Study on the Influence of Typical Land Use Type Change on Soil Erosion Resistance in Northeast Black Soil Region

Yuehua Zhang¹,²,a, Juan Chen¹,b, Changxu Lv¹,c, Bin Yu¹,²,d, Zongming Guo¹,e*

¹College of Health, Yantai Nanshan University, Yantai, Shandong Province, 256713, China
²Health industry Research, Institute Yantai Nanshan Industrial Research Institute, Shandong Province, 256713, China

Abstract. This paper explores the soil anti-scourability characteristics of land use types in the northeast black soil region, takes the surface soil (0-10 cm) of three main land use types (including natural grassland, sylphus pine plantation and cultivated land) in the typical black soil region as the research object, analyzes the difference of soil anti-scourability coefficient of different land use types, and defines the influence of soil physical and chemical properties and root characteristics on soil anti-scourability. Identify the key factors affecting soil scourability. The results showed that: (1) the soil loss under different land use types changed sharply in the first 2 min of scour, and gradually stabilized with the extension of scour time; On the whole, the soil loss of natural grassland was the smallest, while that of cultivated land was the largest. (2) The soil scourability of different land use types was as follows: natural grassland > plantation forest > cultivated land; Compared with the cultivated land after reclamation, the soil anti-scout property of Pinus sylvestris plantation was significantly improved, and the soil loss was significantly reduced. (3) The geometric characteristic parameters of roots of natural grassland and Pinus sylvestris plantation were significantly higher than those of cultivated vegetation, and the root volume density had the greatest effect on soil anti-scour coefficient. The effects of different diameter classes of fine roots on soil scourability of three land use types were as follows: 1.5-2 mm>1-1.5 mm>0.5-1 mm>0-0.5 mm. This study can provide a theoretical basis for evaluating the soil consolidation and water conservation ability of vegetation in northeast black soil region.

1 Introduction

Soil scour resistance refers to the ability of soil to resist mechanical damage caused by runoff, which is an important aspect of soil erosion resistance[1]. It mainly depends on the cmentation between soil particles and micro-structures and the ability of soil structures to resist runoff erosion dispersion[2]. Soil physical and chemical properties and external biological factors have an important influence on the prediction of its size and change[3]. External biological factors mainly refer to vegetation roots in soil. Studies have proved that vegetation roots not only have strong ability to physically hold soil and protect soil nutrients, but also have a positive impact on the stability of soil structures[4], and enhance soil anti-s scour performance. In the aspect of exploring the factors affecting soil scourability, the root system was the key factor affecting soil scourability by comparing the changes of soil scourability in the loess hilly area under different stages of natural abandonment [5]. The ratio of fine roots, root length density and root surface area of plant roots were closely related to the physical and hydrological properties of soil. M. and B[6]. reported that soil stripping rate decreased exponentially with the increase of root length density or root density.

By studying the influencing factors of soil anti-scour under the mixed agroforestry mode in purple soil area, Stoneme found that roots significantly improved soil anti-scour performance[7]. The changes of soil anti-scourability of reclaimed farmland in different locations in the gully region of the Loess Plateau, and found that soil anti-scourability had extremely significant positive correlation with root biomass and root density[8]. The turnover of vegetation roots and the secretions of living roots can promote the content and stability of organic matter in soil[9], and the decomposition of roots can increase the nutrient content of soil and effectively promote the circulation of nutrients in root-soil [10].

Land use and management mode are the most direct factors affecting soil quality change [11]. Different land use types can affect soil anti-scour ability by affecting soil physical and chemical status, soil fertility and soil permeability[12]. studied the differences of soil anti-s scour of different land use types in woodland, grassland and cultivated land. It was found that the soil anti-s scourability of the three soils was woodland > grassland > cultivated land, and it was believed that forest and grassland land could effectively improve soil anti-scourability[13]. The physical, chemical and biological properties of soil under different land use modes are significantly different[14]. Reasonable land use mode

Corresponding author: *zhangyaohua_2008@163.com; †chenjuan8796@126.com; ‡13255510292@163.com; §95189334@qq.com; ¶guozongming163@163.com

