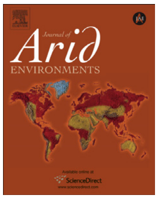
Journal of Arid Environments 131 (2016) 1–5

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv



Factors limiting vegetation recovery processes after cessation of cropping in a semiarid grassland in Mongolia

Aki Yanagawa [a, *], Takehiro Sasaki [b], Undarmaa Jamsran [c], Toshiya Okuro [d], Kazuhiko Takeuchi [e]

[a] School of Environment and Society, Tokyo Institute of Technology, 2-12-1-M1-6 O-okayama, Meguro-ku, Tokyo 152-8552, Japan
[b] Graduate School of Environment and Information Sciences, Yokohama National University, 79-7 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan
[c] Center for Ecosystem Studies, Mongolian University of Life Sciences, Ulaanbaatar 17024, Mongolia
[d] Department of Ecosystem studies, Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo, Japan
[e] Integrated Research System for Sustainability Science, The University of Tokyo Institutes for Advanced Study, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8654, Japan

ARTICLE INFO

Article history:
Received 8 December 2014
Received in revised form
19 February 2016
Accepted 23 March 2016
Available online 6 April 2016

Keywords:
Historical land use
Restoration
Phosphorus
Semiarid grassland
Mongolia

ABSTRACT

Land degradation in an abandoned field, such as the loss of palatable species for livestock and low species richness, is a serious problem in Mongolia where the dominant land use is livestock grazing historically. Here, we show the factors limiting vegetation recovery processes after cessation of cropping in a semiarid grassland. We selected fields abandoned in 1990 (CA18), 1999 (CA9), and 2006 (CA2) and continuously grazed grassland (CGG) as a control site. Plant species cover and soil were sampled during summer (June–July) 2008. Soil physicochemical properties were analyzed. Low similarity index of an early succession stage, CA2, with CGG was associated with abundant P and coarse sand. The proportion of coarse sand was not abundant in middle stage (CA9) because of domination by perennial rhizomatous species. In the later stage (CA18), the fine sand proportion did not increase; however, the dominant species were associated with fine sand in CGG. The results suggest the limiting factors of recovery processes in abandoned Mongolian cropland are abundantly available P and coarse sand at an early succession stage (CA2). The small proportion of fine sand in CA18 indicated that the impacts of cropping in Mongolia persist for a long time.

1. Introduction

Environmental and social-economic changes are leading to increased levels of abandoned cropland worldwide (Ramankutty and Foley, 1999). In particular, grassland is the easiest among all vegetation types to clear for cropping. However, cropland in grassland tends to be abandoned at the second highest rate (11%) compared to that in forest land (14%) (Ramankutty and Foley, 1999). Considering grassland is found mainly in semiarid regions, crop abandonment could drastically reduce its potential to recover to a pre-disturbance state. There are many chronosequence studies showing factors limiting the recovery of abandoned cropland in arid regions. For instance, limited seed availability limits recovery in old Australian fields (Scott and Morgan, 2012). Limitations of total P and soil water are factors limiting recovery on the loess plateau of China (Jiao et al., 2008).

In Mongolia, grassland covers 97.4% of the national land area. Nomadic grazing has occurred for over two thousand years (Montsame, 2008), whereas cropping began only in the past 60 years. There are 436,000 ha of abandoned croplands in Mongolia (National Scientific Office of Mongolia, 2007). A loss of typical species composition and small amounts of organic C and available water for plants in a field abandoned 12 years ago, compared with typical rangeland, have been reported (Hoshino, 2010). However, the recovery process of abandoned cropland in Mongolian rangeland is unknown.

There have been attempts at restoration of a degraded Mongolian field abandoned nine years ago, such as by sowing of perennial grass by the Swiss Agency for Development and Cooperation and by creating gaps by removing annual species at different distances from intact vegetation to determine whether the rhizomatous

---

* Corresponding author. School of Environment and Society, Tokyo Institute of Technology, 2-12-1-M1-6 O-okayama, Meguro-ku, Tokyo 152-8552, Japan.

