SOIL BULK DENSITY IN CROPLANDS OF NORTHEAST CHINA UNDER DIFFERENT LANDSCAPE ATTRIBUTES

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Abstract: It will be of importance for refining agricultural management and sustainable land use to understand the spatial variability and related factors of soil physical properties. The present study addressed the spatial distribution characteristics of bulk density (BD) and effects of landscape attributes in agricultural soils of typical County of Northeast China, using conventional statistics, geostatistics and Geographic Information Systems. Data from 101 locations were collected in a Jiutai County, Northeast China. Results showed that, BD in croplands of the study area generally follows a normal distribution. The experimental variogram of BD has been fitted with linear models. Although not significant at the 0.05 level, soil samples with smaller elevation have relatively higher bulk density than those with bigger elevation. Land use types significantly (P<0.05) affected BD values. Soil samples from dry farming land and from paddy field have higher BD values than those from vegetable land. In explanation, in this area, vegetable land is applied more manure to maintain soil fertility and increase vegetable output.

INTRODUCTION

Soil physical properties are usually recognized as important soil quality indicators (Karlen and Stott, 1994; Arshad et al., 1996; Boix-Fayos et al., 2001; Rezaei and Gilkers, 2005; Li and Shao, 2006). Soil physical properties and in turn plant growth are significantly controlled by variation in landscape attributes including slope, aspect, and elevation which influence the distribution of energy, plant nutrients, and vegetation (Buol et al., 1989; Tian et al., 2003; ). Almost all soil properties exhibit variability as a result of dynamic interactions between natural environmental factors (i.e., climate, parent material, vegetation, and topography; Jenny, 1941). Significant differences in soil physical properties in a small area on uniform geology are known to be related to landscape position (Jenny, 1941; Ruhe, 1956; Zhao et al., 1997; Rezaei and Gilkes, 2005).

Northeast China is one of the main agricultural regions in China. Its cultivated land and total crop yield now account for 19 and 30%, respectively, of the nation’s total. A better understanding of the spatial variability of soil properties is important for refining agricultural management practices and for improving sustainable land use (McGrath and Zhang, 2003). It provides a valuable base against which subsequent and future measurements can be evaluated. This study was to explore how soil bulk density are controlled by natural environmental factors and anthropogenic land use in agricultural soils of Northeast China, taking a representative county as a case study.
MATERIALS AND METHODS

Jiutai County (125°42′- 126°49′E, 43°85′- 44°61′N) is located in the middle part of Jilin Province, Northeast China (see figure 1). The county has an altitude between 147 and 580m with an area of 3376 km². The study area is characterized with a temperate, semi-humid continental monsoon climate. Seasons alternate between dry and windy springs, humid and warm summers with intensive rainfall, windy and dry autumns and long, cold dry winters. The mean annual temperature is about 4.8℃ and the average annual precipitation is 582 mm, with 82% occurring between May and September. The average of sunshine each year is 2571h and average wind speed is about 3.3ms⁻¹. The frost-free period is about 130-140d. In this county, the Second Songhua River, the Mushi River, the Wukai River and the Yinma River flow through the area and then into the Songhua River. The main soils are dark brown forest soil (Haplic Luvisol, FAO), meadow soil (Eutric Vertisol, FAO), aeolian soil (Arenosol, FAO), black soil (Luvic Phaeozem, FAO) and paddy soil (Hydrgric Anthrosol, FAO).

As an agricultural county, more than 70% of the total area of Jiutai County is used as cultivated land. In this study, the soil data were collected in a regional soil fertility investigation. A maximum of two sites were selected at random from each grid with area of 10 km². Samples of 0-20 cm depth from 101 sites were taken in late October 2004, after crops were harvested.

Among 101 points, 80 locations are for dry farming land under maize, 16 locations are for paddy fields and 5 locations are for vegetables. The five replicate samples were homogenized by hand mixing and were sieved after being air-dried. In this study, soil bulk density (BD) was measured with standard methods (Editorial committee, 1996). The locations of the cropland sampling sites are shown in Figure 1.

Some main statistical parameters, which are generally accepted as indicators of the central trend and of the data spread, were analyzed. They include description of the mean, standard deviation, variance, coefficients of variation and extreme maximum and minimum values. To decide whether or not data follow the normal frequency distribution, it may be sufficient to examine the coefficients of Skewness and kurtosis (Paz-Gonzalez et al., 2000). For a population that follows the normal frequency distribution, these coefficients should have values of 0 and 3, respectively. These statistical parameters were calculated with EXCEL 2000 and SPSS 8.0.

