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Vegetation succession of abandoned croplands in Ruanliang and Yingliang in the Ordos Plateau

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ABSTRACT

Shrub encroachment has been a key phenomenon in arid and semi-arid grasslands over the last century. However, little research has been dedicated to vegetation dynamics in the abandoned croplands, which are surrounded by shrub-encroached grasslands. In this study, several abandoned croplands in Ruanliang and Yingliang in the Ordos Plateau were selected, and the biomass, coverage, density, root pattern, and plant litter dynamics were studied. The results showed that: (1) The abandoned croplands in Ruanliang experienced three community types, including weeds community, the subshrub *Artemisia ordosica* community, and the perennial grass community, while the abandoned croplands in Yingliang experienced three community types, including weeds community, perennial *Stipa bungeana* with *Artemisia frigida* community, and *S. bungeana* community. (2) The important value for the annual or biennial grass in abandoned croplands in Ruanliang declined during the restoration process, for the perennial grass it increased, and for the subshrub it first increased and then went down to zero. In Yingliang abandoned croplands, however, the perennial grass remained dominant during the succession process. (3) The root of *A. ordosica* in Ruanliang abandoned croplands was mainly distributed in soil depths of 0–30 cm; the root of the perennial grass was mainly in the 0–20 cm range, and *S. bungeana* was found at soil depths of 0–5 cm. To restore to a natural vegetation state, about 20 years would be needed to recover the total biomass, and 10 years would be needed to restore the vegetation coverage in Ruanliang abandoned croplands. For Yingliang abandoned croplands, about 15 and 20 years would be needed to restore the total biomass and vegetation coverage, respectively, to a state of natural vegetation.

1. Introduction

In later years, shifts in land use and climate changes incurred by artificial factors lead to speedy expansion of woody or shrubby plants in a large scope of the grassland ecosystem. The phenomenon of increased coverage, density and biomass of indigenous woody or shrubby plants in grassland distribution areas is called shrub encroachment [1], also known as woody weed invasion [2], woody thicketization [3] and so forth. Shrub encroachment is the major manifestation of decaying grasslands in arid and semiarid areas in the past century or so [4], as about 10–20% of grassland was going through the trend [5] that affected a population of 2 billion [6]. Shrub encroachment is triggered by overt grazing [7], fire [8], pattern of precipitations [9] and so on that affect the biomass of colonies and species' richness [10], add to direct surface runoff and soil erosion [11] and even lead to possible grassland degeneration or desertification. Therefore, studies on shrub encroachment are of major significance to expound plant community succession processes and mechanisms in grasslands and for guiding ecological recovery of vegetation.

Studies on shrub encroachment are concentrated on African savannas [12], arid and semiarid prairies in North America [13], subalpine meadows [14], highlands of Inner Mongolia in China [15] and so forth. However, most studies are concentrated on shrub encroached grassland disturbed by artificial or natural factors [16–18] and studies of abandoned croplands are rare. In the 1930s–1940s, a large area of the prairie was cultivated and deserted abroad. Many scholars carried out studies on vegetation succession of abandoned croplands [19]. Long-term studies of vegetation dynamics reveal that early-stage vegetation for ecological succession characterizes high fertility with easy-to-transmit propagule yet inferior competitiveness [20]. Varieties of vegetation in the early stage and process of succession are largely related to fertilizers and herbicides used before the cropland is abandoned, as well as on the speed of soil denudation, zonal vegetation prior reclamation and distance from provenance [21]. As the succession progresses, vegetation in the early stage is gradually replaced by gramineous grass or woody

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plants and shows a tendency of zonal vegetation succession [22,23]. However, whether croplands cultivated in grasslands besieged by encroached shrubs would be affected by shrub invasion, the degree displayed by the invasion as well as ultimate succession orientation remain blurred.

Located in the central area of the Inner Mongolia of China, Ordos Plateau is one of the land desertification centers of China [23,24]. The process of shrub encroachment has been ongoing for centuries. It is an ideal venue for digging into the genesis process and exploring mechanism of shrub encroachment. At present, dominant plants in Ordos Plateau are *Artemisia ordosica*, but findings from studies on distribution zones of vegetation indicate that other zonal vegetation should be temperate grasslands dominated by *Stipa bungeana* [25]. Moreover, multiple grassland varieties cover *Stipa grandis* grassland, *Stipa gobica* grassland and so on, which are distributed in Ordos Plateau accompanied by *Lemus Chinensis* [26]. Whether community succession starting with abandoned croplands develops towards *Artemisia ordosica* or *Stipa bungeana* or other intermedium processes during a certain stage due to the heterogeneity of partial environments is unknown. Historically, many croplands in Ordos Plateau were cultivated from shrub encroached grassland in the region of Ruanliang or Yingliang. In these regions the nutrient level is poor. After cultivation it was gradually restored to the *Artemisia ordosica* encroached grasslands. In recent years, the Erdos government has adopted viable measures around grazing prohibition and grain for green. Hence, degradation of ecological systems triggered by shrub encroachment has been taking a turn for the better to a certain degree. In some abandoned croplands covered by sand in Ruanliang, the tendency of succession dominated by *Stipa bungeana* and other perennial herbs emerges, which clashes with the international summary, in particular the conclusion that severe encroached grasslands in prairies of North America can't be naturally restored [27].

