The Successional Trend of Soil Microbial Characteristics after Reclamation Amended with Arsenic Sandstone in the Mu Us Sandy Land, China

Yi Hu1,2,3, Juan Li1,2,3 and Jing Wang1,2,3

1Shaanxi Province Land Engineering Construction Group, LTD, Xi’an 710075, China
2Shaanxi Province Land Engineering Construction Group Land engineering technology research institute co., LTD, Xi’an 710075, China
3Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Land and Resources of China, Xi’an 710075, China

Abstract. Soil microorganisms have played an important role in the formation and evolution of soil ecosystem. Based on sand-binding by arsenic sandstone in Mu Us Sandy Land, to evaluate the effects of land reclamation on soil microbial characteristics, we researched on soil enzyme activities, soil microbial biomass and soil basal respiration rate in different reclamation years. The result showed sandy land reclamation through arsenic sandstone has a positive role in changing the soil texture, accumulation of soil nutrients. Soil catalase activity, dehydrogenase activity, urease activity, alkaline phosphatase activity, invertase activity and arylsulphatase activity increased with the year of reclamation, and significant difference between the different years of reclamation. Soil microbial biomass carbon, soil basal respiration rate and microbial quotient became higher with the increase of the reclamation time, metabolic quotient reduced, that showed sandy land reclamation by blending arsenic sandstone, accelerate succession of the soil ecosystem from low to high range. The results indicate soil enzymes and soil microorganisms play an important role in instructing and predicting the sand soil quality, which provide reference for reasonable sand management measures in Mu Us Sandy Land.

1. Introduction

Mu Us Sandy Land is one of the four large sandy lands in China, unreasonable agriculture development and overgrazing caused serious problems in this area, such as land desertification, grassland degradation and low productivity. In order to make desertification in sandy land controlled and to achieve economic benefits simultaneously, various integrative desertification control methods in consideration have been developed in recent years. Wang et al. (2006) revealed an obvious improvement of sandy soil fertility by comparing physicochemical property of the sandy land before and after loess covering under Ephedra sinica planting. Liu (2010) showed desertification was controlled effectively when huge amount of vegetation or crop was planted. Djajadi et al. (2012) added the mix of clay and organic matter into sandy soils to improve physical texture and water retention so that crops could be planted in sandy land.

Mu Us Sandy Land is not only hazarded by desertification but also featured with a kind of rock-arsenic sandstone, which shows hard-rock property when the weather is dry, while it turns into soft
mud and forms water loss and soil erosion when being watered. However, arsenic sandstone has good water retention capacity, which appropriately makes up the shortage of sand on water and fertilizer losing. Because of the complementarity of properties in material structure, we proposed to blend arsenic sandstone with sand so as to support local agriculture and form new soil resources gradually.

During the sandy soil formation, soil microorganism is one of the active members related to all the soil developmental process. Soil microorganisms are not only the main driving force of the soil organic matter, soil nutrient transformation and circulation, but also involved in the organic matter decomposition, the humus formation, nutrient transformation and cycles, and other biological processes (Shan and Lai 2004). Soil enzymes play important roles in soils, such as mediating biochemical transformations involving organic residue decomposition and cycling (Bandick and Dick 1999). Soil microorganisms and enzymes as the comprehensive biological indicator of soil fertility, is a main content in the research of soil science in recent years. Previous studies of soil properties in Mu Us sandy land focused on the analysis of the physical and chemical properties (Shang et al. 2008; Wang et al. 2008), the systemic analysis of soil biological properties did not appear. In this study, we took the sandy soil after reclamation in Mu Us sandy land as the research object, researched on soil enzyme activities, soil microbial biomass, soil basal respiration rate, investigated the biological properties of the sandy soil binding with arsenic sandstone, so as to provide reference for reasonable sand management measures.

