Bangladesh J. Bot. **49**(3): 757-768, 2020 (September) Special

EFFECTS OF INORGANIC AND ORGANIC AMENDMENTS ON SOIL QUALITY AFTER LAND CONSOLIDATION OF HOLLOW VILLAGES IN SHAANXI, CHINA

LU ZHANG[1,2,3] AND KEHAO CHEN[1]*

Shaanxi Provincial Land Engineering Construction Group Co. Ltd.,
Institute of Land Engineering and Technology, Shaanxi Provincial Land
Engineering Construction Group Co., Ltd., Xi'an 710075, China

Keywords: Apple orchard, Land consolidation, Soil desiccation, Organic amendment

Abstract

Effects of different inorganic and organic amendments on soil quality after land consolidation of hollow villages were investigated to provide evidence for the efficient use and rational land consolidation of abandoned, vacant homesteads in rural China. A plot experiment was conducted using raw soil collected from the hollow village land consolidation project area in Chengcheng County, Shaanxi Province, China. The soil was filled into 0 - 30 cm depth of the plots and mixed with different inorganic and organic amendments: non-amended soil was treated as the control. After one season of summer maize cultivation in the plots, soil water, nutrient, and pH were examined and compared among the four treatments. Following summer maize cultivation, average water content and total water storage in the 0 - 100 cm soil profile were highest in the FS-CM treatment, exceeding the control group by 48.0 and 60.2%, respectively (p values < 0.05). Similar trends were found for soil total nitrogen, available phosphorus, available potassium, and organic matter contents, which were 32.2, 154.0, 14.8 and 85.8%, respectively higher in FS-CM compared with the control (all p values < 0.05). Soil water, available phosphorus, and organic matter levels were significantly higher in FS-CM than in CM, while soil water, total nitrogen, and available potassium levels were increased in CM compared with the control (p values < 0.05). Soil pH was significantly reduced from 7.59 - 5.86 by CM and to 6.72 by FS-CM (p value < 0.05). The effects of FS on the soil properties tested were minimum among the three soil amendment treatments. After land consolidation of hollow villages, addition of different amendments increased both water and nutrient levels and modified pH conditions in the soil, thereby improving its overall quality. Combining chicken manure and ferrous sulfate appears to be the optimal strategy for soil improvement rather than applying either alone.

Introduction

China is a large agricultural country whose human population dwarfs its available land. With regard to basic national conditions, the total arable land area is limited, and general land quality is not high, while the reserve of arable land resources is also insufficient and resource development remains difficult (Zhao *et al.* 2014). In this context, many villages are becoming or have become "hollow". An abandoned village that forms due to delayed village planning along with the accelerated urbanization process is known as a "hollow village" (Cheng *et al.* 2001).

Hollow villages are commonly found in rural China, especially in the poor areas of western China (Li and Li 2008, Yu *et al.* 2016). This phenomenon is also universal, and it has received extensive attention worldwide from government and researchers. Urbanization has received far more attention (Bai *et al.* 2014), whereas the research on hollow villages has started late in China. However, it is worth noting that hollow villages in China are products of rural development policies associated with intensified contradictions and accumulated problems characterizing the

---

*Author for correspondence: <2918173256@qq.com>. [1]Shaanxi Key Laboratory of Land Consolidation, Xi'an 710064, China. [2]Key Laboratory of Degraded and Unused Land Consolidation Engineering, The Ministry of Natural Resources, Xi'an 710021, China. [3]Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710021, China.

country’s long-term urban-rural dual structure. Therefore, in contrast to other countries, it is more complicated and urgent to solve the current problem of “rural hollowing” in China (Jiang and Luo 2014).

In the 1990s, some studies investigated the origins of typical abandoned villages in rural areas and explored relevant solutions based on the contemporary reality of rural development in China (Liu *et al.* 2014). Concerned with increasingly serious problem of “rural hollowing”, the Chinese government formulated hollow village land consolidation policies in 2004 (Chen *et al.* 2010), with great effort devoted to increase land use efficiency and promote rural land reconstruction (Cui *et al.* 2011, Liu *et al.* 2011, Yu *et al.* 2018). In recent years, this has led to specific outcomes, such as “land consolidation”, “old village reconstruction”, and “village relocation and town combination” (Liu and Gan 2007, Kennedy 2013, Zheng *et al.* 2013). Many studies have investigated hollow villages in terms of their spatial patterning (Salvati 2014), dynamic features (Liu *et al.* 2012), formation mechanisms (Qin *et al.* 2012), potential effects (Feng *et al.* 2012), and controlling countermeasures (Yang 2014). Collectively, these studies showed that land consolidation of hollow villages plays a positive role in increasing the regional land use indicator and improving the rural living environment (Zou and Qiu 2015).

Land consolidation of hollow villages for supplementation of arable land is an important practice to ensure there is sufficient arable land in China, which involves vegetation clearing, soil transfer, addition of soil amendments, and the reconstruction of biological chains (Huang *et al.* 2015). Land consolidation of hollow villages has been transformed from simple academic research into a major measure that stimulates domestic demand, promotes new rural construction, and implements strategies such as overall urban-rural development (Liu *et al.* 2008). However, new arable land reclaimed from hollow villages is characterized by poor soil structure and low nutrient content, resulting in low soil fertility that limits the yield of crops (Zhang *et al.* 2015).

