Chapter 10
Influence of Agricultural Reclamation on Vegetation Cover and Biodiversity in the Forests and Steppes of Kulunda

M. M. Silantyeva, N. V. Elesova, I. Hensen, T. A. Terekhina, A. Yu Grebennikova and N. V. Ovcharova

Abstract Throughout Eurasia, steppes are preserved in forms of small fragmented areas within the landscapes of tilled fields, fallow lands, pastures, and infrastructural complexes. In Kulunda, steppes are preserved owing to the areas of alkaline steppe with saline soil complexes as well as secondary steppes formed in uncultivated lands. Intensive agriculture in the steppe and forest-steppe areas of Kulunda exerts the most significant impact such as total plowing of fertile lands, overgrazing by excessively numerous livestock, and inadequate agricultural technologies for certain agroclimatic and landscape-ecological conditions. This led to a whole range of consequences: destruction, fragmentation, and ecotonization of steppe communities, direct extermination of key plant species, forest and birch kolki clearance, biota unification and introduction of alien species, reduction of species and cenotic diversity in steppes as well as destruction of their structure and loss of self-regeneration and self-regulation ability. The start of human influence dates back to the Neolithic age (the cattle-raising stage of the territory development). However, the most devastating impact began in the twentieth century with the arable farming stage. Almost all tillable lands were plowed at the time of Stolypin's agrarian reform in the beginning of the twentieth century and during the years of Khrushchev's land reclamation campaign 1954–1955. Nowadays, agroecosystems have been formed in the places of former natural steppe ecosystems. The influence of agricultural reclamation on the vegetation cover and biodiversity distribution in the steppe and forest-steppe areas of Kulunda is to a large extent studied and documented.

Keywords Agriculture · Agroecosystem · Reclamation · Invasive species · Steppe · Forest · Kulunda · Siberia

M. M. Silantyeva (✉) · N. V. Elesova · T. A. Terekhina · A. Y. Grebennikova · N. V. Ovcharova
Faculty of Biology, Altai State University, Prospect Lenina 61, 65049 Barnaul, Russian Federation
e-mail: msilan@mail.ru

I. Hensen
Institute of Biology/Geobotany and Botanical Garden, Martin-Luther-Universität Halle-Wittenberg, Am Kirchtor 1, 06108 Halle, Germany

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10.1 Introduction

Worldwide, forests and steppes are transformed or destroyed to a large extent by humans. Nowadays in Russia, steppes are preserved in forms of small fragmented areas within the landscapes of tilled fields, fallow lands, and pastures. In southern Siberia, particularly in the Kulunda region, steppes are additionally preserved within areas of saline soils. Another part of steppes is transformed by high-grazing intensity to such an extent that they cannot be restored without active management measures.

For thousands of years, extensive cattle-breeding was predominant in the Kulunda region. During that time, landscape and microclimate were different as soils were covered by dead remains of steppe plants and did not dry out so strongly. Thus, the air was cooler and moister than today, naturally mitigating the consequences of anticyclonic climate effects such as soil aridization (Gnatovskiy 2010).

Agriculture is the most significant factor for the transformation of steppes that strongly influences both vegetation cover and biodiversity. The consequences of, i.e., total plowing of fertile lands, overgrazing by excessively numerous livestock and/or inadequacy of agricultural technologies for certain agroclimatic and landscape-ecological conditions can be various (Fig. 10.1).