2. Materials and methods

2.1. Site Description
The Mu Us Sandy Land (37°27'-39°22'N, 107°20'-111°30'E) located in the East Asian Monsoonal zone, has an area of about 42200 km2. This area has a typical continental semi-arid climate (Huang et al. 2009). Mean annual precipitation decreases from above 400mm in the southeast to 250mm towards the northwest (Dai 2010). About 60%-80% of annual rainfall occurs from June to August. The average annual temperature ranges from 6.0°C to 8.5°C, with the highest average monthly temperature of 22°C in July and lowest temperature of -11°C in January. Major dust storms occur in spring, during this period the climate is extremely dry and very windy (the average wind speed in spring reaches 3.0-3.9 m/s). Resource utilization in the Mu Us Sandy Land are characterized by the coexistence of agriculture and livestock husbandry. Due to marginal rainfall, drought is a major obstacle to rain-fed agriculture, and crop yields are generally low.

2.2. Soil Sampling and Preparation
The study area is located in the south rim of Mu Us Sandy Land which is belonging to the land reclamation demonstration project area of Shaanxi Province Land Engineering Construction Group co. According to the actual situation, five sites of different reclamation years stranded for the regulation changes over the five years. The area of each site was 25 m2 (5m×5m), and sited randomly. In order to make the sample representative, chose three points in the site area with "S" type setting, 5 soil cores were collected from the top 20 cm with an auger and mixed to give a bulk sample. Each soil sample was separated into 2 parts. One part was air-dried and stored at room temperature for determination of physicochemical properties and enzyme activities. The other part was sieved (2mm mesh) and adjusted to 50% of its water holding capacity, then was pre-incubated at 25°C for 7 d and stored at 4°C for not more than one week until the start of microbial analysis.

2.3. Soil Properties Measurement
Soil particle size distribution was determined by the Malvern laser particle size analyser, Soil chemical properties were analysed according to the method described by Agricultural chemistry analysis for soil (Bao 2000). pH of a 1:2.5 soil/water suspension with a pH meter. The potassium dichromate heating method, the semi-micro Kjeldahl method, the hydrofluoric acid-perchloric acid colorimetry method were utilized to determine organic matter, total N, total P, respectively.
Soil enzyme activities were assayed as described by Guan (1987). All enzyme activities were determined from air-dried samples in triplicate, and moisture content was measured after drying at 105°C for 48h. The catalase activity was calculated as mL 0.025 mol\*L\(^{-1}\) KMnO\(_4\) g\(^{-1}\)h\(^{-1}\); the dehydrogenase activity as µg TPF (triphenylformazan) g\(^{-1}\)h\(^{-1}\); the urease activity as mg NH\(_3\)-N (ammonium) g\(^{-1}\)h\(^{-1}\); the phosphatase activity as mg P\(_2\)O\(_5\) g\(^{-1}\)h\(^{-1}\); the invertase activity as mg glucose released g\(^{-1}\)h\(^{-1}\); the arylsulphatase activity as µg nitrophenol g\(^{-1}\)h\(^{-1}\). Soil MBC was determined by the fumigation-extraction method (Vance et al. 1987). In brief, soil fumigated with ethanol-free CHCl\(_3\) and non-fumigated soils (25 g dry weight equivalent) were extracted with 50ml of 0.5 mol/L K\(_2\)SO\(_4\) (soil/extractant ratio 1:2) for 30 min by oscillating shaking at 180 rpm and filtered. Organic C in the extracts was determined after oxidation with 0.2mol/L K\(_2\)Cr\(_2\)O\(_7\) at 180° for 5 min (Lin et al. 1999).

Microbial biomass carbon was calculated as follows: MBC=EC/KEC

Where EC is the difference between organic C extracted from fumigated soils and non-fumigated soils and KEC=0.38.

Soil basal respiration rate was estimated by using the 0.1 mol/L NaOH trap method (Coleman 1978).

Metabolic quotient (qCO\(_2\)) was calculated as BR/MBC. Microbial quotient (MQ), representing the microbial respiration per biomass unit, was calculated as MBC/SOC.