Extensive research work had been carried out on soil amendments used for land consolidation, mining areas contaminated with heavy metals (Fan *et al.* 2011, Chen *et al.* 2014, Hallema *et al.* 2015). Application of Ca^{2+}-containing compounds was found to mitigate soil contamination around a zinc ore mine site (Zhao *et al.* 2015), and adding nutrients (organic manure or peat) improved soil fertility of a coal mining area in the USA (Carlson and Adriano 1993). Furthermore, the use of recycled resources originating from the mining operation, such as sludge, can also achieve satisfactory economic and ecological effects for soil improvement in mine areas (Asensio *et al.* 2014, Cayci *et al.* 2017). Moreover, the combination of organic, chemical, and bacterial fertilizers was reported to increase markedly the species richness and dominance of microbes in reclaimed soil of a coal mining subsidence area (Zhang 2016). Currently, however, there is a dearth of studies involving multiple amendments used to improve soil quality after land consolidation of “hollow villages”, especially how they impact arable land suitability.

Following the principle of "saving land resources, increasing arable land, and ensuring land quality" (Asensio *et al.* 2014), investigating changes to the fertility of soil after adding different amendments to it is useful to better understand soil quality status following crop cultivation in arable land newly added by rural land consolidation. Such research could provide an empirical basis for the rational and effective use of arable land resources under land consolidation of abandoned homesteads across various regions, while also improving the quality of newly added arable land.

In the present study, raw soil from a hollow village in Chengcheng county in China’s Shaanxi Province was selected to investigate the effects of different inorganic and organic amendments on soil water and nutrient conditions after one season of summer maize cultivation. Results provide useful information for land consolidation of hollow villages and the selection of appropriate soil amendments in similar regions.

Materials and Methods

This research was a part of the hollow village land consolidation project in Chengcheng county, Shaanxi Province, China (hereon, the “Chengcheng Project”). This project involved land consolidation in rural vacant and abandoned homesteads across the county, and mainly addressed house excavation, wall pushover, land leveling, soil amendment application, farmland water conservation and irrigation. Selection and practical benefits of different soil amendments were focused.

Three blocks of experimental plots (four plots per block) were designed to simulate the application of soil amendments after land consolidation of abandoned homesteads in hollow villages. These plots were established at the Fuping Experimental Base of the Key Laboratory of Degraded and Unused Land Consolidation Engineering (Ministry of Agriculture of the People's Republic of China 2013). In each plot (2 × 2 m), its surface soil (i.e., 0 - 30 cm depth) was first stripped and removed with a shovel; then a 40 cm high wall was built around each plot, with a 10 cm section protruding above the soil surface. All plots were oriented north to south (Fig. 1). Next, the surface soil (0 - 30 cm) in the Chengcheng Project area was stripped and filled into the experimental plots. Before filling, the soil surface was roughened manually. The thickness of filled-in soil was 30 cm and its bulk density was controlled (1.2 - 1.4 g/cm^3).

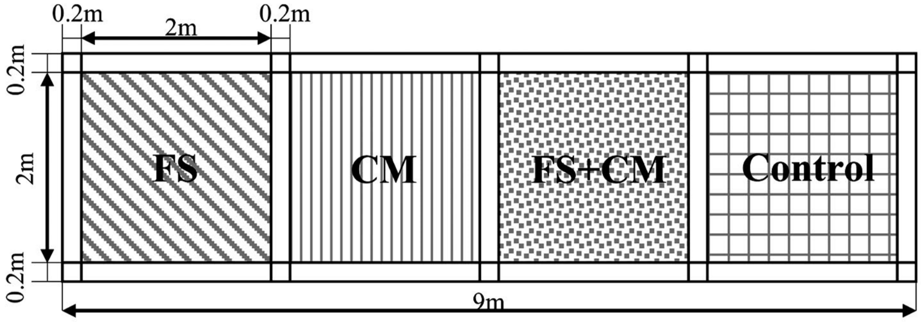

Fig. 1. Schematic diagram for one block of the experimental plots (FS, ferrous sulfate only; CM, chicken manure only; FS + CM, ferrous sulfate plus chicken manure; and control, no amendment). Three blocks were established, giving a total of 12 plots.

An appropriate amount of ferrous sulfate (a cheap inorganic soil amendment) or chicken manure (an organic fertilizer easily obtained), or both were added to the surface soil (0 - 30 cm). Four treatments were applied in each block: ferrous sulfate only (FS), chicken manure only (CM), ferrous sulfate plus chicken manure (FS-CM), and no amendment (control). The amendments were thoroughly mixed with the raw soil, and plots were ploughed and irrigated after their addition. Table 1 summarizes the soil amendment treatments, and the basic nutrient properties of raw soil and chicken manure are presented in Table 2.

The Chengcheng Project was completed in 2017, and the experimental plots were established in March, 2018. All plots received a compound fertilizer (N-P_2O_5-K_2O: 18-18-18) with an application rate of 225 g/m^2, then summer maize (*Zea mays* L. cv. Xianyu 335) was sown at a rate of 6 plants/m^2 in June and harvested in October, 2018. After harvesting, five soil cores were taken in an S-shaped pattern from each plot. A 3.5 cm diameter auger was used to collect soil at depths of 0 - 10, 10 - 20, 20 - 40, 40 - 60, 60 - 80, and 80 - 100 cm. Soil cores from the same depths were mixed to form composite sample. All samples were transported to the laboratory and passed through a 2 mm sieve. After removing any stones and litter, soil samples were air-died and used to determine their soil water, nutrient, and pH conditions.