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).
can improve soil quality, enhance water and fertilizer retention performance, and enhance soil resistance to external environmental changes, while irrational land use mode will break soil structure, nutrient loss, and aggravate erosion degradation [15]. This paper takes the surface soil under three main land use types, including natural grassland, sylphus pine plantation and cultivated land that in typical black soil area as the research object, analyzes the influence of soil physical and chemical properties and root characteristics on soil anti-scour, identifies the difference of soil anti-scour coefficient of different land use types, and identifies the key factors affecting soil anti-scour. The purpose of this study is to provide theoretical basis for the study of soil consolidation and water retention ability of vegetation in typical black soil area.

2 Materials and methods

2.1. Sample site selection and sample collection

According to the disturbance degree of land, land use types in the study area were divided into three types: Natural grassland, Pinus sylvestris plantation and Arable land. Natural grassland is the land system with minimum human disturbance, and the dominant vegetation species are Artemisia annua and Carex tristachya. Pinus camphor plantation for the original history of cultivation, and later planted pinus camphor tree species, has become a forest; The main crop under cultivation is maize, which has a long history of cultivation. Choose the above three kinds of land for soil samples collected. After clearing the litter layer, 4 ring cutter samples and 4 aluminum box samples were taken from each representative area under each land use type to determine the soil bulk density. The surface undisturbed soil was collected with a 15cm3 volume undisturbed soil sampler with 3 replicates per plot for the determination of soil aggregate and mechanical composition. The surface undisturbed soil was collected by undisturbed soil sampler with 3 replicates per plot to determine soil anti-scourability. 2.5 kg of surface soil was collected and brought back to the laboratory for treatment. After air drying, the surface soil was finely ground and sifted. 4 replicates were performed for each sample site to determine soil chemical properties.

2.2. Determination of physical and chemical properties of soil

Soil bulk density, soil moisture content, total porosity and aggregate were determined using part of the agricultural industry standard soil detection method. There were 4 repetitions of indexes in each sample plot, and the average value was taken for correlation analysis. Soil mechanical composition was determined by pipette method [16]. Soil pH was measured by potentiometric method. The content of soil organic carbon and total nitrogen was determined by elemental analyzer. The content of total phosphorus in soil was determined by sulfuric acid-perchloric acid-molybdenum-antimony resistance colorimetric method.

<table>
<thead>
<tr>
<th>Type of land use</th>
<th>Serial number</th>
<th>Altitude/m slope/(°)</th>
<th>Density plant</th>
<th>Percentage of water-stable aggregate mass(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>natural meadow</td>
<td>I</td>
<td>302</td>
<td>4</td>
<td>5.067±</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.233±</td>
</tr>
<tr>
<td>Pinus sylvestris</td>
<td>II</td>
<td>302</td>
<td>7</td>
<td>0.113±</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.057±</td>
</tr>
<tr>
<td>Cultivated land</td>
<td>III</td>
<td>306</td>
<td>6</td>
<td>0.873±</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.623±</td>
</tr>
</tbody>
</table>

**Note:** Different lowercase letters represent the difference of particle size of different aggregates under the same land use type;

### 2.3. Determination of root characteristic parameters

Clods of soil resistance to erosion test in the fine mesh (0.25 mm) aperture rinsed repeatedly, access to clean the plant root system, after scanning in root scanner, use the root analysis system (EPSON LA 2400), according to the root diameter 0-0.5 mm, 0.5- 1.0 mm and 1.0-1.5 mm, Root parameters, such as root length, root surface area and root volume, were obtained by analyzing the scale of 1.5-2.0 mm. Root length density (RLD) is the root length per unit volume of soil, which can reflect the degree of root interpenetration and entanglement in soil. Root surface area density (RSD) is the surface area of roots contained in a unit volume of soil, which can reflect the degree of contact between roots and soil[17]. Root bulk density (RVD) reflects the space occupied by plant roots. Root length density RLD, root surface area density RSD and root volume density RVD were calculated.