2.4. Statistical Analyses
All statistical work was done using the SPSS22.0. One-way ANOVA was used to analyze means, significance were determined using the Duncan’s test to least significant difference at the 5% level.

3. Results and Analysis

3.1. The Characteristics of Soil Physical and Chemical Properties
The changes in soil physical and chemical properties in different reclamation years were presented in Table 1. The results showed that reclamation improved soil quality and soil fertility, SOM, TN, TP linearly increased with the reclamation age. Compared with the 1-yr reclamation land, the values of TN in the 2-yr, 3-yr, 4-yr, 5-yr reclamation land increased by 22.22%, 38.89%, 61.11%, 72.22%; the values of TP in the 2-yr, 3-yr, 4-yr, 5-yr reclamation land increased by 25%, 66.67%, 83.33%, 100%, respectively; the values of SOM in reclamation land increased by 64.05% to 194.38%. The increase of SOM content in reclaimed land soil was due to cultivation and plant residues return to the soil, resulting into accumulation of organic matter in surface soil. By contrast, soil pH was decreased with the reclamation years, and the value ranging from 8.99 to 8.42 in the 1-yr reclamation land to the 5-yr reclamation land. The soil mechanical composition has changed with the reclamation years, the content of sand declined, the content of silt and clay raised, significant difference between the different time of reclamation (P<0.05).

| Years of reclamation | Sand (%) | Silt (%) | Clay (%) | O.M(g/kg) | T.N (g/kg) | T.P (g/kg) | pH |
|----------------------|----------|----------|----------|-----------|------------|------------|-----|
| 0                    | 96.35e   | 3.20a    | 0.45a    | 1.54a     | 0.18a      | 0.09a      | 8.99c |
| 1                    | 94.87 e  | 4.53 a   | 0.60 a   | 1.89 a    | 0.18 a     | 0.12 a     | 8.99 c |
| 2                    | 81.22 d  | 16.05 b  | 2.74 b   | 3.11 b    | 0.22 b     | 0.15 a     | 8.55 b |
| 3                    | 73.39 c  | 22.15 c  | 4.46 c   | 3.31 b    | 0.25 b     | 0.20 b     | 8.52 ab |
| 4                    | 45.25 b  | 45.61 d  | 9.14 d   | 5.30 c    | 0.29 c     | 0.22 bc    | 8.49 a |
| 5                    | 18.10 a  | 72.14 e  | 9.76 e   | 5.57 c    | 0.31 c     | 0.24 c     | 8.47 a |

Table 1. The characteristics of soil physical and chemical properties.
3.2. The Characteristics of Soil Enzymes

As it can be seen from Fig. 1, soil enzyme activities increased gradually with the increasing of reclamation years. Soil enzyme activities were related to nutrients such as mineralization of N, P and C, and can be used as indicators to detect changes in the fertility and microbial functioning of soil.

Compared to the reclamation land of 1-yr, catalase activity increased by 19.88%, 79.54%, 99.42%, 298.27% from 2-year to 5-year reclamation land, soil catalase activity in 3-yr, 4-yr, 5-yr showed significantly different compared with 1-yr. Dehydrogenase activity is considered as an indicator of oxidative metabolism in soils and thus microbiological activity. Dehydrogenase activity showed a similar trend consistent with catalase activity. Compared to the 1-yr reclamation land, dehydrogenase activity of 2-yr to 5-yr reclamation land increased by 48.26%, 67.16%, 71.14%, 103.98%. Except for 3-yr and 4-yr, significant difference was found in soil dehydrogenase activity in the rest of the years.