Table 1. Description of the treatments for the addition of different inorganic and organic soil amendments after land consolidation of hollow village.

Treatment	Soil amendment	Addition rate (kg)	Bulk density (g/cm^2)
FS	Inorganic (ferrous sulfate)	0.24	1.38
CM	Organic (chicken manure)	0.8	1.30
FS-CM	Ferrous sulfate + chicken manure	0.12 + 0.4	1.33
Control	None	0	1.24

Table 2. The pH and nutrient levels of raw soil and chicken manure.

Property	pH	Total N (g/kg)	Available P (mg/kg)	Available K (mg/kg)	Organic matter (g/kg)
Raw soil	7.44 ± 0.3404	0.09 ± 0.0067	4.81 ± 0.3966	48.02 ± 3.2517	1.05 ± 0.2352
Chicken manure	4.25 ± 0.5543	1.88 ± 0.1300	12.7 ± 0.8185	126.7 ± 1.9079	7.59 ± 0.3816

Soil water content was determined by the oven-drying method (105°C, 24 hrs), and soil water storage at each depth interval was calculated using Eq. (1).

$$SWS = \theta_m \times \rho_b \times H \times 10 \qquad (1)$$

where SWS is soil water storage (mm), θ_m is soil mass water content (%), ρ_b is soil bulk density for each depth interval (g/cm^3), and H is the thickness of a given soil depth interval (cm).

Soil pH was determined in a 1 : 2.5 soil: water suspension using a PHS-3C pH meter (Leici, Shanghai, China). Total nitrogen was analyzed by using a UDK 129 Kjeldahl destillations system (VELP Scientifica, Italy); available phosphorus analyzed by a TU-1810 UV-visible spectrophotometer (Purkinje, Shanghai, China); and available potassium analyzed by a FP640 flame photometer (Aopu, Beijing, China). Soil organic matter was determined with a 476026 digital bottle-top burette (BRAND Titrette®, Germany).

The experimental data (mean ± standard error) were subjected to an analysis of variance using SPSS v19 Statistics (SPSS Inc., Chicago, USA). A p-value of less than 0.05 was considered to indicate a significant difference.

Results and Discussion

Results presented in Fig. 2 showed that the water content in the 0 - 100 cm soil profile under the different treatments. The surface-soil water content (0 - 20 cm) was always higher than the subsurface-soil water content (20 - 80 cm) across all four treatments after one season of summer maize cultivation. Relatively low levels were found at the 40 cm soil depth, especially in the FS treatment. Among the four treatments, average water content in the 0 - 100 cm soil profile was ranked as FS-CM > CM > FS > control, with the three soil amendment treatments having 48.0, 41.2 and 21.5%, respectively more water than the control.

The water content was also significantly different between treatments at specific soil depths. Within the 0 - 20 cm depth, significant differences were found in soil water content between the control and all three soil amendment treatments ($p < 0.05$). For the 20 - 60 cm depth, there were significant differences between the control (or TS) and CM (or FS-CM) treatments ($p < 0.05$). For the 60 - 80 cm depth, the water content differed significantly between the control (or FS-CM) and TS (or CM) treatments ($p < 0.05$). For the 80 - 100 cm depth, a significant difference was observed between the control and CM treatment only ($p < 0.05$).

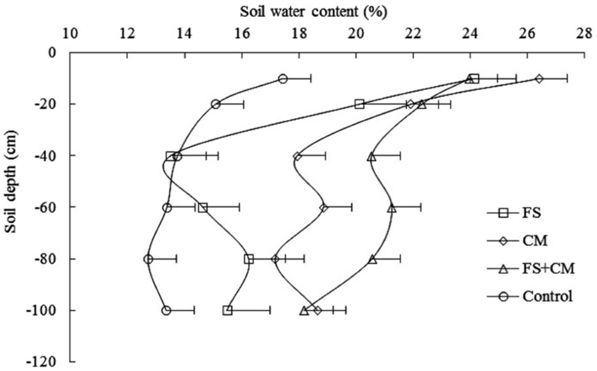

Fig. 2. Soil water content at different depths of the experimental soil added with inorganic and organic amendments (θ m/%). FS, ferrous sulfate only; CM, chicken manure only; FS+CM, ferrous sulfate plus chicken manure; and control, no amendment. Values are the mean ± standard deviation (n = 5).

After the harvest of maize in October, soil water storage in the 0 - 100 cm soil profile was the highest, 276 mm, in the FS-TCM treatment (Fig. 3), being 6.4 and 21.9% higher than those of CM ($p > 0.05$) and FS treatments ($p < 0.05$), respectively. A significant increase (60.2%) was also found in the soil water storage of CM treatment when compared with the control ($p < 0.05$).

