HACQUETIA 14/1 • 2015, 65–78

DOI: 10.1515/hacq-2015-0016

ECOSYSTEM FUNCTIONS OF STEPPE LANDSCAPES NEAR LAKE BAIKAL

Julia V. VANTEEVA[1] & Svetlana V. SOLODYANKINA[1]

Abstract

Recreational activity has a significant impact on the Priol'khonie steppes and forest steppes, which are part of the Pribaikalskyi National Park (western coast of Lake Baikal, Russia). The aim of this investigation is the assessment of different landscapes' values for the provision of ecosystems functions and services. To meet these objectives, fieldwork was conducted in the Priol'khonie steppes and forest steppes during the summer of 2013. The function of phytomass formation was considered for different land-cover types identified in the area, and the above-ground phytomass and inter-rill erosion were measured. The level of landscape degradation was estimated and draft maps of phytomass stocks and vulnerability to soil erosion of the investigated area were compiled. To show the dependence between the studied ecosystem functions and the ecosystem services provided by them, a scoring of the latter was made. It was found that characteristics of ecosystem functions varied significantly in the steppes of the Priol'khonie.

Keywords: clipping, ecosystem service, forest steppe, phytomass stock, rainfall simulation, Russia, soil erosion.

Izvleček

Na stepe v Priolhonju in gozdne stepe, ki so del nacionalnega parka Pribajkalskij (zahodna obala Bajkalskega jezera, Rusija) imajo pomemben vpliv rekreacijske aktivnosti. Namen raziskave je ocena različnih vrednosti krajine za zagotavljanje ekosistemskih funkcij in uslug. Izvedli smo terenske raziskave v stepi Priolhonje in gozdnih stepah poleti leta 2013. Za različne krajine smo v raziskovanem območju ocenili funkcijo nastanka fitomase in izmerili nadzemno fitomaso in erozijo med jarki. Ocenili smo stopnjo degradacije krajine in naredili karto zaloge fitomase in ranljivosti zaradi erozije tal raziskovanega območja. Da bi prikazali odvisnost med obravnavanimi ekosistemskimi funkcijami in ekosistemskimi uslugami, ki jih le-te zagotavljajo, smo slednje ovrednotili. Ugotovili smo, da se značilnosti ekosistemskih funkcij v stepi v Priolhonju značilno razlikujejo.

Ključne besede: rezanje, ekosistemske usluge, gozdna stepa, zaloga fitomase, simulacija padavin, Rusija, erozija tal.

1. INTRODUCTION

Ecosystem functions are factors of life maintenance. Ecosystem functions are the biological, geochemical and physical processes that take place within an ecosystem (Mace et al. 2012, Maynard et al. 2014). Such functions as production of biomass, hydrological and nutrient cycles play important roles in the provision of ecosystem services. Maintaining ecosystem functions is important to support the capacity of the region to provide ecosystem services. Identification of indicators of ecosystem functions can be the basis for the development of land-use regulations and management, landscape-planning and the assessment of ecosystem services (Kachergis et al. 2011).

Lake Baikal (Russia) and the surrounding terrestrial ecosystems, play an important role in forming local nature conditions. Its catchment basin has a high biodiversity, with more than 2,500 species of vascular plants (Pleshanov et al. 1990, Savenkova 2001), for instance, and many of these species are indigenous to the region (Berkin et al. 2009).

[1] V. B. Sochava Institute of Geography SB RAS, 1, Ulan-Batorskaya St., Irkutsk, Russia, 664033, ula.vant@mail.ru, sveta@irigs.irk.ru

The number of tourists in the region has increased significantly during the last 5–10 years. The Priol'khonie region and Island Ol'khon, Chivyirkuyskiy Bay, Posol'skiy Sor and the settlements of Listvyanka and Sludyanka, are subject to the strongest recreational pressures (Figure 1). Uncontrolled recreational activities have a significant impact on the Priol'khonie region (the west coast of Lake Baikal). In the Baikal Basin, the steppes are only located in the Priol'khonie region. According to government data (Olkhon District' Administration 2012), about half a million people visit the Priol'khonie region every year. More than 75 recreation centers accommodate tourists here. In summer, about 20 children's health camps operate on the coast. The attractiveness of the Priol'khonie is due to its special microclimate, landscape diversity and picturesque nature. The impact of uncontrolled grazing on the steppe has reduced, and some landscapes have had the opportunity to recover. From the early 20th century to the mid 1970–80s, the number of livestock increased, and subsequently reduced in later years (Table 1) (Symenov et al. 2004, Olkhon District' Administration 2012).

