Regional difference for soil fertility after land consolidation in the Guanzhong Plain

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Abstract. Maintaining adequate soil nutrient in newly cultivated soil is critically important for crop growth. In this study, knowledge of the regional distribution patterns of soil organic matter (SOM), total nitrogen (TN), available phosphorus (AP) and available potassium (AK) factors of 565 soil samples from major land consolidation areas in the Guanzhong Plain in northwest of China, were investigated from 2012 to 2014. Soil organic matter content were found range from 2.3 g kg\(^{-1}\) to 36.7 g kg\(^{-1}\), with a corresponding total nitrogen content from 0.17 g kg\(^{-1}\) to 3.64 g kg\(^{-1}\), and 0.29 mg kg\(^{-1}\) to 55.7 mg kg\(^{-1}\) for soil available phosphorus, available potassium content between 22.7 mg kg\(^{-1}\) and 389 mg kg\(^{-1}\), respectively. Compared to the recommended land consolidation samples, SOM and TN content belongs to 2-3 level account for the largest proportion among all samples while AP and AK were the 3-4 standard predominantly. SOC was positively correlated with AP and AK content for all samples. For Each 1 g kg\(^{-1}\) increase in TN content resulted in a corresponding increase in SOC content of 0.5 g kg\(^{-1}\), each 1 g kg\(^{-1}\) increase in SOC content resulted in a corresponding decrease in AP content of 3.7 mg kg\(^{-1}\) and AK content of 0.28 mg kg\(^{-1}\) in the consolidated soil. Therefore efforts to simultaneously increase soil essential nutrient in order to achieve high standard farmland remain a challenging endeavor for farmers.

1. Introduction
Land-use practices affect the distribution and supply of soil fertility by directly altering soil properties and influencing biological transformations. Land consolidation is essential for ensuring rural development and increasing land use effectiveness [1, 2]. The variability Land consolidation is a worldwide phenomenon, which is not only important for increasing cultivated land areas, improving its quality and productivity, also enhancing production conditions and the ecological environment [3, 4, 5]. Ensuring national food security and promoting the general development of rural areas is also of great significance and, nowadays this work is vigorously promoted in China. Land consolidation is a
complicated engineering task which involves integration of farmland, water, roads, forests and village structures [6, 7].

Soil plays a key role in the global carbon cycle, which linking carbon transformation with the pedosphere, biosphere, and atmosphere [8]. Soil surveys generate spatial of soil classes, where the soil properties are estimated within a mapping unit [9]. Values for soil properties are predicted for the majority of locations in the region where the values are not actually measured [10, 11].

SOM indirectly contributes to soil structure by serving as a nucleus for aggregate formation [12]. It is generally understood that OM is greatly reduced and diluted with topsoil stripping and/or storage prior to mining from increased microbial activity and soil horizon mixing [13, 14]. A number of experts on soil carbon (C) have hypothesized that there is a large potential to sequester SOC in disturbed and degraded soils [15, 16]. Because these soils commonly have lost a large part of their SOM content as a result of disturbance or during the degradation process, there is the potential to replace this material through proper management. SOM plays a major role in soil productivity because it represents the dominant reservoir and source of plant nutrients such as N, P, K, it also influences pH and soil structure [17]. The profound benefits of SOM to soil fertility and its significance in global warming phenomena force us to intensify research activities on SOM dynamics in soils.

Therefore, an investigation was performed in major land consolidation sites of 2012, 2013, and 2014 in the Guanzhong Plain by collecting 565 samples to determine the following: (1) Whether the current essential nutrient could satisfy for the local plant growth; (2) The distribution of SOM, TN, AP and AK content across different land consolidation areas, and their relation.

2. Materials and Methods

2.1. Study area
This study covered the area of the Guanzhong Plain in the centre of Shanxi province, northwestern China (spanning from 33°9′38″-35°14′10″ and 106°5′6″-110°10′8″E). The average elevation of this region is approximately 400 m. The mean annual precipitation varied from 500 mm to 800 mm, and about 60% of the rainfall occurs between June and September. The annual mean temperature varies from 6 to 13°C. This area is subjected to water stress and drought condition, the study region has an area of 3.4×104 km2, which accounts for 36% of the province. The main soil types are cinnamon according to Chinese Soil Taxonomy.

2.2. Sampling sites
A total of 565 samples were selected, were collected from major consolidation areas in 2009 (n = 90), 2010 (n = 108), and 2011 (n = 367) (Fig.1). A total of 565 soil profiles were sampled between 2012 to 2014. The number of samples collected was dependent on the size of the plain’s consolidation zone (i.e. more samples were collected from sites with typical consolidation areas). Sampling sites were randomly determined at the county level. Selected samples were collected from project fields or newly increased plow lands. Each sample were collected from at least 5 different sampling points within each field, and then blended to form a composite sample. Samples were then packaged in uniformly designed sample bags, and mailed or brought to the ministry of land and resources degradation and unused key laboratory.