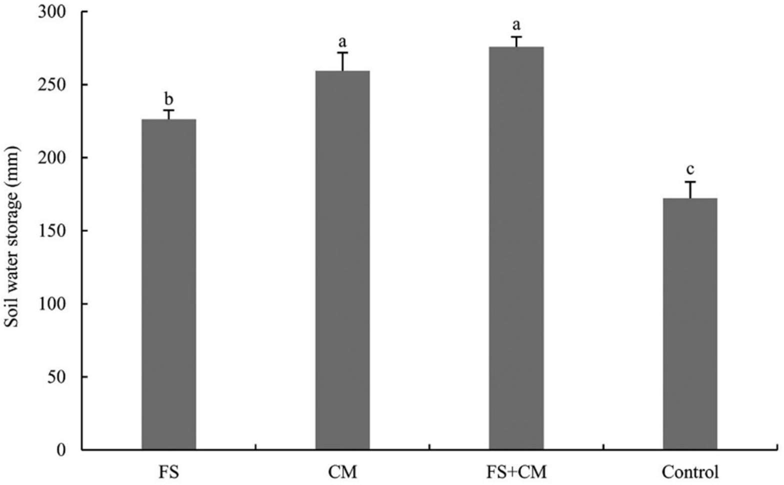

Fig. 3. Total water storage in the 0 - 100 cm soil profile added with inorganic and organic amendments (mm). Values are the mean ± standard deviation (n = 5). Means with different lowercase letters at the top of the column indicate significant difference at $p < 0.05$.

The addition of inorganic and/or organic amendments appeared to reduce soil pH in the 0 - 100 cm profile (Fig. 4). Average pH levels of FS, CM, and FS-CM treatments were 7.1% ($p > 0.05$), 22.8% ($p < 0.05$), and 11.5% ($p < 0.05$), respectively lower than the control. A significant difference in soil pH was also recorded between the CM and FS-CM treatments ($p < 0.05$).

Total nitrogen analysis revealed that, within the 0 - 100 cm soil profile, the maximum nitrogen concentration occurred at the 20 - 40 cm depth across all four treatments (Fig. 5), with a significant difference in CM (or FS-CM) compared with the control ($p < 0.05$). For the 0 - 100 cm soil profiles of FS, CM, and FS-CM treatments, their average total nitrogen concentration was 22.2, 29.5 and 32.2%, respectively higher than the control.

Except for the control, the available phosphorus concentrations of all other three treatments reached their highest level in the 0 - 10 cm surface soil (Fig. 6), with a significant difference between the control (or FS and CM) and FS-CM treatments ($p < 0.05$). In terms of the average available phosphorus concentration for the entire 0 - 100 cm soil profile, the four treatments were ranked as FS-CM > CM > FS > control; the three soil amendment treatments exceeded the control value by 154.0, 98.6 and 72.7%, respectively (p values < 0.05).

With the increase of soil depth, the available potassium concentration generally declined (Fig. 7). Average available potassium concentrations in the 0 - 100 cm soil profile of the different treatments were ranked as FS-CM > CM > FS > control; the corresponding values of the three soil amendments were 14.8, 2.9 and 1.9% higher than the control. In particular, available potassium concentrations at the 10 - 20 and 40 - 60 cm soil depths differed significantly between the control and soil amendment treatments (p values < 0.05).

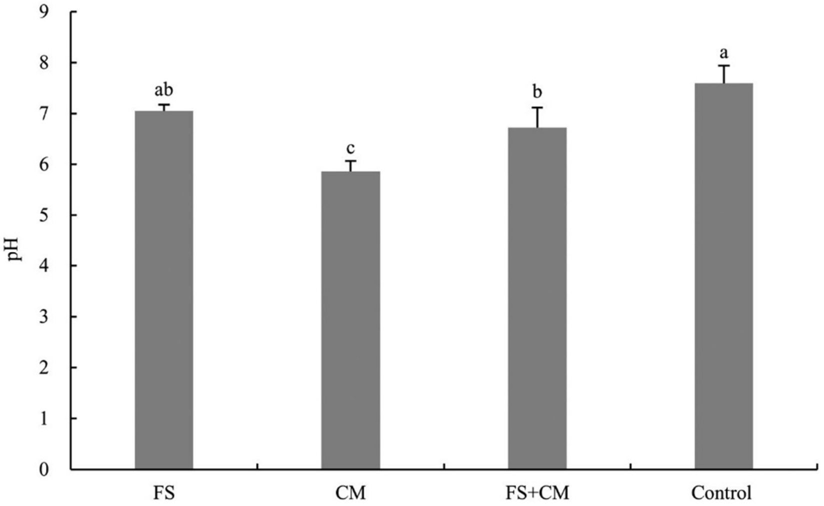

Fig. 4. Average pH in the 0 - 100 cm soil profile added with different organic and inorganic amendments. Means with different lowercase letters at the top of the column indicate significant difference at $p < 0.05$.

Within the 0 - 100 soil profile, organic matter content was drastically reduced from 0 to 40 cm depth, especially in the CM and FS-CM treatments (Fig. 8). In terms of the 0 - 100 cm average, the four treatments were ranked as FS-CM > CM > FS > control, with the corresponding values of the three soil amendments exceeding the control by 85.8, 79.6 and 30.1%, respectively (p values < 0.05). A significant difference was found between FS-CM > CM treatments in the 0 - 10 cm surface soil only ($p < 0.05$).