Figure 1: Lake Baikal and the locations of touristic places with strong pressures to ecosystems: 1 – Priol'khonie plateau (study area), 2 – Island Ol'khon, 3 – Listvyanka settlement, 4 – Sludyanka settlement, 5 – Posol'skiy Sor bay, 6 – Chivyirkuyskiy bay.
Slika 1: Bajkalsko jezero in lokacije turističnih krajev z močnim vplivom na ekosisteme: 1 – Priolhonska planota (raziskovano območje), 2 – otok Olhon, 3 – naselje Listvjanka, 4 – naselje Sljodjanka, 5 – zaliv Posolskij Sor, 6 – zaliv Čivjirkujskij.

Table 1: Livestock number changes.
Tabela 1: Spremembe števila živine.

Year	Livestock number (head)
1930	23,291
1980	68,196
2003	15,900
2012	8,279

The Priol'khonie steppe and forest steppe are part of the Pribaikalskyi National Park, and consequently nature conservation plays an important role in human activity here.

As the landscapes satisfy a diverse range of anthropogenic demands, there are many land-management conflicts, in particular, between the Pribaikalskyi National Park and the administration of the area and the local inhabitants.

Natural landscapes surrounding Lake Baikal provide functions involved in the protection of water quality and water storage, phytomass production and other environment formation functions (for example, microclimate forming by Primorskiy range, which acts as a barrier to the movement of air masses and affects the Baikal water mass) and others. The water protection function has great importance for the conservation of the unique ecosystems of Lake Baikal. The specific climate and soil conditions and human activity lead to erosion processes in the study area. Sediment loads are transferred into Lake Baikal and affect water quality. The estimation of the effects of land-cover, soil type variability and stage of landscape degradation on water runoff and soil erosion has become critically important (Grismer 2011), especially for water quality of Lake Baikal.

The study area has a large variety of steppe and forest steppe habitats, differing in the form of relief, soil types, vegetation species composition and degree of anthropogenic impact. These differences fundamentally affect the intensity and effectiveness of ecosystem functioning, which is why the quantification of phytomass and process of silt transfer by rainfall was conducted for the different steppe and forest steppe land-cover types identified in the study area. The function of phytomass formation and its proactive role in sedimentation and mitigation of silt detachment by rill and inter-rill erosion are considered in this study to be important indicators of the ecosystem functions for steppe and forest steppe habitats. The assessment of the ecosystems' capacity to provide certain ecosystem services (erosion regulation, fodder, wild food, recreation, landscape aesthetic and natural heritage) are conducted. As the study area is intensively used for tourism, we paid particular attention to cultural services.

2. STUDY AREA

The steppe and forest steppes of the Priol'khonie were selected as the research area.

The study area (19.86 km^2) is located on the western shore of Lake Baikal (Kurkutskyi Bay), in the northern part of the Priol'khonie plateau (Figure 1). From the one side the landscape is influenced by the Primorsky Range, serving as an orographic barrier to the movement of air masses from the west, and from the other by the water mass of Lake Baikal. The exogenous factors, such as selective denudation, karst, wind erosion and abrasion, affect the formation of the relief. Currently, the relief is represented by denudated low hills with slopes from 3° to 40°. The altitudes of the hills reach 456–990 m a.s.l. (Kasyanova 2004, Zagorskaya 2004). The morphological relief structures consist of waterlogged valley bottoms with shallow lakes, slopes and the ridge. The depth of the slope sediments is low. In some places there are bedrock exposures (Semenova 2000).

The climate is continental; summer is dry and warm with heavy rains, and the winter is windy with little snow. The annual rainfall is 200–300 mm, which is the minimum for Lake Baikal. Snow cover reaches a depth of 10–15 cm. The average annual temperature is –1 °C. The thermal growth period (with average daily temperature above 5 °C) is 4–4.5 months (from the second half of May to the end of September) (Semenov et al. 2004).

The following types of soil are formed in the dry steppe climate of the Priol'khonie: chernozemic and chestnut soils, steppe raw soils, steppe non-calcareous soils, soddy soils and saline soils. The features of chestnut soils are light-textured with a high content of rubble and the absence of gypsum. The non-percolative regime, which was formed under the influence of local climatic conditions and soil-forming processes, is typical for soils of the study area. Only the soil surface is moist (Semenova 2000, Kasyanova 2004). Most of precipitation moisture is carried to the lake with runoff, transferring silt and forming gullies.