### 2.4. Soil scourability test

The scour method of undisturbed soil trough is adopted. The size of the undisturbed soil sampler was 16 cm in diameter and 6 cm in height. Before the scouring test, the soil samples were placed in a flat bottom basin, the water level in the basin was no higher than the upper edge of the sampler, and soaked for 24 h to make the soil samples reach capillary water saturation. Then, the saturated undisturbed soil was placed on an iron platform for 8 h to remove soil gravity water, and the scouring slope was set at 6°. The maximum runoff generated by...
the local standard runoff plot was used to calculate the unit discharge as the scour discharge, namely 3L/min, and the scour time was 15 min. During the scouring test, the run-off sediment samples were collected once every 1 min in the first 3 min after the self-generated flow with the sampling bucket, and then once every 2 min, and a total of 9 samples were collected. At the end of the scour test, the sampling bucket was set to be clarified, and the upper clear liquid was poured out after complete sediment precipitation. The remaining mud samples were transferred to the iron box and dried in the oven at 105 °C for 8 h. Then the dry mass of sediment (g) was measured, and the anti-scor coefficient of soil AS was calculated, that is, the water required to scour 1 g of soil (L/g). The greater the anti-scor coefficient of soil, the stronger the anti-scor property of soil. Equation (4) is used to calculate [18].

Coefficient of erosion resistance (AS) = $f \times \frac{v'}{w}$ (4)

2.5. Data Processing

Excel and Origin-22 software were used to fit and process the empirical equations. SPSS 21.0 was used for correlation analysis and regression analysis of the data, and EPSON LA 2400 root analysis system was used for data processing and analysis.

3 Results and analysis

3.1. Differences in physical and chemical properties of soils of different land use types

The results of soil physical and chemical properties under different land use types are shown in Table 1. The bulk density of soil in natural grassland is the smallest, while that in cultivated land is the largest, which is 1.781 and 1.199 times of that in natural grassland and Pinus sylphus plantation, respectively (P<0.05). Among the three land use types, natural grassland had the largest moisture content, reaching 70.837%, which was 3.308 and 2.914 times of that of plantation and cultivated land, respectively, and the difference was significant compared with the other two land types (P<0.05). The total porosity of natural grassland was significantly higher than that of the other two land types (P<0.05), and was 1.215 and 1.240 times of that of plantation and cultivated land, respectively. The mechanical composition of the three land use types was mainly silt, with the content ranging from 50.207% to 60.227%. It can be seen from Table 1 that the soil texture of natural grassland and plantation plantation is silty clay loam, while that of cultivated land is silty clay.

Table 2 Results of soil physical and chemical properties under different land use types

<table>
<thead>
<tr>
<th>Type of land use</th>
<th>Soil bulk density(g·cm⁻³)</th>
<th>Soil moisture content(%)</th>
<th>Total porosity(%)</th>
<th>Composition of machinery(%)</th>
<th>Soil (pH)</th>
<th>Organic matter content (g·kg⁻¹)</th>
<th>Total phosphorus (g·kg⁻¹)</th>
<th>Total nitrogen (g·kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>natural meadow</td>
<td>0.690±0.020</td>
<td>0.708±0.046</td>
<td>70.881±6.331</td>
<td>58.321±1.348</td>
<td>5.834±0.835</td>
<td>132.461±0.036</td>
<td>0.825±0.007</td>
<td>6.356±0.019</td>
</tr>
<tr>
<td>Pinus sylvestri s</td>
<td>1.025±0.025</td>
<td>0.214±0.040</td>
<td>55.977±12.276</td>
<td>55.781±0.992</td>
<td>5.565±1.062</td>
<td>61.731±0.026</td>
<td>0.666±0.034</td>
<td>3.016±0.010</td>
</tr>
<tr>
<td>Cultivate land</td>
<td>1.229±0.007</td>
<td>0.243±0.063</td>
<td>50.207±6.751</td>
<td>50.143±0.687</td>
<td>5.912±0.601</td>
<td>50.220±0.063</td>
<td>0.755±0.013</td>
<td>2.414±0.004</td>
</tr>
</tbody>
</table>

Note: Lowercase letters indicate significant differences in physical and chemical properties of soils of different land use types. (P<0.05).