Urease catalyzes the hydrolysis of urea to CO₂ and NH₃. It can be seen from the figure 1C, along with the year of reclamation, soil urease activity showed significant difference, compared to that of 1-yr reclamation land, soil urease activity increased 11.2%, 40.91%, 44.03% and 11.2% of 2-yr, 3-yr, 4-yr, 5-yr, respectively. Phosphatases catalyze the hydrolysis of both organic phosphate (P) esters and anhydrides of phosphoric acid into inorganic. As Figure 1D showed, a significant difference was found in soil alkaline phosphatase activity of the different reclamation years, in 2-yr, 3-yr, 4-yr, 5-yr reclamation land, soil alkaline phosphatase increased 34.74%, 51.86%, 65.89%, 142.31%, compared with the 1-yr reclamation land. Invertase reflects the law of accumulation and decomposition of soil organic carbon and indicates soil C cycling and important biochemical activity. Soil invertase activity increased with the reclamation year, soil invertase activity of 2-yr, 3-yr, 4-yr, 5-yr was 1.57 times, 1.55 times, 1.67 times, 2.28 times higher, respectively, than that of 1-yr reclamation land. Arylsulphatase activity can promote the mineralization of soil organic sulfur, plays an important role in the transformation and circulation of sulfur element, is an important biological indicator of soil quality. Soil Arylsulphatase activity showed significant difference among the different reclamation years, and increased 197.27%, 216.04%, 291.13%, 446.76% of 2-yr, 3-yr, 4-yr, 5-yr than 1-yr.

The results were consistent with studies by Badiane (2001) who found that many soil enzymes were immediately responsive to soil disturbance or restoration. So, many soil enzymes can be used as indicators to evaluate the stability and sustainability of reclamation land.
Figure 1. Enzyme activities under different reclamation years.

A. Catalase activity; B. dehydrogenase activity; C. urease activity; D. alkaline phosphatase activity; E. Invertase activity; F. Arylsulphatase activity. Error bars were means±SD. The Fisher’s least significant difference value was plotted to scale significant mean separation (P<0.05).

3.3. The characteristics of soil microbial biomass C (MBC), soil basal respiration rate (BR), metabolic quotient (qCO2) and microbial quotient (MQ)

The changes in soil microbial biomass C (MBC), soil basal respiration rate (BR), metabolic quotient (qCO2), and microbial quotient (MQ) of different reclamation years were presented in Table 2. MBC is considered to be more sensitive than total organic carbon to indicate soil changes for the reason that it is related to soil microorganisms that are sensitive to soil variations (Liu et al. 2003; Wang and Gong 1994). This result indicated that the land reclamation based on sand-binding by
arsenic sandstone promoted a strong increase in the MBC contents, which ranged from 120.49 mg/kg in 1-yr reclamation land to 423.37 mg/kg in 5-yr reclamation land, and significantly differences were found in the 5-yr and 4-yr reclamation land compared with the 1-yr, 2-yr and 3-yr reclamation land.

The soil basal respiration rate showed significantly different values among the sites of different reclamation years. The soil BR was increased as the year of reclamation increased, from 34.02 mg/kg to 106.23 mg/kg.

The microbial metabolic quotient has been used as a bio-indicator of environmental stress on microbial communities, disturbance and ecosystem development. When soil environment comes in for stress or disturbed conditions, soil microbes need more energy to maintain survival, and result in the metabolic quotient augment (Wardle D A 1995), the qCO2 reduced with the year of reclamation. qCO2 presented down trend with ecosystem succession from low to high and the soil with lower microbial metabolic quotient had high rate for carbon utilization, the energy to sustain the microbial growth is relatively small, the soil quality is good (Zhou et al. 2007), this result indicated that the soil quality improved because of reclamation.

As Table 2 showed, The change of soil Microbial quotient (MQ) were consistent with MBC and BR, the values increased with the reclamation age, but no significant differences in the soil microbial quotient (MQ) among different reclamation year.