The steppe landscapes, which cover 75.3 % of the study area, are mainly rocky, occurring on gentle slopes with *Festuca* spp. and *Poa* spp. or with *Agropyron cristatum* L., *Koeleria cristata* L., *Galium verum* L. and *Stipa* spp. on chestnut or soddy shallow soils, which in some places gradually change to forest steppe and larch forest (Figure 2), which cover about 24.7% of the study area.

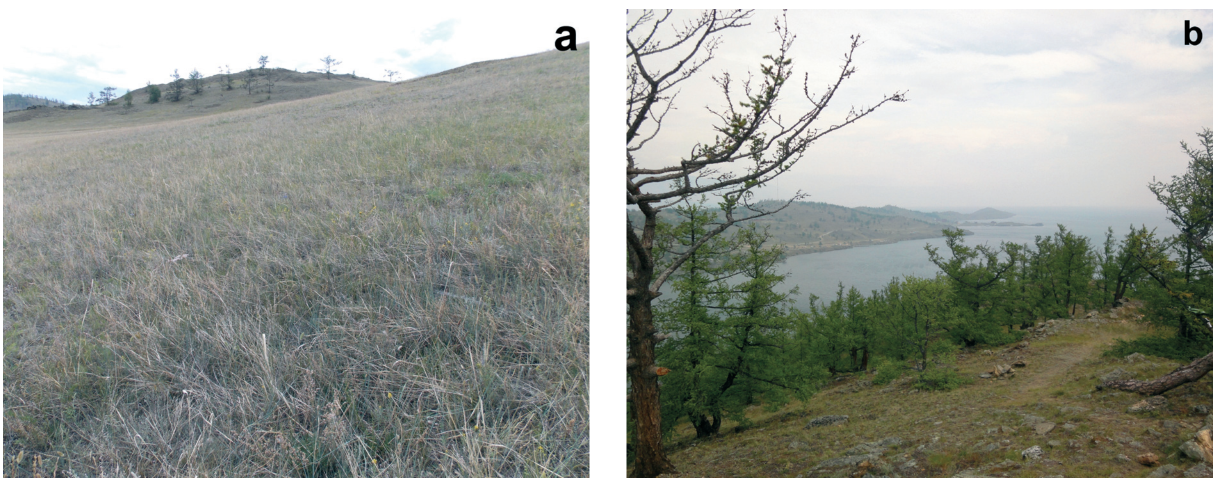


Figure 2: Landscapes of the Priol'khonie: a – *Stipa* steppe with forb; b – Sparse larch forest steppe with *Poa* spp.
Slika 2: Priolhonska krajina: a – stepa z bodalicami in zelišči; b – redka macesnova gozdna stepa z vrstami rodu *Poa* spp.

The study area has a long period of historical development by Buryat (semi-nomad stock-raising) and Russian (arable farming) ethnic cultures. During the soviet period, this area was intensively used for agriculture. The Buryat method of stock-raising, with uncontrolled grazing, is still present here. In the study area, there is only the one settlement with 224 inhabitants, who are mostly employed in tourism during the summer season.

3. METHODS

For quantification of ecosystem functions and scoring of ecosystem services, we used the results of other studies which deal with plant ecology and water exchange of the territory (Kasyanova 2004), landscape structure (Zagorskaya 2004), anthropogenic transformation of landscapes (Yevstropieva 1999, Ponomarenko 2003).

The following spatial materials were used in the research: the land-cover map and relief map (scale 1 : 25,000) compiled by Zagorskaya (2004); topographic information (scale 1 : 200,000); fieldwork.

The initial land-cover map was prepared 10 years ago. Since then, the study area has been intensively developed (the expansion of dwellings, recreation facilities, roads), and there was a need to update the data of land-use and land-cover, to determine its present state. For these purposes, satellite image (SPOT 4 7. 11. 2010) processing was made using data from the public cadastral map (2013) and the results of fieldwork. The updated map is presented in Figure 3. Initial (year 2003) and updated (year 2013) maps of land-cover were compared and the changes in the areas of settlements and recreation facilities during 10 years were calculated by GIS tools.

The fieldwork was conducted in the study area during July and August of 2013. Thirty-two study sites (10 m × 10 m), which characterized different steppe and forest steppe (31 land-cover types were determined in the legend of the land-cover map (Figure 3)) were established. The selection of study sites was determined by the following criteria: occurrence in all land-cover types and being the most representative for each land-cover type. The plots (0.25 m^2) for measurements of phytomass and transferred silt were selected in each study site.