3.2. Differences in root geometric characteristics of different land use types

The enhancement effect of roots on soil anti-scorability is an important aspect of vegetation control of soil erosion. Plant roots can enhance soil anti-scorability through network series and root-soil bonding [15]. The changes of geometric characteristic parameters of soil roots of different land use types are shown in Table 2. The root length density RLD, root surface area density RSD and root volume density RVD of natural grassland were 0.5 mm~0.5 mm, 1.5 mm~1.5 mm, and 1.5 mm~2 mm, and the RSD (0-0.5) was significantly different from other parameters (P<0.05). RSDS and RVD of the four diameter classes were not significantly different. The changes of root geometric characteristics in plantation and cultivated land were consistent with those in natural grassland. The root length density RLD, root surface area density RSD and root volume density RVD of the four diameter classes of natural grassland were significantly higher than those of plantation and cultivated land (P<0.05). In addition, root length density of fine roots with diameter of 0-0.5 mm accounted for 82.906%~89.945% of total root length density, root surface area density accounted for 55.414%~69.595%, and root volume density accounted for 35.714%~42.857% of total root length density. The root length density of 0-1 mm diameter fine roots accounted for 96.764%~98.700% of the total root length density, the root surface area density was 85.987%~93.216%, and the root volume density was 71.429%~85.714%. It can be seen that the main body of the root system is the fine roots with diameter of 0-1 mm.

Table 3 Changes of geometric characteristic parameters of soil roots in different land types

<table>
<thead>
<tr>
<th>Type of land use</th>
<th>Root length density(cm/1m)</th>
<th>Root surface density(cm²/1m)</th>
<th>Root volume density(cm³/1m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-0.5mm</td>
<td>1.5-2.0mm</td>
<td>0.5-1.0mm</td>
<td>1.5-2.0mm</td>
</tr>
<tr>
<td>0.5-1.0mm</td>
<td>1.5-2.0mm</td>
<td>0.5-1.0mm</td>
<td>1.5-2.0mm</td>
</tr>
<tr>
<td>1.0-1.5mm</td>
<td>1.5-2.0mm</td>
<td>0.5-1.0mm</td>
<td>1.5-2.0mm</td>
</tr>
</tbody>
</table>
which is manifested as loose soil structure and reduced soil microorganisms and high organic matter content, adequate light and water conditions, resulting in active soil porosity and reduced soil bulk density. Compared with the formation of soil aggregates, loosen the soil, increase network consolidation and biochemical action promote has a stronger correlation with soil anti-scour coefficient, FIG. 3 shows that, compared with sand content, silt content, the more the more conducive to infiltration. FIG. 4 shows that, compared with soil erosion resistance ability is different, which was attributed to the fact that mechanical tillage would destroy soil aggregates, increase soil bulk density and reduce the stability of soil structure. On the one hand, soil biological activities are inhibited by fertilizers and pesticides due to the underdeveloped root system. On the other hand, soil compaction and compaction are caused by agricultural activities such as watering, seeding and frequent trampling behavior, which damages soil pore connectivity.

3.3. Differences in soil loss characteristics of different land use types

The soil loss rate of natural grassland was 1.947 g/min in 0-1 min, decreased rapidly in 1-2 min, and stabilized at 0.167 g/min after 6 min. The soil loss rate of Pinus sylvestris plantation was 4.421 g/min in 0-1 min, decreased rapidly in 1-2 min, and stabilized at 0.077 g/min after 10 min. The soil loss rate of cultivated land was 25.249 g/min in 0-1 min, decreased rapidly in 1-2 min, and stabilized at 2.042 g/min after 2 min. In conclusion, the soil loss rates of the three land use types all had the maximum value within 0-1 min, and the soil loss rates of cultivated land were the largest, which were 12.968 and 5.711 times that of natural grassland and Pinus sylvestris plantation, respectively, and the soil loss rates of the three land use types gradually stabilized with the increase of erosion time.

4 Discussion

4.1. Land use type change Influence of soil physical and chemical properties on soil scourability

The physical and chemical properties of soil are the inherent characteristics of soil itself, reflecting soil texture, soil looseness and other conditions[17]. Numerous research results show that different land use types can affect soil particle composition, organic matter content, pH value, etc., mainly through different soil surface vegetation cover and land management methods (tillage, fertilization, etc.) affecting soil physical and chemical properties[18].