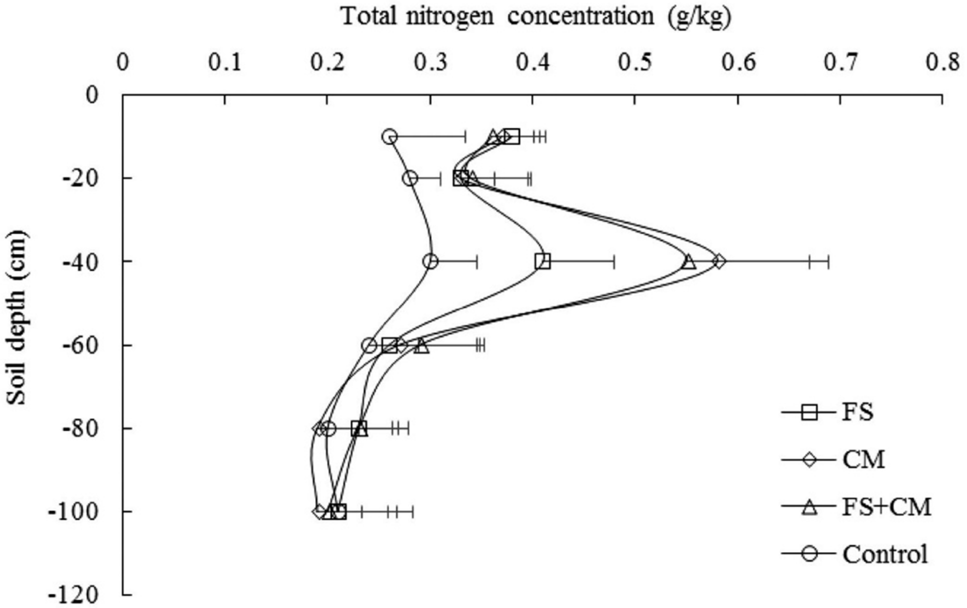

Fig. 5. Effects of different organic and inorganic amendments on total nitrogen concentration in the 0 - 100 cm soil profile (g/kg).

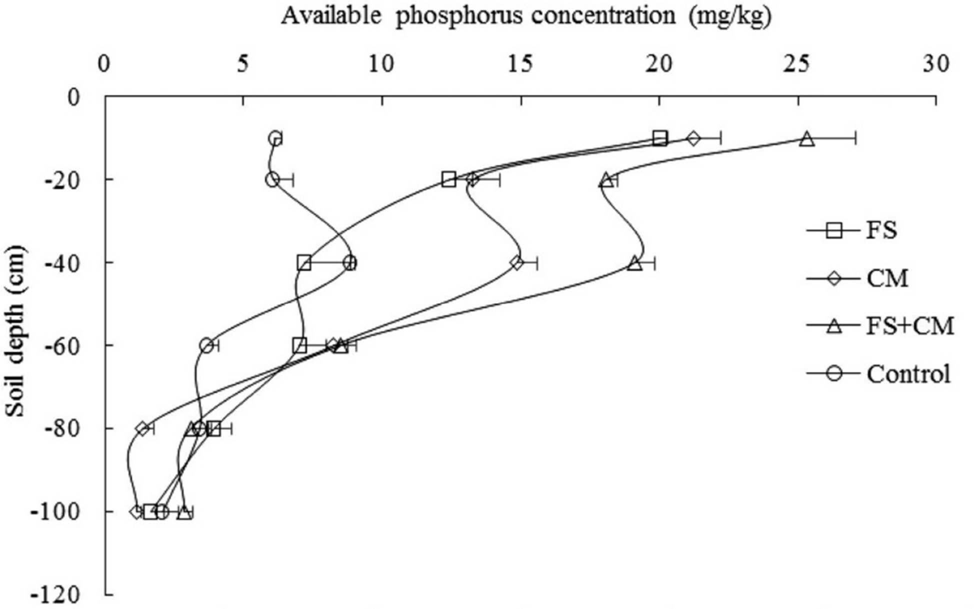

Fig. 6. Effects of different organic and inorganic amendments on available phosphorous concentration in the 0 - 100 cm soil profile (mg/kg).

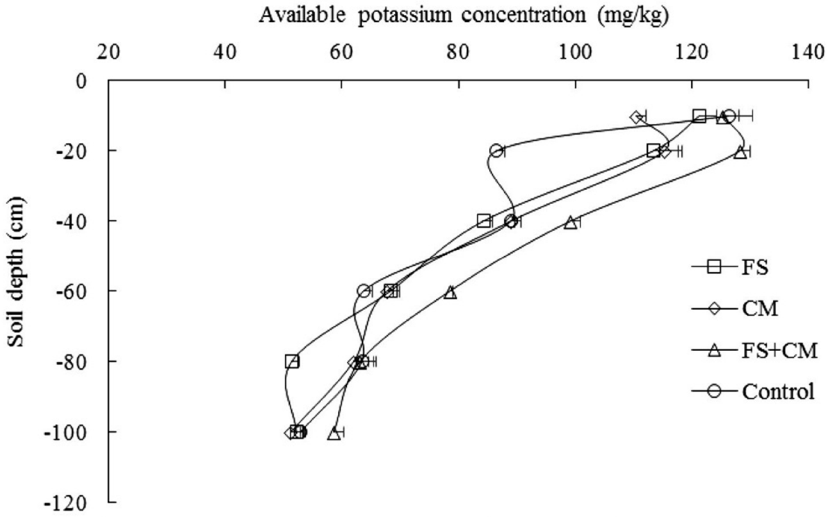

Fig. 7. Effects of different organic and inorganic amendments on available potassium concentration in the 0 - 100 cm soil profile (mg/kg).