The coordinates of the study sites, and information on relief, vegetation cover and soil characteristics (texture, depth of soil horizons, color, and soil moisture) were recorded. Cover scores of herbaceous species in different land-cover types are shown in Table 2.

Since anthropogenic impacts (grazing, tourism) affect species composition and vegetation cover (Yevstropieva 1999), the level of degradation was also taken into account. The estimation of landscape degradation (Table 2) was based on the classification of Ponomarenko (2003) as follows:

Stage 1 – the landscape is almost undisturbed. There are only indigenous plant species. The trampling of vegetation cover is minimal (about 5–10%). There are no fire sites.

Stage 2 – the landscape is partially disturbed. Indigenous plant species predominate. The trampling of vegetation cover is 10–20%. There are one to three fire sites in an area of 100 m^2.

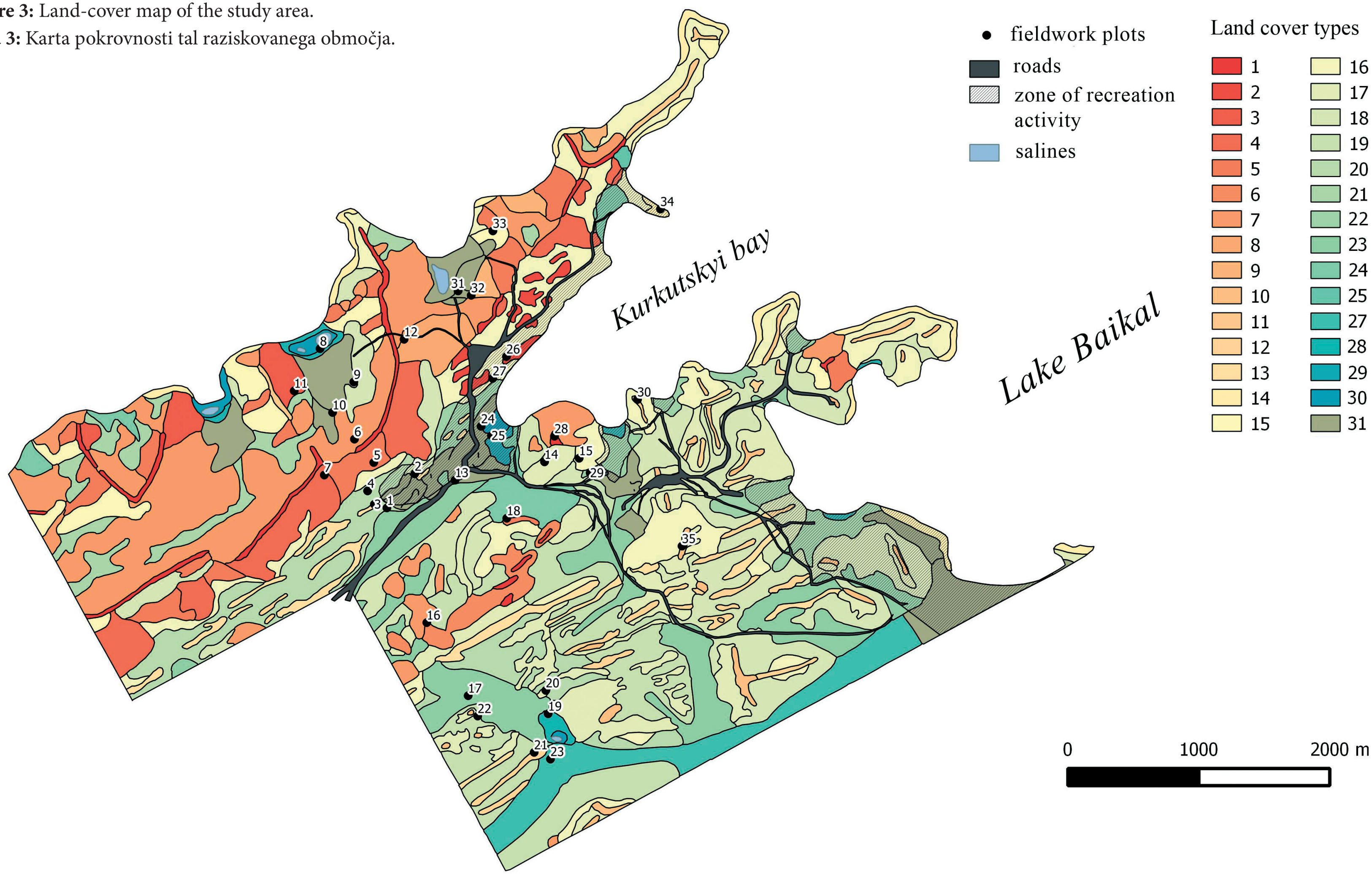
Stage 3 – low level of landscape disturbance. Plant species resistant to trampling appear in the vegetation. The trampling of the vegetation cover is 30–50%. There are four to five fire sites in an area of 100 m^2.