2.3. Soil sampling and analysis
At each sampling plot, five soil pits were randomly excavated and mixed into a composite sample at depths of 0–30 cm. Soil samples were air-dried, hand-picked to remove plant residues, visible soil organisms, and stones, and weighed. The air-dried samples were then sieved through a screen with 2 mm openings, and a proportion of samples were finely ground to pass through a 0.25 mm sieve and analyzed for soil organic matter by the K2Cr2O7-H2SO4 oxidation method. Soil total nitrogen content measured by using kjeldahl determination. Soil available phosphorus content was measured using 0.5 mol/L NaHCO3 extraction. Soil available potassium was measured by NH4OAc extraction-flame photometry method [18].

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2.4. **Data calculation and analysis**
Frequency distribution of soil organic matter, Soil total nitrogen, Soil available phosphorus and Soil available potassium, and the simple linear regression analysis between each were generated using Excel 2010 software. Geographical mapping of the spatial distribution of sampling sites in the Guanzhong Plain was performed using ArcGIS 10.2 software.

![Figure 1. 565 sampling sites from 2012 to 2014 in the Guanzhong Plain.](image)

3. **Results and Analysis**

3.1. **Soil essential nutrient indicators**

3.1.1. **Soil organic matter.** Soil organic matter content ranged from 2.3 g kg\(^{-1}\) to 36.7 g kg\(^{-1}\), with an average of 13.4, 12.7, and 12.9 g kg\(^{-1}\), respectively in 2012, 2013, and 2014. And 54%, 27%, and 46% of samples’ soil organic matter content were higher than the corresponding average (Fig.2). According to the soil nutrient classification standard in Shaanxi province in China, the soil organic matter belongs to 1-4, 1-5 and 1-4 level respectively over three years. And the soil organic matter content belonged to 2 level account for the largest proportion among all samples.
3.1.2. Soil total nitrogen. Total nitrogen content varied across years (Fig. 3). The total nitrogen content ranged from 0.17 g kg$^{-1}$ to 3.64 g kg$^{-1}$, with an average of 0.61, 0.83, and 0.79 g kg$^{-1}$ for the three successive sampling years. The 2 stage (0.5-0.75 g kg$^{-1}$) account for highest percent were mostly observed in 2012, with a percentage of 100%. Whereas, the soil total nitrogen content all belonged to 1-4 level (<1.5 g kg$^{-1}$) for 2013, the remarkable (3 level, 0.75-1 g kg$^{-1}$) percentage rate was as high as 29% among them. Lower percentage rate were observed in 2013, with a range of 4%-48%.

3.1.3. Soil available phosphorus. Soil available phosphorus content ranged from 0.29 mg kg$^{-1}$ to 55.7 mg kg$^{-1}$ for the three years. The average soil available phosphorus content in 2012, 2013 and 2014 was 9.24, 8.92, and 11.4 mg kg$^{-1}$, respectively (Fig. 4). The average soil available phosphorus content over the three-year period was 10.6 mg kg$^{-1}$. In this study, soil available phosphorus content belongs to 1-5, 1-5 and 1-6 level respectively over three years. And the soil available phosphorus content belonged to 3 level (5-10 mg kg$^{-1}$) account for the largest proportion among all samples. Soil available phosphorus content was in the higher level range for 2014 than the rest of years.
3.1.4. Soil available potassium. Soil available potassium varied among 2012-2014 (Fig.5). The soil available potassium content ranged from 22.7 mg kg\(^{-1}\) to 389 mg kg\(^{-1}\), with an average of 135.1 mg kg\(^{-1}\), 128.9 mg kg\(^{-1}\), and 123.5 mg kg\(^{-1}\) for the three successive sampling years. The 3 level (50-100 mg kg\(^{-1}\)) account for highest percent were mostly observed in 2013, with a percentage of 41%. Whereas, the soil available potassium all belonged to 3-6 level (<1.5 mg kg\(^{-1}\)) for 2012, the remarkable (3 level, 50-100 mg kg\(^{-1}\)) percentage rate was as high as 41% among them, lower percentage rate were observed in 2013 and 2014, with a range of 1.8%-41% and 1.9%-32%.