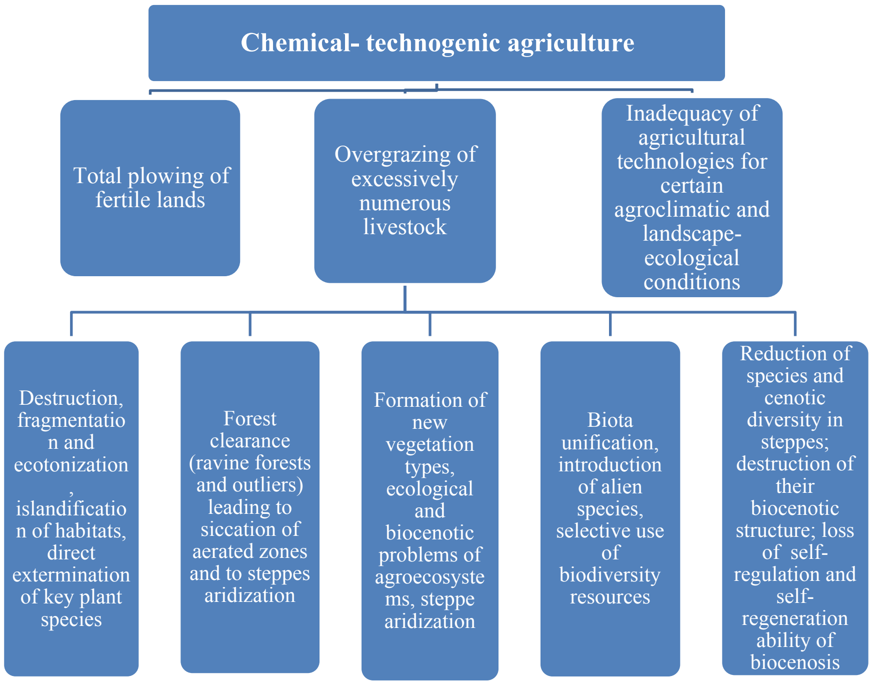

Fig. 10.1 Influence of agricultural reclamation on vegetation cover and biodiversity in the Kulunda region. *Source* Silantyeva, M

10.2 Changes of the Vegetation Cover in Kulunda Due to Agricultural Development

Pasture farming is characterized by local pasture degradation and by uncontrollable autumn burnings for the purpose of preparing spring pastures. However, before the colonization of the Kulunda region by Russian farmers, these impacts were of a local character. Before the sixteenth century, the land was inhabited by rare groups of nomad stock raising Teleut tribes who only bred cattle. Uncontrolled peasant migration started not earlier than in the first 30 years of the eighteenth century, following dowsers and designated peasants to the Kulunda territory. This gave rise to the process of a wildland reclamation. From the middle of the eighteenth century onwards, agriculture became permanent and the cultivated territories expanded consistently. From the 60s and 70s of the nineteenth century, the region witnessed an increase in the entry of migrants that cut down much of the forest for construction purposes.

Practically, all tillable land was already plowed in the first decade of the Stolypin agrarian reform in the twentieth century. Along with the disappearance of virgin Kulunda steppes, forests were disappearing as well. The first scientific consideration of Kulunda vegetation cover, performed in 1910 (the expedition of the Migratory Administration) showed that extensive areas were already tilled, and even small areas of wildland were very difficult to find (Krylov 1913a, b, 1915; Kuznetsov 1914). The disappearance of forests composed by large birches (mixed with aspen) and low ridge birch forests in the northern part of the Kulunda steppe were particularly highlighted by the authors. In the central part of Kulunda, the woody vegetation was represented by small fragments (hereafter forest outliers) of bushy birches developing as coppice shoots and by outliers consisting of small bushes of birch and aspen scattered at some distance from each other (Baranov 1927). Secondary steppes developed at the sites of the disappearing forest outliers.

The second turning point in the transformation of the vegetation cover in Kulunda took place in the 50s of the previous century and was connected to the reclamation of wildlands and fallow lands by thousands of Russian immigrants. Most of the remaining steppes were converted to farming land. A total of 2.3 million ha of the true steppes on the southern black soils and the dry steppes on the dark chestnut and chestnut soils were plowed (Frühauf et al. 2004). In 1960, the area of croplands accounted for 7.5 million ha, while at present it accounts for 6.5 million ha (61.3%) out of 10.6 million ha of agricultural lands. This is the largest tillage area among all the regions of the Russian Federation.