Geostatistics uses the semi-variogram to quantify the spatial variation of a regionalized variable, and provides the input parameters for the spatial interpolation. Detailed description of geostatistics could be found in lots of literatures (McGrath and Zhang, 2003; Zhang and
In our study, the geostatistical analyses were carried out with GS+ (version 3.1a Demo), and maps were produced with GIS software ArcView (version 3.2a) and its extension module of Spatial Analyst (version 2.0).

RESULTS AND DISCUSSION

We analyzed the quantitative parameters of the probability distribution and the significance level of the Kolmogorov-Smirnov test for conformance to a normal distribution for the variables. The BD data have rather small skewness (-0.002) and kurtosis (-0.828).

The coefficient of variation, standard deviation, and basic statistical parameters of percentiles and means are shown in Table I. BD has CV of 10.16%, which could be linked to the heterogeneity of land use pattern and landscape position. We can see that BD ranges from 1.00 to 1.59 Mg m\(^{-3}\), with the arithmetic mean of 1.28 Mg m\(^{-3}\). The geometric mean and median of BD are 1.28 and 1.30 Mg m\(^{-3}\), respectively.

<table>
<thead>
<tr>
<th>Variables</th>
<th>C.V.</th>
<th>S.D.</th>
<th>Min</th>
<th>5%</th>
<th>25%</th>
<th>Median</th>
<th>75%</th>
<th>95%</th>
<th>Max</th>
<th>Mean</th>
<th>GeoMean</th>
</tr>
</thead>
<tbody>
<tr>
<td>BD (Mg m(^{-3}))</td>
<td>10.16</td>
<td>0.13</td>
<td>1.00</td>
<td>1.07</td>
<td>1.18</td>
<td>1.30</td>
<td>1.38</td>
<td>1.49</td>
<td>1.59</td>
<td>1.28</td>
<td>1.28</td>
</tr>
</tbody>
</table>

For BD, the semivariogram model and best-fit model parameters are shown in Table II. BD shows a positive nugget, which can be explained by sampling error, short range variability, random and inherent variability. In general, the nugget-to-sill ratio can be used to classify the spatial dependence of soil properties (Cambardella et al., 1994). The variable is considered to have a strong spatial dependence if the ratio is less than 25%, and has a moderate spatial dependence if the ratio is between 25% and 75%; otherwise, the variable has a weak spatial dependence. In our study, the nugget-to-sill ratio of BD showed moderate spatial dependence (0.72), which might be attributed to intrinsic (soil-forming processes) and extrinsic factors (soil fertilization and cultivation practices).

<table>
<thead>
<tr>
<th>BD</th>
<th>Model</th>
<th>Range a (km)</th>
<th>Effective range (km)</th>
<th>Nugget</th>
<th>Sill</th>
<th>Nugget/Sill (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linear</td>
<td>121.10</td>
<td>21.10</td>
<td>0.0098</td>
<td>0.03477</td>
<td>71.8</td>
</tr>
</tbody>
</table>

We used GIS software Arcview© to analyze the spatial distribution of BD with different elevation. The samples were assigned to 3 elevation groups: class 1 (<200), class 2 (201-250) and class 3 (>250), based on which contour line the sampling location is close to.

To find whether the differences of BD among the elevation groups are significant, analysis of variance (ANOVA) was applied, as shown in Table 3. For raw data and log-transformed data of BD, the Levene tests showed that the variances between the groups of the data set are not homogenous at the significance level of 0.012 and 0.014, thus Duncan’s test can not be applied. Results of Tamhane showed that, the difference between the three groups is not significant (with all significance level bigger than 0.05), which indicated that in our study area, elevation is not a main factor in relation to the BD. Although not significant at the 0.05 level, soil samples from class 1 and class 2 elevation groups have relatively higher bulk density (1.29 and 1.28 Mg m\(^{-3}\), respectively) than that of samples from class 3 elevation.
group (BD is 1.28 Mg m$^{-3}$).

To explore impacts of slope on BD, the differences of values between samples under different slope were carried out. For BD, ArcView software was used to assign the samples of to 2 slope groups: group 1 (0-3°) and group 2 (>3°), and t-tests were done to compare mean values of the 2 groups (Table III).