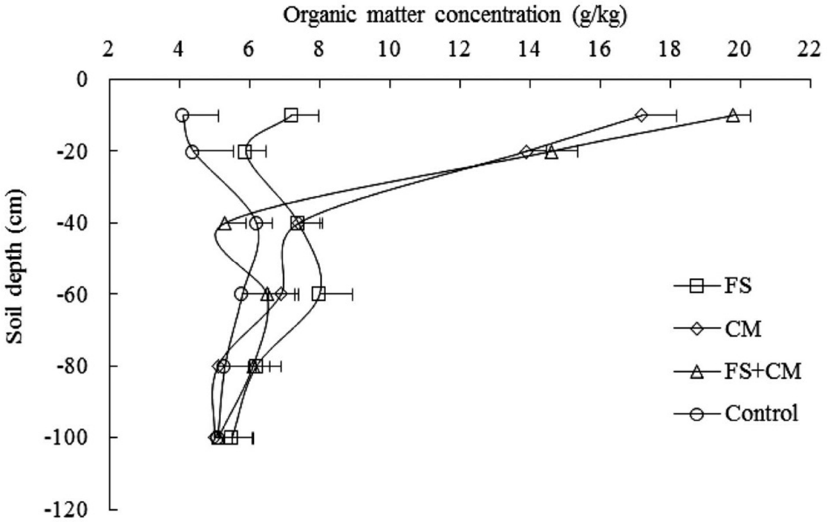

Fig. 8. Effects of different organic and inorganic amendments on organic matter concentration in the 0 - 100 cm soil profile (g/kg).

How to solve the pressing problem of hollow villages is currently an important topic in the revitalization of rural China (Liu and Li 2017). Generally, the Chinese Government continues to implement homestead consolidation; that is, to reclaim low-efficiency or abandoned (discarded) homesteads acquired illegally for arable land, in accordance with overall land use planning, as well as the planning of land consolidation, reclamation, and development (Huang *et al.* 2015). However, during such large-scale land consolidation, how to achieve rapid development and efficient use of the remnant raw soil remains an outstanding issue whose resolution is key for rural revitalization.

In the present study, raw soil from the Chengcheng Project area following the consolidation of rural construction land (homestead) was collected. This project represents a major innovation in the reform of the rural land system in Shaanxi Province to strike a sustainable balance between land for construction versus agriculture. Results showed that the addition of different organic and inorganic amendments had positive effects on the development of this type of raw soil. Especially when ferrous sulfate and chicken manure were jointly added. Soil water and nutrient conditions were improved markedly with the lowering of the pH level when compared with the control soil. Importantly, all of these soil property values met the standard of arable land suitability (Afshari and Mafi 2014), indicating the application potential of adding inorganic-plus-organic amendments for soil improvement after land consolidation of hollow villages.

The raw soil used in this study was rich in insoluble phosphorus and potassium nutrients that are difficult to release into an alkaline environment (Hu *et al.* 2017). Therefore, ferrous sulfate as an inorganic amendment to reduce soil pH and to promote the conversion of nutrients into the available form needed for plant uptake were selected. Present results showed that the ferrous sulfate treatment effectively lowered soil pH by 7.1% relative to the control used. This suggests adding ferrous sulfate alone can function to partly mediate soil acidity, while sulfate (SO_4^{2-}) is involved in loosening the soil structure (Huang 2005). For the organic amendment chicken manure was used because of its convenience for acquisition, transportation, and utilization in local rural areas. The soil amendments which were selected can be applied alone or in combination to accelerate the development of newly added arable land, thus improving the comprehensive soil fertility to rapidly generate ideal growing conditions for crops.

Results also showed that adding chicken manure alone improved soil fertility more efficiently than would applying ferrous sulfate only, as indicated by the former's increases in soil water content (16.2%) and water storage (14.7%). In the 0 - 100 cm soil profile, relatively low water content at the 20 - 40 cm depth irrespective of treatment was observed. This result could be related to water consumption by the crop plant tested and subsurface soil compaction (Zhang *et al.* 2017). The nutrient concentrations such as total nitrogen available phosphorus, available potassium, and organic matter generally increased by 6.0, 15.0, 1.0 and 38.1%, respectively. The maximum effects of organic compared with inorganic amendment can be attributed to the high nutrient content of chicken manure, a high-quality organic fertilizer particularly rich in organic matter (Wang *et al.* 2002). After its application into soil, chicken manure can increase the nutrients in soil and improve its physical, chemical, and biological properties, leading to prominent effects on soil development and fertility (Ministry of Agriculture of the People's Republic of China 2013). Moreover, when applied, chicken manure can also increase organic colloids in soil while contributing to the decomposition of organic matter into organic colloids via microbial activity (Wang *et al.* 2002). This would greatly increase the total soil adsorption surface and produce many adhesive substances. In this way, soil particles become cemented to form a stable agglomerate structure, thus improving the capacity of the soil capacity for water retention, nutrient conservation, permeability, and temperature control (Wood *et al.* 2016). A popular proverb in rural China, "the land is maintained with manure and the seedlings are grown with manure", to some extent conveys the key role of chicken manure application that plays in soil improvement.