### 3.4. Correlation between soil chemical properties and soil microbial properties

Some of soil microbial properties (catalase, dehydrogenase, urease, alkaline phosphatase, invertase, arylsulphatase, MBC, BR, MQ) were positively correlated with soil chemical properties (SOM, STN, STP). However, negative correlations were found in qCO2 with SOM, STN and STP. Soil pH were negatively correlated with dehydrogenase activity ($R=-0.91, P<0.05$) and arylsulphatase activity ($R=-0.86, P<0.05$), positively correlated with pH ($R=0.85, P<0.05$).

|                  | SOM  | TN  | TP  | pH     |
|------------------|------|-----|-----|--------|
| catalase         | 0.82*| 0.86*| 0.84*| -0.57  |
| dehydrogenase    | 0.90*| 0.95**| 0.95**| -0.91* |
| urease           | 0.89*| 0.95**| 0.96**| -0.72  |
| alkaline phosphatase | 0.88*| 0.92*| 0.90*| -0.71  |
| invertase        | 0.86*| 0.89*| 0.86*| -0.8   |
| arylsulphatase   | 0.93**| 0.96**| 0.93**| -0.86* |
| MBC              | 1.00**| 0.97**| 0.92**| -0.76  |
| BR               | 0.99**| 0.97**| 0.92**| -0.76  |
| qCO2             | -0.96**| -0.92**| -0.85*| 0.85*  |
| MQ               | 0.84*| 0.91*| 0.94**| -0.64  |

Note: *and ** indicate significance at the 0.05 and 0.01 level, respectively.

### 4. Discussion

The present study clearly revealed that land reclamation with arsenic sandstone in Mu Us Sandy Land altered physicochemical properties and soil microbial properties significantly. Soil organic matter, total nitrogen and total phosphorus contents significantly increased with the year of reclamation. This indicated the sandy land blending with Arsenic Sandstone could enhance the accumulation of soil organic and soil nutrients. This was due to the mixed arsenic sandstone in the sand, soil sand content reduced, silt and clay content increased, the soil texture has changed, the results were consistent with Li (2013), soil moisture storage performance enhancements (Zhang et al. 2014). Arsenic sandstone mixed with sand, improved the negative characteristics of arsenic sandstone and sand, created new soil
properties, provided favourable conditions for the growth of plants, soil nutrient content is further increased by planting crops. Compared with the soil of 1-yr reclamation land, soil pH reduced in the soils of the rest reclamation time. Increasing dissolved carbon dioxide concentrations of soil microbial respiration resulted in the soil pH decrease (Bååth and Anderson, 2003).

Soil microbes promoted decomposition of humus and improved soil nutrient transformation and cycling, and is an important indicator of soil fertility (Yang et al. 2010). With the increase of reclamation year, plant litter containing fresh organic carbon and dense root secretions gradually accumulated, leading to enhanced soil biological activity in the surface soil. Soil enzyme activities increased gradually with the time of reclamation also demonstrated that sand land reclamation by arsenic sandstone had a promoting effect on soil enzyme activities. Soil enzymes involved in many important soil biochemical process and material circulation, soil enzyme activity enhancement accelerated the sand various organic material in the enzymatic reaction, promoted the organic compound cycle, improved the properties of the sand (Shao and Zhao 2001).

As an active component of SOC, microbial biomass is an important attribute of soil quality and also serves as a sensitive indicator of change and future trends in organic C (Zhang and Fang 2007). Soil basal respiration rate and microbial metabolic quotient reflect soil microbial activities were obviously affected by the eco-environment changes. The soil basal respiration rate risen with the year of reclamation, otherwise the values of the metabolic quotient cut down. The metabolic quotient is a valid indicator of the efficiency of energy use by microbes (Yan et al. 2003). The reduced qCO$_2$ values with increased reclamation years suggested that Mu Su Sandy land reclaimed by arsenic sandstone can support a more stable ecosystem. In conclusion, our study proved that microbial properties could be the indicator of soil quality in reclamation land.

The sandy soil had good air permeability; rapid decomposition of organic matter, the material basis for the microbial life was poorer before reclamation. Soil texture as an important physical properties of soil, had effect on soil microbial quantity through the soil air permeability, and the influence of soil nutrient. Numerous studies (He 2003; Chen et al. 2002) showed that soil texture can significantly affect soil microbial quantity and activity, Xue (2004) studies suggested that the difference of soil texture can cause the difference of soil water retention and air permeability, thus affect the soil microbial quantity and activity.