In the 60s of the previous century, the geobotanist E.I. Lapshina stated the fact that the elimination of birch forest outliers in Kulunda created the conditions preventing reforestation and promoting the further steppification of the whole deforested territory (Lapshina 1963). Meadow steppes appeared at the sites of the former birch forest outliers, while secondary steppes with halophytes appeared on the unplowed salinized areas. The recent existence of these forest outliers could be traced only by lignified leftovers within forb meadow vegetation, scattered among tilled fields and areas of fescue-feather grass steppes. Under the arid conditions of the southern forest-steppes, forest outliers were indicated by saucer-like hollows ranging from 10 to 100–200 m in diameter and of different depths situated on the elevated relief elements where the drainage was better and without salinification ("kolki vegetation"; Lapshina 1963).

In 2012, we tried to find remains of natural vegetation, described during the field work of the Migratory Administration by P.N. Krylov in cooperation with L.A. Utkin and Reverdatto. Krylov (1915) distinguished 11 areas of steppe vegetation in the Kulunda region (within the modern boundaries of Altai Krai). We have chosen typical wildland spots and—for lack of the latter—fallow lands. With high certainty, we found three remaining areas of those described 100 years ago by Krylov (1916) but did not rediscover the complete species composition. The correspondence between the descriptions of 1913 and 2012 (Silantyeva et al. 2012a, b) varied from 30 to 83%. Species we did not rediscover were: *Aster alpinus* L., *Allium nutans* L., *A. clathratum* Ledeb., *A. globosum* M. Bieb. ex Redoute, *Adonis villosa* Ledeb. and others. At the same time, several steppe grasses were still preserved, such as *Stipa pennata* L., *S. capillata* L., *Festuca valesiaca* Gaudin, *F. pseudovina* Hack. ex Wiesb., *Poa angustifolia* L., and *Helictotrichon desertorum* (Less.) Nevski. Thus, grasses now dominate in the remaining steppe fragments which confirm their high competitive strength (Silantyeva et al. 2011, 2012a, b).

Another part of the agricultural reclamation in Kulunda was the degradation of the vegetation cover as a result of stock-breeding development. Long-term pasture operation led to the fact that most of the rangelands in central Kulunda transited to the third–fourth stages of the pasture degradation scale in the 80s–90s of the twentieth century (see Silantyeva et al. 2012a, b for more details of this classification). This resulted in a strong reduction of pasture yield, as cover of the herbaceous layer decreased from 70% to 40%, and of the amount of litter. Consequently, soil temperatures increased, which led to xerophytization and halophytization of the vegetation cover as a result of the alteration in the topsoil hydrological regime, to the decrease of plants non-resistant to grazing, and to the expansion of resistant, unpalatable weed species. Number of plant species decreased strongly, while coverage of dwarf semishrubs (*Artemisa frigida* Willd., *A. nitrosa* Weber *ex* Stechm., *Atriplex canescens* (Pursh) Nutt.) increased sharply from the second to the forth pasture degradation stages. Repeated studies between 2009 and 2011–2012 showed that under dry steppe conditions, processes of pasture rehabilitation were very slow, even taking into consideration the fact that livestock stocking rates were reduced in the beginning of the twenty-first century (Elesova 1990; Silantyeva et al. 2012a, b).

Observations of recovery processes at several monitoring sites and ecological profiles (Fig. 10.2), situated on the banks of Lake Kulundinskoye (the villages of Znamenskoye and Uspenka, former villages of Demyan Bedniy and Priozernoye, Tabunskiy District), reflect the fact that nowadays the anthropogenic influence is reduced (Elesova 2009; Silantyeva and Elesova 2013). Grazing and haying take place close to the villages, the number of cattle stocks reduced tenfold in comparison with the 80s of the twentieth century, cows and horses breeding prevails, and the number of sheep is low. Impelled recovery influenced the species composition of the