In this research, studies on vegetation succession of abandoned croplands with different abandoned years in Ruanliang and Yingliang in Ordos Plateau can reveal the vegetation succession tendencies, which further allow for the discussion of the probability of succession of abandoned croplands to *Stipa bungeana* zonal vegetation, and help expound restoration mechanism of shrub encroachment and provide theoretical foundations for vegetation restoration in Ordos Plateau.

2. Region and methods

2.1. Study region

Ordos Plateau is located within the range of 37°35′24″–39°29′37.6″ N and 106°42′40″–111°27′20″ E. With an elevation of 850–1600 m, it is circa 400 km from east to west and around 340 km from south to north. As a transitional zone from the Gobi desert in Northwest China to the Loess Plateau, it demonstrates a subtle natural ecological surrounding. The area has a classical semiarid continental climate characterized by freezing winters and cool summers. It shows a gradual drop from 400 mm to 200 mm from the east to the west in terms of precipitation with 93% of rainfalls clustering over the period of April to October. Landscapes in Ordos Plateau are categorized into three types, respectively Ruanliang, Yingliang and bottomland Tandi with the former two accounting for about 90% of the landscape types [23]. As a core area for high productivity of agriculture, woods, fruits, herds and so forth in Ordos Plateau [28], the Tandi witnesses comparatively less deserted tillage. Abandoned croplands in regions of Ruanliang and Yingliang constitute the main body of abandoned croplands. Zonal vegetation in Erdos Plateau is *Stipa bungeana* warm temperate grassland, which are only dispersed in the upland of Ruanliang and Yingliang. The subshrub *Artemisia ordosica* community is the most common vegetation distributed in sandy soil [29]. The research spots were located at Ejin Horo town in Ejin Horon Banner of Ordos City, which falls to abandoned croplands between 39°24–26′ N and 109°50–52′ E. Ruanliang deserted croplands are found within the area of the sample plot is between 1355 and 1367 m in elevation, while the Yingliang falls from 1383 to 1377 m in height.

2.2. Research methods

2.2.1. Selection of the sample plots

The field experiment was carried out in late August 2015. Through plenty of early-stage investigation, the most representative sample plots for observation in abandoned croplands in both Ruanliang and Yingliang areas were selected. The Yingliang contained croplands that had been abandoned for 3 years, 6 years, 10 years, 15 years and 20 years respectively while those in Ruanliang had been deserted for 1 year, 6 years, 10 years, 15 years and 20 years respectively. Uncultivated natural vegetation in Yingliang and Ruanliang areas were respectively taken as contrasting (Table 1). Three replicates are set up in each of the sample plots. Bushy quadrant covered 5 m × 5 m, while the herbal quadrant covered 1 m × 1 m. Sample abandoned croplands with varying years in both the Yingliang and Ruanliang areas should remain consistent with contrast sample areas in terms of minor ambiances covering topography, geomorphology and so forth and each area should be constrained to the scope of 2 km in order to ensure consistency of climate and environmental terms.

2.2.2. Research in sample plots

Data was recorded in each quadrat as species composition of community, total coverage of community, litter coverage, coverage of different individuals, individuals' height, density of species and so forth. Cutting methods were adopted to gauge above-ground biomass that, along with litters on the ground, were taken to the laboratory and dried to a constant weight at a temperature of 80 °C. The soil core method (inner diameter at 16 cm) was adopted to gauge the underground biomass and root distribution of herbaceous plants. Stratified sampling was taken at an interval of 5 cm for the first 0–10 cm of the soil layer followed by intervals of 10 cm until the root system could scarcely be seen. Root system sieving and drying was carried out with reference to methods by Ravenek [30]. Uprooting of a whole plant was adopted to measure the distribution of roots of *Artemisia ordosica*. Specifically speaking, the roots of *Artemisia ordosica* were taken to be the base point. Soil was extracted within a 1 m radius. Stratified sampling was taken at intervals of 5 cm for the first 0–10 cm of the soil layer followed by intervals of 10 cm. Sieving and collection of root system soil at each layer was collected until the root system could scarcely be seen.

2.2.3. Data analysis

Data analysis was conducted in SPSS 18.0. One-way ANOVA analysis and multiple comparisons (LSD, $P = 0.05$) were adopted to analyze community biomass, coverage, importance values and density of varying varieties of abandoned croplands of different years in Ruanliang and Yingliang areas. Calculation formulas of importance value (IV) were:

$$IV = RDE + RCO + RFE$$

In the formula, *IV* refers to the importance value; *RDE* refers to relative density; *RCO* refers to relative coverage; and *RFE* refers to relative frequency. Life forms are determined by the degree of lignification of varying plants that are categorized into annual or biennial herbs, perennial herbs and subshrubs.

3. Results

3.1. Changes on species component during the succession process

Community succession of abandoned croplands in Ruanliang went through three stages: (1) Annual or biennial weed community stage (*Setaria viridis* + *Agriophyllum squarrosum*). In the preliminary 1-3a of abandoned croplands, tilled farming trails could still be seen. Annual and biennial weeds such as *Setaria viridis* and *Agriophyllum squarrosum* made a rapid intrusion and took the dominating position. (2) Thicketization of *Artemisia ordosica*. Abandoned croplands covered around 3-10a. Annual and biennial weeds such as *Setaria viridis* and