Soil pH was negatively correlated with dehydrogenase activity and arylsulphatase activity. Previous studies pointed out that enzyme activities and biotransformation processes in soil were closely associated with the pH values in the environment (Deng and Parham 2006; O'Donnell et al. 2001). The changes in microbial and biochemical properties were partly due to changes of soil pH.

Further research is needed to confirm the role of microbial properties in soil succession of sand-binding by arsenic sandstone in Mu Us Sandy Land. The relevance of these changes in surface soil to the long-term sustainability of this ecosystem needs further evaluation.

5. Conclusion
After Mu us Sandy land has reclaimed by Arsenic sandstone, the content of sand reduced, silt and clay content increased, soil texture changed, soil abilities of water and fertility retention enhanced. Soil organic matter, total nitrogen, total phosphorus showed increasing trend along with the land reclamation time, the value of soil pH decline. The results illustrate the use of arsenic sandstone for sandy soil reclamation has a positive role in changing the soil texture, accumulation of soil nutrients and improve soil quality. Soil catalase activity, dehydrogenase activity, urease activity, alkaline phosphatase activity, invertase activity and arylsulphatase activity increased with the time of reclamation, and significant difference between the different years of reclamation, soil enzymes can be used as one of the important biological indicators of soil quality. Soil microbial biomass carbon, soil basal respiration rate and microbial quotient higher with the increase of the reclamation time, metabolic quotient reduced, that showed sand land reclamation by blending Arsenic sandstone, accelerate succession of the soil ecosystem from junior to senior. Therefore, soil enzymes and soil
microorganisms plays an important role in instructing and predicting in the sand soil quality of Mu us Sandy land which reclaimed by arsenic sandstone.

Acknowledgments
This study was supported by Shaanxi province key scientific and technological innovation team project degradation and unused land management innovation team (2016KCT-23) and the Scientific Research Item of Shaanxi Provincial Land Engineering Construction Group (DJNY2018-12). We are grateful to researchers at the field experiments.

References
[1] Bååth E, Anderson T H. 2003. Comparison of soil fungal/bacterial ratios in a pH gradient using physiological and PLFA-based techniques. Soil Biology and Biochemistry, 35 (7): 955-963.
[2] Badiane N N Y, Chotte J L, Patea E, et al. 2001. Use of Soil Enzyme Activities to Monitor Soil Quality in Natural and Improved Fallows in Semi-arid Tropical Regions. Appl Soil Ecol, 18: 229-238.
[3] Bandick A K, Dick R P. 1999. Field management effects on soil enzyme activities. Soil Biology and Biochemistry, 31 (11): 1471-1479.
[4] Bao S D. 2000. Agricultural chemistry analysis for soil. Beijing: China Agricultural Press. (in Chinese)
[5] Chen G C, He Z L, Huang C Y. 2002. Turnover of microbial biomass C in red soils and its significance in soil fertility evaluation. Actapedologicasinica, 39 (2): 152-160. (in Chinese)
[6] Coleman D C, Anderson R V, Cole C V, et al. 1978. Trophic interactions in soils as they affect energy and nutrient dynamics, IV, Flows of metabolic and biomass carbon. Microbial Ecol, 4: 373-380.
[7] Dai Z G. 2010. Intensive agro pastoralism: Dryland degradation, the Grain—to—Green Program and islands of sustainability in the Mu Us Sandy Land of China. Agriculture, Ecosystems and Environment, 138 (3-4): 249-256.
[8] Deng S P, Parham J A. 2006. Animal manure and anhydrous ammonia amendment alter microbial carbon use efficiency, microbial biomass, and activities of dehydrogenase and amidohydrolases in semiarid agroecosystems. Applied Soil Ecology, 33: 258-268.
[9] Djajadi, Lynette K A, Christoph H. 2012. Synergistic impacts of clay and organic matter on structural and biological properties of a sandy soil. Geoderma, 183-184.
[10] Guan S Y. 1987. Soil Enzyme and Its Research Methods. Beijing: Agricultural Press, 274-339. (in Chinese)
[11] Huang Y Z, Wang N A, He T H et al. 2009. Historical desertification of the Mu Us Desert, northern China: A multidisciplinary study. Geomorphology, 110 (3-4): 108-117.
[12] Li J, Han J C, Li X M. 2013. Effects of remixed soil with soft rock and sand on physical characters and winter wheat yield. ActaAgriculturaeBoreali-occidentalisSinica, 22 (11): 15-19. (in Chinese)
[13] Liu J Q. 2010. The cause and countermeasures of desertification in Mu Us sandland. Inner Mongolia Forestry
[14] Liu M Q, Hu F, He Y Q, Li H X. 2003. Seasonal dynamics of soil microbial and its microbial biomass and its significance to indicate soil quality under different vegetations restored on degraded red soils. ActaPedologicaSinica, 40: 937-944. (in Chinese)
[15] O’Donnell A G, Seasman M, Macrae A et al. 2001. Plants and fertilizers as drivers of change in microbial community structure and function in soils. Plant and Soil, 232: 135-145.
[16] Shan N N, Lai B. 2004. Study progresses and prospect on the ecological characteristics of soil—inhabiting microorganism in soil forming process of Aeolian sand soil. Environmental Protection of Xinjiang, 26 (Suppl): 79-82. (in Chinese)
[17] Shang A J, Bo Y J, Ai H J, et al. 2008. Research on temporal and spatial patterns and dynamic laws of soil moisture in Yulin sand district. Journal of Soil and Water Conservation, 22 (4):
86-89. (in Chinese)