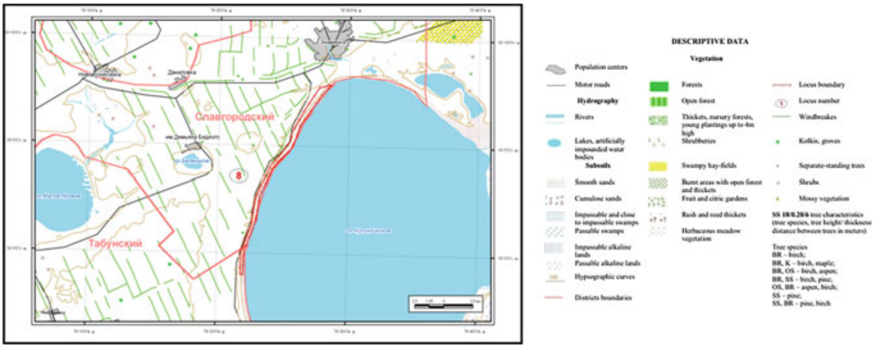

Fig. 10.2 Location of the monitoring sites on the banks of Lake Kulundinskoye. *Source* Kurepina, N. Yu

steppe and meadow communities in a positive way. The number of plants species increased by 1.2–1.5 times owing to the appearance of feather grasses, legumes, and forbs. Coverage of the dominant grass species (*Stipa pennata*, *S. capillata*, *Festuca valesiaca*, *F. pseudovina*, *Puccinellia tenuissima* Litv. ex V.I. Krecz.) improved and so did their average height and bunch diameter. The vertical profile of the fescue steppes lengthened by 15–30 cm (from 25 to 40–60 cm) due to the increase of steppe grass species (mainly fescue and wheat grass), and legumes and forbs reappeared. The main part of the aboveground phytomass concentrated in the 0–30 cm layer (previously 0–15 cm). The general projective cover extended by about 10% in the fescue steppes and by 20–30% in the alkaligrass salt meadows. Thus, the reduction in pasture load positively influenced community productivity. The overall stock of the phytomass increased twice in the fescue pastures and by half in the alkaligrass salt ones (Elesova 2009; Silantyeva and Elesova 2013). However, in the case of *Stipa pennata*, isolation was shown to negatively affect genetic diversity, highlighting that fragmentation can have potentially strong impacts on genetic structure even in natural grasslands (Heinicke et al. 2016).

In summary, the facts mentioned above regarding the changes in the vegetation cover of Kulunda are indicative of the destruction, fragmentation, and ecotonization of plant communities, the reduction of species numbers and cenotic diversity in the steppes, the destruction of their biocenotic structure, and the loss of phytocenoses' self-regulation and self-regeneration ability. Moreover, the elimination of the previously existing forest types (ravine forests and forest outliers) had a significant impact on the development of the steppe vegetation, which led to desiccation and to further aridization of the steppes.

10.3 Current Species Diversity of Agrophytocenoses

More than 200 years of agricultural development gave rise to ecosystems of a new type—agroecosystems—in the place of the former natural ecosystems. Agrophytocenoses appeared, accompanied by a new type of vegetation—agrophyton. However, the prevalence of the chemical-technogenic approach in agriculture in the second half of the twentieth century led to a great reduction in their biodiversity.

The agrophytocenoses in Kulunda as well as all over the world are mostly monocultural. A small number of high-yielding species and breeds are used; mainly cereal crops occupy vast uniform agricultural areas. Beside wheat and corn, people grow sunflower and forage grasses; in the forest-steppe regions of Kulunda, additionally, buckwheat, rye, sugar beet, flax, rapeseed, and soya bean are cultivated. Herbicides are widely used to fight weeds, and fertilizers are used to increase crop yield. The existing traditional technologies of the farming steadily led to soil erosion and dehumification, loss of soil fertility and soil ecosystems biodiversity (Frühauf et al. 2004).