4. DISCUSSION

4.1. Regional distribution of SOM
Total number and average scale on land consolidation projects of Shannxi province were 6049 sites and 10.46 hm\(^{2}\) [19]. SOM content and its relation to site characteristics are important in evaluating current
regional, continental, and global soil C stores and projecting future changes. Data from 565 soil samples were compiled for land regions of Guanzhong Plain from 2012 to 2014. The SOM of this region soil ranged from 2.3 g kg\(^{-1}\) to 36.7 g kg\(^{-1}\) while average SOM content was 12.9 g kg\(^{-1}\), which is normally distributed in the study for the 0–30 cm profile. Regional accumulations of SOM were examined relative to precipitation, evaporation, temperature and elevation \([20, 21]\). Our SOM content analysis showed a result for dominated systems, according to Shanxi Province’s second soil survey “the classification standard of soil nutrients in Shanxi Province” and that reported the soil organic matter belongs to 1-4, 1-5 and 1-4 level respectively over three years. And the soil organic matter content belonged to 2 level accounts for the largest proportion among all samples.

4.2. Regional distribution of TN
Nitrogen (N) is an essential plant nutrient, and it can be released into available form from the soil organic matter by mineralization \([22]\). We hypothesized that vegetation, through patterns of allocation, would be the major determinant of the relative vertical distribution of TN. Information from many experiments is needed to identify the main variables involved on a global scale, consequently collating data from many experiments offers an efficient means of generalizing from past research. In this study, The total nitrogen content ranged from 0.17 g kg\(^{-1}\) to 3.64 g kg\(^{-1}\) and the average TN content was 0.74 g kg\(^{-1}\), which belonged to 1-4 level (<1.5 g kg\(^{-1}\)) for 2013. Compared to Zhang from a study of 124 soil samples with average TN content of 0.70 g kg\(^{-1}\), 0.69 g kg\(^{-1}\), 0.60 g kg\(^{-1}\) in moisture soil, saline soil and cinnamon soil in the Henan province in the North China \([23]\). The remarkable 3 level (0.75-1 g kg\(^{-1}\)) percentage rate was as high as 29% among them.

4.3. Regional distribution of AP
Phosphorus is a particular element, because it can accumulate in soil and reach concentrations greater than those needed for optimum crop production \([24]\). In our study, soil available phosphorus content ranged from 0.29 mg kg\(^{-1}\) to 55.7 mg kg\(^{-1}\) for the three years. The average soil available phosphorus content over the three-year period was 10.6 mg kg\(^{-1}\). Samples from Shandong province demonstrated that AP of 0.82 mg kg\(^{-1}\) \([25]\). Top, high, medium and low quality land in western regions account for 0.06%, 14.92%, 54.25% and 30.7%, respectively, of which medium and low quality land play a dominant role\([26]\). Moreover, soil available phosphorus content belongs to 1-5 and 1-6 level respectively over three years. And the soil available phosphorus content belonged to 3 level (5-10 mg kg\(^{-1}\)) account for the largest proportion among all samples.

4.4. Regional distribution of AK
The average AK content was 126 mg kg\(^{-1}\), This was higher that reported by The soil available potassium content ranged from 22.7 mg kg\(^{-1}\) to 389 mg kg\(^{-1}\), with an average of 135.1 mg kg\(^{-1}\), 128.9 mg kg\(^{-1}\), and 123.5 mg kg\(^{-1}\) for the three successive sampling years. A previous study conducted in Shandong province demonstrated that average AK of 71.16 mg kg\(^{-1}\) (Wang, 2013). The 3 level (50-100 mg kg\(^{-1}\)) account for highest percent were mostly observed in 2013, with a percentage of 41%. Whereas, the soil available potassium all belonged to 3-6 level (<1.5 mg kg\(^{-1}\)) for 2012, the remarkable (3 level, 50-100 mg kg\(^{-1}\)) percentage rate was as high as 41% among them, lower percentage rate were observed in 2013 and 2014, with a range of 1.8%-41% and 1.9%-32%.

5. Conclusion
Average SOM content in the Guanzhong Plain from 2012 to 2014 was 12.9 g kg\(^{-1}\). Correspondingly, the average TN content was 0.74 g kg\(^{-1}\), and the AP, AK content were 10.6 mg kg\(^{-1}\) and 126 mg kg\(^{-1}\), respectively. According to the recommended land consolidation samples, SOM and TN content belongs to 2-3 level account for the largest proportion among all samples while AP and AK were the 3-4 standard predominantly. SOC was positively correlated with AP and AK content for all samples. The total N, AP and AK contents of consolidation soil were lower than those of normal soil in most regions. Therefore, efforts to simultaneously adjust soil fertility in order to achieve high standard soil, effective measures
should be taken in the subsequent cultivation, combined with crop rotation low-toxin chemical, application of some suitable fertilizers, the promotion of straw returned in the long run.

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