Since chicken manure is a strongly acidic fertilizer (Voelklein *et al.* 2016), its application alone markedly reduced the soil pH, from 7.59 to 5.86 relative to the control soil. The present results demonstrated that the combined application of chicken manure plus ferrous sulfate did more to improve soil quality than the application of chicken manure alone. The disadvantage of applying chicken manure only is that its composting may produce high temperatures and thereby drive nitrogen loss (Wang *et al.* 2013). One study reported that ferrous sulfate could be applied into the composts of livestock manure for nitrogen retention (Lehrsch *et al.* 2015). In this experiment, once these soil amendments were made, substantial changes occurred in soil nutrient concentrations at 0 - 60 cm depth, whereas nutrient levels were mostly stabilized at 60 - 100 cm depth, with some minor variations. This suggests that treatment effects on soil nutrients were limited to deep soil, yet mainly reflected in the upper soil layer (Kobaissi *et al.* 2013, Van Groenigen *et al.* 2014). Therefore, in engineering practices concerned with land consolidation of hollow villages for arable land, soil amendments should be applied to the upper soil layer only, which would reduce associated construction costs.

This study showed that the combination of ferrous sulfate and chicken manure offers an optimal strategy for increasing soil water and pH levels while improving soil nutrient conditions after land consolidation of hollow villages. Although sole applications of ferrous sulfate or chicken manure alone also appeared to improve soil quality to some extent, these inorganic and organic amendments are disadvantageous because of their high costs and nitrogen losses, respectively. By combining ferrous sulfate with chicken manure, the water content, water storage, total nitrogen, available phosphorus, available potassium, and organic matter in the 0 - 100 cm soil profile were all considerably increased, and soil pH decreased, after just one season of summer maize cultivation. Overall, this fertilization practice clearly shows promising effects for promoting soil development after land consolidation of hollow villages. The present results may thus help to suggest, and guide future use of newly added arable land.

Acknowledgments

This work was financially supported by the Fundamental Research Funds for the Central Universities, CHD (300102270504).

References

Afshari M and Mafi E 2014. Land capability assessment for regional planning using AHP and GIS at Shandiz urban region, northeast Iran. Environment and Urbanization ASIA **5**(1): 105-118.

Asensio V, Vega FA and Covelo EF 2014. Effect of soil reclamation process on soil C fractions. Chemosphere **95**: 511-518.

Bai XM, Shi PJ and Liu YS 2014. Realizing China’s urban dream. Nature **509**(1799): 158-160.

Carlson CL and Adriano DC 1993. Environmental impacts of coal combustion residues. J. Environ. Qual. **22**(2): 227-247.

Cayci G, Temiz C and Sözudogru OKS 2017. The effects of fresh and composted chicken manures on some soil characteristics. Commun. Soil Sci. Plan. **48**(13): 1528-1538.

Chen Q, Liu SJ, Bai Y, Li YX, Gao CH, Zhang Q and Li JH 2014. Screening and identification of phosphate-solubilizing bacteriafrom reclaimed soil in Shanxi mining area. Journal of Plant Nutrition and Fertilizer **20**(6): 1505-1516. (in Chinese)

Chen YF, Sun H and Liu YS 2010. Reconstruction models of hollowed villages in key agricultural regions of China. Acta Geographic Sinica **65**(6): 727-735. (in Chinese)

Cheng LS, Feng WY and Jiang LH 2001. The analysis of rural settlement hol lowizing system of the southeast of Taiyuan basin. Acta Geographic Sinica **56**(4): 437-446. (in Chinese)

Cui WG, Li YR and Liu YS 2011. Rural hollowing in key agricultural areas of China: characteristics, mechanisms and countermeasures. Resources Science **33**(11): 2014-2021. (in Chinese)

Fan WH, Bai ZK, Li HF, Qiao JY and Xu JW 2011. Effects of different vegetation restoration patterns and reclamation years on microbes in reclaimed soil. Transactions of the CSAE **27**(2), 330-336. (in Chinese)

Feng CC, Zhao RX and Gu WY 2012. Study on the social economic factors of the land use changes in rural residential areas of China. China Population, Resources and Environment **22**(3): 6-12. (in Chinese)

Dennis WH, Jonathan AL, Yann P, Silvio JG, Ge S and Jean C 2015. Long-term effects of peatland cultivation on soil physical and hydraulic properties: case study in Canada. Vadose Zone J. **14**(6): 1-12.

Hu M, Xiang YS and Lu JW 2017. Effects of lime application rates on soil pH and available nutrient content in acidic soils. Soil and Fertilizer Sciences in China (04): 75-80. (in Chinese)

Huang CY 2005. Soil Science. Beijing: China Agricultural Press, China. (in Chinese).

Huang YH, Wang K, Su TT and Yang JH 2015. Research on the characteristics of soil fertility and the transformation and utilization of soil in rural land reclamation in Chongqing. Journal of Southwest University (Natural Science Edition) **37**(1): 33-39. (in Chinese).

Jiang SJ and Luo P 2014. A literature review on hollow villages in China. China Population, Resources and Environment **24**(6): 51-58. (in Chinese).

Kennedy JJ 2013. Finance and rural governance: centralization and local challenges. The Journal of Peasant Studies **40**(6): 1009-1026.

Kobaissi AN, Al-souki KS, Kanbar HJ and Kanso AA 2013. Further curing of Lebanese compost: improving quality and stability. International Journal of Scientific & Technology Research **2**(5): 199-209.