One of the peculiarities of the agrophytocenoses biodiversity in Kulunda is the low species diversity of segetal plants in comparison with European agrophytocenoses, which is due to particular climatic characteristics (Terekhina 2000). In the crops of Kulunda, segetal species comprise not more than 2–3 weed species. Approximately, 150 species are noted in all types of agrophytocenoses, with about 30 species being abundant, i.e., *Chenopodium album* L., *Ch. polyspermum* L., *Salsola collina* Pallas, *Amaranthus retroflexus* L., *A. albus* L, *A. blitoides* S.Wats, *Fallopia convolvulus* (L.) A. Love, and *Corispermum declinatum* Stephan ex Iljin. A distinctive feature of these annual and biennial species is their ability to form long-term persistent seedbanks. In Kulunda, the number of viable seeds in the 0–20 cm layer was found to range from 2000 to 220,000 m^{-2} (Terekhina 2000). During arid years, many species are able to produce seeds already at the stage of the first 2–3 leaves. One individual of a segetal plant might produce up to 15,000 seeds. In addition, the spherical form of the seeds of some weed plants, and their production in the postharvest period, contribute to long-distance seed dispersal, if the wind speed is high enough (Terekhina 2000). In addition, there are perennial weeds, with, e.g., *Convolvulus arvensis* L., *Euphorbia virgata* Waldst. et Kit., *Sonchus arvensis* L., *Mulgedium tataricum* L., and *Vincetoxicum sibiricum* (L.) Decne. being the most widespread. All of them successfully reproduce both by seeds and root suckers, and demonstrate a significant resistance to different groups of pesticides (Terekhina 2000).

10.4 Invasive Species

Immigration of invasive plant species to the Kulunda region was favored by the frequent disturbances characteristic for agrophytocenoses and degraded rangelands. As invasive species are known to transform natural communities, they are considered to be the second significant threat to biodiversity (after habitat destruction). One

Fig. 10.3 **a** Oleaster (*Elaeagnus angustifolia* L.); **b** The communities formed by the oleaster in the lakeside hollow. *Source* Silantyeva, M. M

example of an invasive tree species is the oleaster (*Elaeagnus angustifolia* L.). Its planting started from 1926 onwards due to specialized agroforestal nursery areas created in Rubtsovsk and Slavgorod, and from 1931 onwards in Kluchi, Rodino, Volchikha, and Blagoveshenka (Paramonov et al. 1997). Being an undemanding and quickly growing species, *Elaeagnus angustifolia* spread rapidly within the steppes of the region. In 10–20 years, it was established even under driest soil conditions and in the salinized areas (Fig. 10.3a, b). Oleaster was the only species surviving within windbreaks where the formerly dominant species such as birch and poplar—and in some places, even the associated species such as green ash, sugar maple, or elm tree—died due to desiccation and salinization.

In the territory of Altai Krai, *Elaeagnus angustifolia* is a "transformer" species that intrudes actively into natural and seminatural communities, changes the ecosystems character, acts as an ecosystem engineer, and becomes highly dominant. References to the "natural oleaster communities" were infrequent just 20 years ago. Nowadays, such communities are validated as a new vegetation type in Kulunda (Silantyeva 2006, 2008).

Among the transformer species, we can also add sumpweed (*Cyclachaena xanthiifolia* (Nutt.) Fresen). It was first registered on the territory of Altai Krai in 1993 in Mikhaylovskiy district (Terekhina 1995a, b) as a ruderal plant. Most probably, it got there with different freights from the direction of Kazakhstan. Within 10 years, the sumpweed spread quickly over the territory of the region. At present, it grows in all anthropogenically transformed phytocenoses of Kulunda (Krasnoborov 2000; Silantyeva et al. 2013a, b).