Stage 4 – medium disturbed landscape. Plant species resistant to trampling dominate in the vegetation cover. The trampling of the vegetation cover is 60–70%.

Stage 5 – highly disturbed landscape. There are only species resistant to trampling in the vegetation cover or an area of land completely without vegetation. A total of 80–100% of vegetation cover is trampled.

Stock phytomass estimation was made to assess the ecosystem function of phytomass formation. The plot for phytomass collection was selected after visual inspection of the study site. The most indicative vegetation parameters (species composition (%), vegetation cover (%)) of certain land-cover types were used as criteria for the designation of the plots. The method of clipping was chosen for the estimation of production of above-ground herbaceous phytomass. This method is frequently applied for phytomass estimation on grasslands and agricultural lands (Ganquelin et al. 1996, Catorci et al. 2009, Deák et al. 2011, Kelemen et al. 2013). Living phytomass (the dead material was separated on the sites) was collected in July 2013, at the peak of biomass production, from thirty-two plots (0.5 m × 0.5 m) for the growing season from different land-cover

Figure 3: Land-cover map of the study area.
Slika 3: Karta pokrovnosti tal raziskovanega območja.



Land-cover types: 1 – Sparse larch forest with *Poa*; 2 – Sparse larch forest with forb; 3 – Larch forest with *Rhododendron*; 4 – Larch forest with forb and sagebrush; 5 – Steppefied larch forest; 6 – Larch forest with forb; 7 – Sparse larch forest with *Cotoneaster* and *Poa*; 8 – Larch forest with *Cotoneaster*; 9 – Sparse larch forest; 10 – Steppe with *Poa* and *Caragana*; 11 – Forb steppe with *Caragana* and sagebrush; 12 – Forb steppe with *Caragana* on the rocks; 13 – Short grass steppe; 14 – Lytomorphic vegetation on the rocks; 15 – *Caragana* steppe with sagebrush; 16 – *Caragana* steppe with forb; 17 – *Fescue* steppe with *Chamaerhodos*; 18 – Forb steppe; 19 – *Stipa* steppe with tall grass; 20 – Forb (polydominant) steppe; 21 – Tall grass steppe; 22 – Forb steppe with *Fescue*; 23 – Forb steppe with *Stipa* grass; 24 – *Stipa* grass steppe; 25 – Forb steppe with sagebrush; 26 – Sagebrush steppe; 27 – Sagebrush steppe (fallow land); 28 – Bent grass meadow with sedge; 29 – Turfy sedge marsh; 30 – Marsh with *Poa*; 31 – Settlements and recreational facilities.

Table 2: The list of the most abundant herbaceous species in different land-cover types (the names of the species are in rows, the numbers of the land-cover types (according to Figure 3) are in columns, and the cover (%) is in table cells).

Tabela 2: Seznam zeliščnih vrst z največjo abundanco v različnih tipih pokrovnosti tal (imena vrst so v vrsticah, številke v stolpcih predstavljajo različne tipe pokrovnosti tal (v skladu s sliko 3), v celicah pa je pokrovnost v odstotkih (%)).