E-mail addresses: yanagawa.a.aa@m.titech.ac.jp (A. Yanagawa), sasa67123@gmail.com (T. Sasaki), j_undarmaa@muls.edu.mn (U. Jamsran), aokuro@mail.ecc.u-tokyo.ac.jp (T. Okuro), takeuchi@ir3s.u-tokyo.ac.jp (K. Takeuchi).

http://dx.doi.org/10.1016/j.jaridenv.2016.03.008
0140-1963/Published by Elsevier Ltd.

species *Leymus chinensis* could invade and grow in abandoned cropland (Hoshino et al., 2009). However, the sowing of perennial grass failed, owing to unexpected drought in summer. The rhizomatous species did not expand into the gaps, although they were adjacent to tracts of the rhizomatous species. These failures of restoration activities result from the selection of inappropriate restoration targets without considering underlying restoration constraints (Hobbs and Harris, 2001). Soil conditions may be limiting if annual species are not removed. However, the recovery process and the factors limiting its recovery are unknown. Moreover, whether limiting factors change during the recovery process is unknown. Therefore, our objective was to characterize the recovery process of vegetation and soil and the factors limiting recovery by sampling across a chronosequence of abandoned Mongolian cropland.

2. Materials and methods

The study was conducted in forest steppe in Hustai National Park (HNP, 47°50′N, 106°00′E), Mongolia (Fig. 1A). The average elevation of HNP is 1240 m a.s.l. The region's climate is semiarid and cold with a short summer. Most of the annual precipitation falls in summer (May–July) and is critical for the growth of grasses. Based on data from the HNP weather station, annual precipitation averaged 232 mm (CV 31% and 76% of rain fall in May to August), and annual temperature averaged 0 °C (the range was −19 °C in January to 20 °C in July) during 1999–2005. The zonal soils were classified as Kastanozems by soil profile morphology and physicochemical properties.

Some parts of the study area had been tilled and then abandoned at different time periods. We consulted the municipal archives and interviewed landowners to determine the abandonment time. We selected fields abandoned in 1990 (CA18), 1999 (CA9), and 2006 (CA2). Wheat with chemical fertilizer and without irrigation was grown since 1977 in CA2, CA9, and CA18. Cropping systems and agricultural materials at each site followed the guidance of the government until 1992, so that the conditions of the abandoned croplands were almost the same from 1977 to 1992. Since abandonment, all fields were moderately grazed as a buffer zone in the park. We also selected continuously grazed grassland (CGG) as a control site in the buffer zone. The size of the buffer zone is 462,000 ha. All four study sites were located in flat locations in the buffer zone, so that only land use history differed among the sites. Although each abandoned cropland site experienced a different duration of cultivation (14, 23, and 30 years in CA18, CA9, and CA2, respectively), half of the change in soil physicochemical properties occurred during the first eight years, and subsequent changes were slow (Zhao et al., 2005). We accordingly assumed minimal effects of different durations of cultivation on our results.

Vegetation and soil were sampled during summer (June–July) 2008, for five fields at each site (CA2, CA9, CA18, CGG) at least 300 m apart, which were randomly selected and located in homogenous subsurface soil on flat land. We sampled the subsurface soil to 50 cm depth with a hand auger. In each field, a 100 × 100 m plot away from the field edges was delineated. We then systematically sampled five 1 × 1 m quadrats along three transects in each plot. Fifteen quadrats in five fields at four sites constituted 300 quadrats in total. Each transect was separated from its neighbor by 30 m, and the distance between the quadrats in each transect was 20 m. In each quadrat, we recorded the percentage cover of each species. The soils were sampled in every alternate quadrat at the depth of 0–15 cm (three samples per transect and nine samples in five fields at four sites, for a total of 180 soil samples). The volumetric water contents were measured at the soil sampling points before sampling with a mobile soil sensor (WET-2, Delta-T Device Ltd, Cambridge, England). The soil was too dry for moisture measurement at some of the points, so the number of data points for volumetric water content were 24, 24, 26, and 28 for CA2, CA9, CA18, and CGG, respectively. Each abandoned field was compared with the control site.