[18] Shao Y Q, Zhao J. 2001. Distributions in number of soil microorganism in fixed sand dunes with Artemisia ordosica in the Kubuqi of Inner Mongolia. Grassland of China, 21 (1):88-92. (in Chinese)

[19] Vance E D, Brookes P C, Jenkinson D S. An extraction method for measuring soil microbial biomass C. Soil Biology Biochemical, 1987, 19:703-707.

[20] Wang X J, Gong Z T. 1994. Assessment and prediction of soil changes under different land use patterns at a small area level in red soil hilly region. ActaPedologicaSinica, 35:135-139. (in Chinese)

[21] Wang Y W, Liao C Y, Xu H. 2008. Soil physical properties of sand—fixing forests in Maowusu Sand land. Journal of Northwest Forestry University, 23 (3): 36-39.(in Chinese)

[22] Wang Z, Peng R Y, Wang L et al. 2006. Studies on soil properties of aeolian sandy land improvement and utilization in South edge of Mu Us Desert. Journal of Soil and Water Conservation, 20 (2): 14-21.(in Chinese).

[23] Wardle D A, Ghani A, 1995. A critique of the microbial metabolic quotient (qCO2) as a bioindicator of disturbance and ecosystem development. Soil BiolBiochem, 27:1601-1610.

[24] Yang Z P, Hao J M, Miao G Y. 2010. Effect of immature loess subsoil fertilization in current year on rhizospheric soil biological activity and nutrient of mixture cropping. Journal of Soil and Water Conservation, 24 (5): 223-227, 257.

[25] Zhang L, Han J C, Luo L T et al.2014. Water—holding characteristics of compounded soil with feldspathic sandstone and Aeolian sandy soil. Journal of Northwest A&F University (Nat.Sci.Ed.), 42 (2): 207-211. (In Chinese)

[26] Zhang M K, Fang L P. 2007. Effect of tillage, fertilizer and green manure cropping on soil quality at an abandoned brick making site. Soil Till.Res, 93 (1): 87-93.

[27] Zhou L X, D M G.2007. Soil microbial characteristics as bioindicators of soil health. Biodiversity Science, 15 (2): 162-171.