TABLE 3: Results of Levene’s test and t-tests between samples under 0-3 slope degree and those under >3 slope degree

<table>
<thead>
<tr>
<th></th>
<th>Levene’s test for equality of variances</th>
<th>t-test for equality of means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Significance</td>
</tr>
<tr>
<td>BD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equal variances assumed</td>
<td>2.066</td>
<td>0.154</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>0.160</td>
<td>0.874</td>
</tr>
</tbody>
</table>

Results indicated that, for BD, the variances between the two data sets are homogenous at the significance level of 0.154, based on results of the Levene test. Thus, for BD, the t-value of 0.142 with “equal variances assumed” was used. The significance level of 0.887 for the 2-tailed test showed that there is no a significant difference between BD under 0-3 slope degree and those under >3 slope degree.

To find the effect of soil type on BD, comparison of data among soil samples from different soils was conducted. For raw data and log-transformed data of BD, the Levene test showed that the variances between the groups of the data set are not homogenous at the significance level of 0.010 and 0.014, thus Duncan’s test can not be applied. Then Tamhane method was adopted. Results of Tamhane showed that, the difference between the soil type groups is not significant (with all significance bigger than 0.05), which indicated that in our study area, soil type is not a main factor in relation to the BD.

In this study, the soil samples were from three land use types. One-way ANOVA was applied to explore effect of land use type on BD. Results of the Levene’s test show that the variances between groups are homogenous at the significance level of 0.643 and thus Duncan’s test can be applied. The three groups of samples can be separated into two subsets. The first subset contains samples from vegetable land, while the second subset consists of samples from dry farming land growing maize and those from paddy field. The differences within subsets are not significant at the 0.05 level, with significance levels of 1.000 and 0.372 (Table 4), respectively, whereas, the difference between the subsets is significant at the level of 0.005, with an F-value of 5.688. This result indicated that, in the study area, land use type is one of important reasons influencing soil bulk density. Soil samples from dry farming land and from paddy field have higher BD values than those from vegetable land. To explain, in the study area, for vegetable land, peasants often apply more manure to maintain the soil fertility and increase vegetables output. Accordingly, more income could be obtained.
Table 4: Results of post hoc tests in ANOVA with Duncan’s method (with mean values of BD of soils from different land use types)

<table>
<thead>
<tr>
<th>Land use type</th>
<th>n</th>
<th>S.D</th>
<th>Subset 1</th>
<th>Subset 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry farming land</td>
<td>80</td>
<td>0.1280</td>
<td>1.2849</td>
<td></td>
</tr>
<tr>
<td>Paddy field</td>
<td>16</td>
<td>0.1180</td>
<td>1.3331</td>
<td></td>
</tr>
<tr>
<td>Vegetable land</td>
<td>5</td>
<td>0.1078</td>
<td>1.1160</td>
<td></td>
</tr>
</tbody>
</table>

Significance level

1.000 0.372

The parameters of the Linear models were used for Inverse Distance Weighting (IDW) interpolation method to produce the spatial distribution map of BD in soils of study area. The final results of the spatial interpolation were shown in Figure 2. For BD, the data of the interpolated values ranges from 1.11 to 1.49 Mg m$^{-3}$. This is noticeably narrow than that of the raw data listed in Table 1, which is expected because of the smoothing effect of the spatial interpolation. However, this smoothing effect helps to identify the general spatial patterns and reduces the local variations and the negative effect of random errors. Comparison between spatial distribution map of BD and land use map of the study area can give us the information the spatial distribution of BD is to a certain extent consistent with different land use type, in line with results we obtained above.

![Fig. 2 Spatial distribution map of BD in Jiutai County, Northeast China](image)

**CONCLUSIONS**

The data of bulk density of agricultural soils in a typical county of Northeast China follow a normal distribution, with arithmetic means of 1.28 Mg m$^{-3}$. Relationships between soil physical properties and landscape attributes including elevation, slope, soil type and land use type were explored. Our study indicated that, among all these factors, land use type significantly affected BD values. It is essential to recognize the effects of landscape attributes on soil physical properties in Northeast China, as shown in the present study. Consequently, the results should be taken into account in soil fertility assessment and land use management.

**BIBLIOGRAPHY**