The composition of soil reflects the soil particle composition and soil texture, soil particle size is different, the soil erosion resistance ability is different, has a great influence on the permeability of soil, the soil sand content, the more the more conducive to infiltration. FIG. 3 shows that, compared with sand content, silt content has a stronger correlation with soil anti-scour coefficient, and a very significant positive correlation. On the one hand, there is little human disturbance, and the root network consolidation and biochemical action promote the formation of soil aggregates, loosen the soil, increase soil porosity and reduce soil bulk density. Compared with woodland, natural grassland vegetation has more adequate light and water conditions, resulting in active soil microorganisms and high organic matter content, which is manifested as loose soil structure and reduced bulk density. The bulk density of cultivated land was the largest and significantly different from the other two land use types, which was attributed to the fact that mechanical tillage would destroy soil aggregates, increase soil bulk density and reduce the stability of soil structure. On the one hand, soil biological activities are inhibited by fertilizers and pesticides due to the underdeveloped root system. On the other hand, soil compaction and compaction are caused by agricultural activities such as watering, seeding and frequent trampling behavior, which damages soil pore connectivity.

4.2. Effects of root geometric characteristics changes of different land use types on soil anti-scourability

Plant roots form root networks through interpenetration and entanglement in soil, which play the role of consolidation of soil. This mechanical network effect makes soil structure stable and not easy to be scour and dispersed by water. On the other hand, the existence of plant roots can improve the physical and chemical properties of soil, make the soil structure more reasonable, and thus improve the soil anti-scour performance. Changes of geometric characteristics of soil roots in different land types; It can be seen from Table 3 that the four diameter class parameters of RLD, RSD and RVD are all in the order of natural grassland > plantation forest > cultivated land. It can be seen that the root system of natural grassland has high surface density and large contact area with soil, forming a good root network. The correlation between root geometry parameters and soil anti-scour at the same diameter class was as follows: root volume density RLD > root surface area density RSD > root volume density RVD for fine roots at 1.5-2 mm diameter class, and root volume density RVD > root surface area density RSD > root length density RLD for all diameter classes. The average correlation coefficient of root volume density was the highest. This is because the volume density of roots represents the proportion of space occupied by roots in the soil, and the larger the volume density of roots, the larger the space occupied by roots in the soil. Since roots are relatively small, small changes in the volume density of roots can bring about great changes in soil anti-scour. Because the volume density of root is too small, the improvement of soil anti-scourability is limited. When the volume density of roots increases, the vegetation roots become dense, and the ability to improve soil resistance to erosion by water flow is greatly enhanced.
5 Conclusion
The soil loss under different land use types changed dramatically in the first 2 min of erosion, and stabilized after 6 min with the extension of erosion time. Under the same conditions, soil loss in natural grassland was the minimum, while soil loss in cultivated land was the maximum. Different land use types resulted in different soil scour resistance, which was natural grassland > plantation forest > cultivated land. Plantation forest significantly improved soil scour resistance, and significantly reduced soil loss. Further, the root system, natural grassland, mongolica plantation root geometric feature parameters of vegetation were significantly greater than the cultivated land vegetation, and root volume density influence on impact coefficient for soil is the largest. Three land use types with different diameter grade fine roots effect on soil resistance to erosion are characterized by: 1.5-2 mm, recommendations will be 1.5-2 mm diameter level characteristics of fine root index as an evaluation of the northeast black earth area vegetation index of soil water retention, and 1.5-2 mm diameter level of fine root and soil impact coefficient relationship more closely, Moreover, root characteristic parameters were positively correlated with soil anti-scurc coefficient, indicating that the longer the root system, the larger its surface area and volume, the stronger the soil anti-scurc.

Acknowledgments
Supported by Wisdom health and pension service and management specialty construction special fund- department of shandong province: JKZHYL202205; Yantai Nanshan University youth science and technology fund: 2021QKJ01. Longkou City Science and Technology Research and Development Plan Project(2021KJJH026).

References