Lehrsch GA, Brown B, Lentz RD, Johnson-maynard JL and Leytem AB 2015. Sugarbeet yield and quality when substituting compost or manure for conventional nitrogen fertilizer. Agron. J. **107**(1): 221.

Li J and Li XJ 2008. The microscopic analysis on village-hollowing in medium income and hilly land region of Henan province. China Population, Resources and Environment **18**(1): 170-175. (in Chinese)

Liu HB and Gan H 2007. Renovation of "hollow village" in the construction of new countryside. Agricultural Modernization Research **28**(5): 586-588. (in Chinese)

Liu QQ, Pan YC, Chen BS, Li SH and Guo AQ 2012. Analysis on the relationship and its dynamics between rural settlements and linear features using Gis and Rs. Intell. Autom. Soft Co. **18**(8): 1053-1062.

Liu Y, Fang F and Li Y 2014. Key issues of land use in China and implications for policy making. Land Use Policy **40**: 6-12.

Liu YS and Li YH 2017. Revitalize the world’s countryside. Nature **548**: 275-277.

Liu YS, Long HL, Zhang XL and Qiao JJ 2011. Research progress and prospect in the disciplines of agricultural geography and rural development in China. Progress in Geography **30**(12): 1498-1505. (in Chinese)

Liu YS, Wang LJ and Long HL 2008. Spatio-temporal analysis of land-use conversion in the eastern coastal China during1996-2005. J. Geogr. Sci. **18**(3): 274-282.

Mclaughlin K 2016. Rural China is no country for old people. Science **352**(6283): 283.

Ministry of Agriculture of the People's Republic of China 2013. Bio-organic Fertilizer Standard – Agricultural Industry Standards of the People's Republic of China (NY 884-2012). China Agriculture Press: Beijing.

Qin TT, Qi W, Li YQ and Qu YB 2012. Suitability evaluation of rural residential land based on niche theory in mountainous area. Acta Ecologica Sinica **32**(16): 5175-5183.

Riney-Kehrberg P 2009. Survival of rural America: small victories and bitter harvests. West. Hist. Q. **40**(2): 230-231.

Salvati L 2014. The spatial pattern of soil sealing along the urban-rural gradient in a Mediterranean region. Journal of Environmental Planning and Management **57**(6): 848-861.

Van Groenigen KJ, Qi X, Osenberg CW, Luo YQ and Hungate BA 2014. Faster decomposition under increased atmospheric CO2 limits soil carbon strage. Science **344**(6183): 508-509.

Voelklein MA, Jacob A, O’shea R and Murphy JD 2016. Assessment of increasing loading rate on two-stage digestion of food waste. Bioresource Technol. **202**: 172-180.

Wang LQ, Zhou CJ, Wang JR, Li SX and Shao MA 2002. Organic acids in chicken feces and their effects on availability of nutrients in loess soil. Acta Pedologica Sinica **39**(2): 268-275. (in Chinese)

Wang Y, Dou S and Zhang J 2013. Studies on dynamic change of humic acid in chicken manure composting. Functions of Natural Organic Matter in Changing Environment 147-152.

Wood SLR, Rhemtulla JM and Coomes OT 2016. Cropping history trumps fallow duration in long-term soil and vegetation dynamics of shifting cultivation systems. Ecol. Appl. **27**(2): 519-531.

Yang Y 2014. Discussion on existing problems and countermeasures of rural fire control - take Yunnan province as an example. Procedia Engineering **71**: 519-522.

Yu H, Verburg PH, Liu L and Eitelberg DA 2016. Spatial analysis of cultural heritage landscapes in rural China: land use change and its risks for conservation. Environ. Manage **57**(6): 1304-1318.

Yu ZW, Xiao LS, Chen XJ, He ZH and Henrik V 2018. Spatial restructuring and land consolidation of urban-rural settlement in mountainous areas based on ecological niche perspective. J. Geogr. Sci. **28**(2): 131-151.

Zhang L, Han JC and Ma ZH 2015. Soil properties under hollow villages of different reclamation years in hilly area. Journal of Soil and Water Conservation **29**(5): 176-180. (in Chinese)

Zhang L, Wang YQ, Han JC, Shi ZL, Jiao CQ and Pang GW 2017. Soil moisture dynamics and balance in apple orchards in the Weibei rainfed highland, northwest China. J. Soil Water Conserv. **72**(4): 374-381.

Zhang P 2016. Study by different kinds of fertilizer on reclamation soil microbial functional diversity at coal mining area. Taiyuan: Shanxi Agricultural University. (in Chinese)

Zhao FJ, Ma Y, Zhu YG, Tang Z and Mcgrath SP 2015. Soil contamination in China: current status and mitigation strategies. Environ. Sci. Technol. **49**(2): 750-759.

Zhao XL, Zhang ZX, Wang X, Zuo LJ, Liu B, Yi L, Xu JY and Wen QK 2014. Analysis of Chinese cultivated land's spatial-temporal changes and causes in recent 30 years. Transactions of the CSAE **30**(3): 1-11. (in Chinese)

Zheng YY and Gao S 2013. Exploration on the eco-village planning from the perspective of low-carbon. Applied Mechanics and Materials **357-360**: 1945-1948.

Zou YF and Qiu YD 2015. The consolidation potential of rural residential land at a provincial scale in Guangxi. Resources Science **37**(1): 28-36. (in Chinese)

(Manuscript received on 30 June 2020; revised on 9 September 2020)