root of the value.

4. RESULTS

As one of the most important grain production base, North China Plain is featured by a relatively higher SOC stock in the top soil. The aggregated SOC stock at each one by one square kilometer grid pixel is ranged from 0.39% to 9.61%. The average SOC stock of North China plain is 1.21%, a slight lower than that of the average level of SOC stock for the entire China, 1.78%.

There are an obvious spatial difference on the SOC stock in North China plain (Figure 3 and Table 1) that is the values are much higher in the north and west than that in the south and east. According to the regional difference of SOC stock over the space, we divided the entire North China plain into a couple of zones with three levels. The highest level of region is Jing-Jin-Tang plain with an average value of 2.16% in the soil China. Taihangshan piedmont plain, Northern Anhui plain and Eastern Henan plain rank the second highest level region with an average
value of 1.29%, 1.25% and 1.22%, respectively. And the lowest level region is Huanghai plain, Jiaodong peninsula, Jiaozhong, Jiaoxi Yellow River flood plain hilly land and Xu-Huai plain with an average value of 0.79%, 0.76%, 0.88%, and 0.99%, respectively. The highest value of SOC stock is briefly identified as the same trend as that of the average values of SOC stock. The high value is up to 9.60% in the Jing-Jin-Tang plain and Taihangshan piedmont plain. And following it, the value of Eastern Henan plain is 5.81%. We can find that the max values in the other regions is rather low, it is only about 1%, which clearly illustrates the existence of a regional difference of the SOC stock between the north and the south, the east and the west of the North China Plain. The lowest value is around zero and three regions of all the nine regions, Jiaoxi Yellow River flood plain, Xu-Huai plain, Jing-Jin-Tang plain, is like this case.

5. CONCLUSION

In conclusion, a better understanding of the spatial variability of SOC stocks on the interpolated soil information is of great importance to improve the management of agricultural activities to improve the sustainable land uses. This paper provides a lot of detailed decision-making information on soil carbon management and constitutes a nation-wide baseline for studies on spatial variability of soil organic carbon. The spatial variability of SOC stock is interpolated by using Kriging interpolation method. This method can be used to simulate the spatial variability of SOC stocks.

The distribution of SOC stock in the north China plain illustrates an obvious regional difference. Jing-Jin-Tang plain, Taihangshan piedmont plain, Northern Anhui plain and Eastern Henan plain, these four regions, with much developed agricultural activities and higher population density, are rich in SOC stock.

Given that SOC stock, as an essential indicator of soil quality, plays an important role in soil chemical, physical, and stability, it is of great importance to understand the spatial variability of Soil Organic Carbon (SOC) stocks, closely related to the land use pattern and agriculture development at the regional scale, which will definitely offer most important reference data to support the decision-making in carbon management.

### Table 1. Statistics on levels of soil organic matter in the top soil by region

<table>
<thead>
<tr>
<th>Zone</th>
<th>Mean</th>
<th>SD</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jing-Jin-Tang plain</td>
<td>2.16</td>
<td>2.97</td>
<td>9.60</td>
<td>0.00</td>
</tr>
<tr>
<td>Huanghai plain</td>
<td>0.79</td>
<td>0.15</td>
<td>1.22</td>
<td>0.39</td>
</tr>
<tr>
<td>Taihangshan piedmont plain</td>
<td>1.29</td>
<td>1.35</td>
<td>9.60</td>
<td>0.86</td>
</tr>
<tr>
<td>Jiaozhong hilly land</td>
<td>0.76</td>
<td>0.11</td>
<td>1.04</td>
<td>0.39</td>
</tr>
<tr>
<td>Xajixi Yellow River flood plain</td>
<td>0.88</td>
<td>0.16</td>
<td>1.04</td>
<td>0.71</td>
</tr>
<tr>
<td>Xajixi Yellow River flood plain</td>
<td>0.73</td>
<td>0.11</td>
<td>1.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Jiaoxi Yellow River flood plain</td>
<td>0.99</td>
<td>0.29</td>
<td>2.22</td>
<td>0.00</td>
</tr>
<tr>
<td>Northern Anhui plain</td>
<td>1.25</td>
<td>0.11</td>
<td>1.87</td>
<td>0.91</td>
</tr>
<tr>
<td>Eastern Henan plain</td>
<td>1.22</td>
<td>1.04</td>
<td>5.81</td>
<td>0.58</td>
</tr>
</tbody>
</table>

6. REFERENCE


ACKNOWLEDGMENT

The financial supports from the National Natural Science Foundation of China (70503025), Chinese Academy of Sciences (kzcx2-yw-305-2; kscx2-yw-n-039), Ministry of Science and Technology of China (2006DFB919201; 2006BAC08B03; 2006BAC08B06) are appreciated. Any remaining errors and omissions are wholly the responsibility of the authors.