10.5 Role of Windbreaks in the Vegetation Cover of Kulunda

As steppes and forests in Kulunda were destroyed within a short period of time, people started to create windbreaks, in order to mitigate climatic conditions. Windbreaks were established from 1926 onwards, as a result of the severe drought of 1925, when people were exposed to heavy dust storms for the first time. In 1942, the total tree plantation area in the Kulunda steppe accounted for 32,000 ha, but as the windbreaks were not maintained, they often died due to the lack of attention. The range of the species used at that time was very wide. It included *Populus balsamifera* L., *Populus laurifolia* Ledeb., *Betula pendula* Roth, *Ulmus parvifolia* Jacq., *Ulmus minor* Mill., *Acer saccharum* Marshall, *Fraxinus americana* L., *Larix sibirica* Ledeb., *Pinus sylvestris* L., *Malus baccata* (L.) Borkh., *Caragana arborescens* Lam., *Ribes aureum* Pursh, *Sambucus racemosa* L., *Elaeagnus angustifolia* L., *Hippophae rhamnoides* L., and *Lonicera tatarica* L. (Dyachenko and Zemlyanitskiy 1947). Some of these species have naturalized later and constitute an adventitious component of the Kulunda flora. The problem aggravated after the big land reclamation in the 50s of the twentieth century when dust storms started to blow millions of tons of the soil fertile layer into the air. Therefore, from 1928 to 2002, 200,000 ha of windbreaks were established. In recent years, however, a significant part of the windbreaks has been lost as many of the composing tree species have reached their maximum age and died due to natural reasons. Another reason for their disappearance is anthropogenic factors (burnings, grazing, wood-felling; own observations).

The windbreaks in Kulunda did not only play a significant ecological and landscape role but also became a habitat for a great number of steppe plants. From these "stepping stones," species spread to the fallows and other degraded communities. Within the windbreaks, such conspicuous and colorful species as the steppe peony (*Paeonia hybrida* L.) were protected (Fig. 10.4). The presence of these windbreaks may contribute to explaining why genetic effects of recent fragmentation were found to be still limited for three long-living steppe species of the Kulunda area (*Adonis villosa* Ledeb., *Jurinea multiflora* (L.) B. Fedtsch. and *Paeonia hybrida*; Rosche et al. 2018).

Fig. 10.4 Steppe peony (*Paeonia hybrida* L.) in front of a windbreak (Mikhaylovskiy district). *Source* Silantyeva, M. M

10.6 Peculiarities of the Species and Cenotic Diversity in Kulunda

Nowadays, the natural vegetation cover of Kulunda is represented by pine forests stretching from the north-east to the south-west; salt steppes; birch forests (mostly outliers); complexes of aquatic and semi-aquatic vegetation, shrub and meadow vegetation used as pastures leading to degradation; and small areas of meadow and true steppes used for haying or grazing. Agrocenoses as a special type of vegetation occupies about 60–90% of the area in Kulunda depending on the district.

Unfortunately, we cannot estimate diversity of the Kulunda flora in the preagricultural period as there are no historical records. At present, the remaining steppes of Kulunda host about 700 plant species, out of which 88 species (about 13%) are adventitious (alien) in this territory. About 50 plant species of the Altai region flora are endemics. Rigid endemics (neoendemics) of the district are *Lotus krylovii* Schischk. ex Serg., and *Puccinella kulundensis* Serg. Most important genera are *Artemisia*, *Carex*, *Potentilla*, *Astragalus*, *Atriplex*, *Allium*, *Juncus*, *Ranunculus*, *Salix,* and others (Silantyeva et al. 2013a, b, c). However, the influence of the agricultural reclamation in connection with the formation of agroecosystems and inadequacy of the agricultural technologies for certain agroclimatic and landscape conditions led to a sharp deterioration and unification of the phytodiversity, intrusion of alien species, and loss of several steppe species.

In the twenty-first century, we have a significantly transformed vegetation cover on the territory of Kulunda. At the same time, the small-area elements of the natural ecosystems are preserved. The transition to green land-use management and agricultural production and the introduction of an adaptive landscape specific agriculture are the key to the resolution of the existing conflict between the further depletion of the natural ecosystems and the decrease in the agricultural efficiency. In the first place, one needs to differentiate between the land-use modes in the steppe area and to expand the natural ecosystems.

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