Bulk soil samples were air-dried and sieved (<2.0 mm) for measuring soil properties. Particle size distribution (sieving and hydrometer analysis), soil organic carbon (wet oxidation method), total N (Kjeldahl method), available P (Olsen method), available K (flame photometry), and cation exchange capacity (CEC)

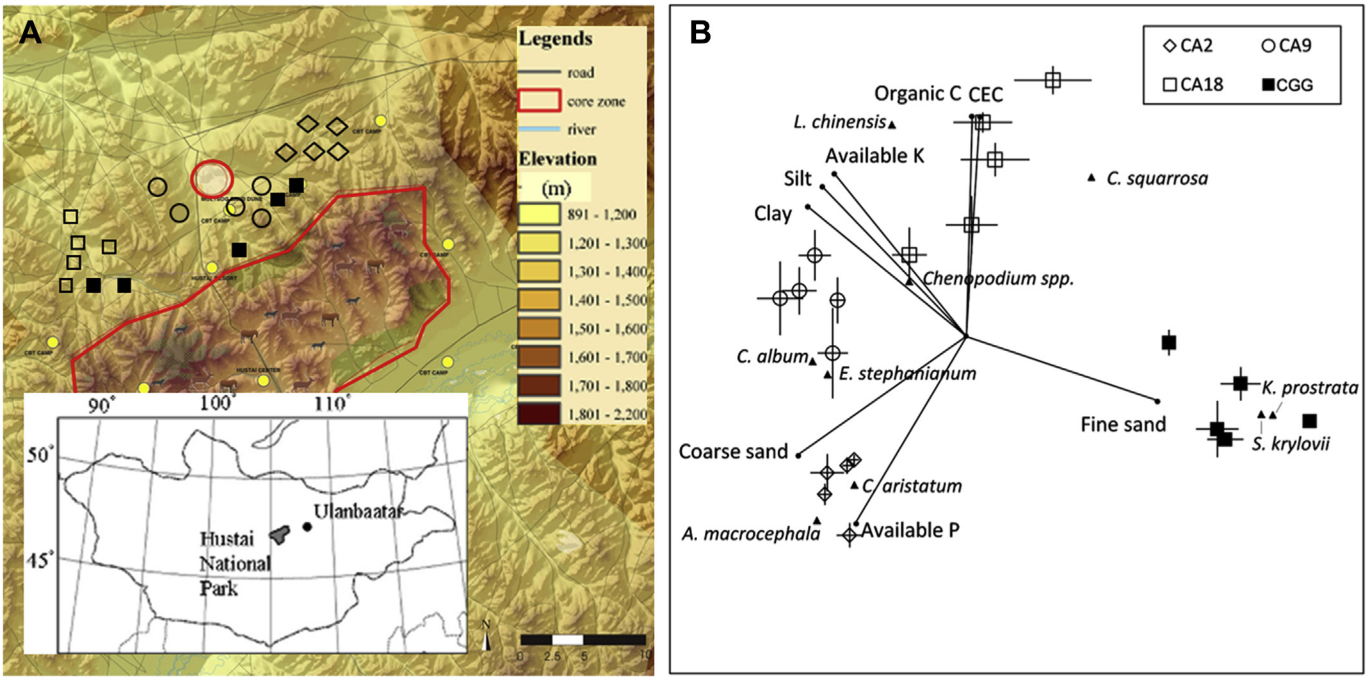


Fig. 1. A. Schematic map of the research site and NMDS of the species composition with soil properties in each plot in each site. B. Significant soil vectors are shown in the ordination (stress = 0.14). The dominant species are plotted in the figure. Vertical and horizontal error bars indicate standard errors of 15 samples in each field (5 fields at each site).