Herbaceous species	Land-cover type																													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
Achnatherum splendens Trin.	0	0	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Allium ramosum L.	0	0	0	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Agropyron cristatum L.	10	0	15	0	0	0	5	0	10	10	0	0	0	10	5	0	0	0	0	10	0	20	0	25	10	0	0	0	10	10	0
Antennaria dioica L.	5	0	0	0	0	0	0	0	0	5	10	0	0	0	5	0	0	10	0	0	0	15	0	0	0	0	0	0	0	0	0
Arenaria meyeri Fenzl	0	0	0	0	0	0	0	0	5	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia frigida Willd.	0	0	0	20	0	0	0	0	20	20	0	0	20	0	0	15	10	5	20	15	5	15	0	5	55	40	50	0	0	0	10
Artemisia vulgaris L.	10	20	0	15	35	0	0	0	0	10	0	0	0	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bupleurum scorzonerifolium Willd.	0	0	5	0	0	5	0	0	10	0	0	10	0	0	0	0	0	10	5	0	0	0	5	0	0	0	0	0	0	0	0
Caragana pygmaea (L.) DC.	10	20	0	20	25	0	0	0	0	10	0	10	0	0	20	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex duriuscula C.A. Mey	0	20	0	5	0	0	20	0	0	0	0	0	0	5	30	0	0	0	0	0	0	0	5	10	0	0	10	0	0	25	30
Carex pediformis C.A. Mey	0	0	15	5	20	20	0	15	0	0	10	10	0	20	0	5	5	5	10	20	10	0	10	0	0	5	0	0	0	0	0
Carex cespitosa L.	40	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	60	0	0	10
Chamaerhodos altaica Laxm.	0	0	0	0	5	0	0	0	0	30	40	20	30	0	0	5	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbaria daurica L.	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Festuca lenensis Drobow	0	0	0	10	0		20	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca valesiaca Schleich. ex Gaudin	0	0	15	10	0	30	0	0	0	0	10	0	0	0	5	10	20	20	5	30	30	35	20	0	5	10	0	0	10	10	0
Galium verum L.	0	0	10	0	5	5	5	0	10	0	0	0	5	0	0	0	0	0	10	0	0	0	5	5	0	0	0	5	0	0	0
Halerpestes salsuginosa (Pall. ex Georgi) Greene	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	30	0
Iris flavissima Pall.	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Koeleria cristata L.	0	0	0	0	0	0	0	0	0	0	0	10	0	5	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	10	10
Leontopodium campestre Ledeb.	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Leymus chinensis (Trin.) Tzvelev	0	5	0	0	0	0	10	0	10	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orostachys spinosa (L.) C.A. Meyer	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	20	5	0	0	0	0	0	0	0	0	0	20	20	35	0	0
Oxytropis oxyphylla Pall.	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Plantago major L.	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa botryoides (Trin. Ex Griseb.)	20	0	20	0	0	10	0	0	0	0	0	0	15	0	0	0	0	35	5	0	25	0	10	0	0	0	0	10	25	10	10
Polygonum lapathifolia (L.) Gray	0	0	0	0	0	0	0	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Potentilla acaulis L.	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	0	5	0	5	30
Pulsatilla turczaninovii Kryl. et Serg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga bronchialis L.	0	0	0	0	5	0	0	0	0	5	15	0	10	0	0	20	15	0	0	0	0	5	0	10	0	10	0	0	0	0	0
Schizonepeta multifida (L.) Briq.	0	0	10	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5	0	0	0	0	0
Silene amoena L.	0	0	0	0	0	0	5	0	0	0		0	0	0		0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Stellaria dahurica Willd. ex Schltdl.	0	0	0	5	0	0	10	0	5	0	5	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stemmacantha uniflora L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	10	0	0	0	0	0	0
Stipa baicalensis Roshev.	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	5	20	40	0	10	5	0	0	0	0
Stipa capillata L.	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	10	0	5	10	0	0	10	0	0
Thymus baicalensis Serg.	0	5	0	0	5	0	5	0	0	0	10	0	10	0	5	5	5	0	0	10	0	5	0	0	0	5	0	0	0	0	0
Urtica dioica L.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0
Veronica incana L.	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Vicia olchonensis (Peschkova) Nikif.	0	0	0	0	0	10	5	25	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4: Portable rainfall simulator. **Slika 4:** Prenosni simulator padavin.

types. The vegetation was clipped at 1 cm above the ground and was subsequently field air-dried and weighed to an accuracy of 1 g.

The stock biomass of forest-steppe tree stands was calculated using the values of volume-conversion coefficients for major tree species in Russia, which were published by Zamolodchickov et al. (2003, 2005). For this calculation, the following data were taken into account: the average tree diameter (cm) and height (m), tree density (number of trees per hectare), age of trees (estimated by number of branches and knot clusters on the tree).

For defining landscape vulnerability to soil erosion and the pro-active role the vegetation-soil system plays on sedimentation and silt transfer by rainfall, we quantified the transfer of silt in different land-cover types. To estimate the values of different land-cover types to slow down run off, a portable rainfall simulator (Grismer 2011) was assembled (Figure 4).

The rainfall simulator allows the measurement of the amount of transferred silt under the influence of simulated heavy rainfall. The simulated rainfall characteristics are mean drop size of 2 mm in diameter, drop fall height of 0.5 m, intensity range of 13 mm/h (quarter of mean July rainfall). Precipitation falls mostly in the summer in the form of heavy rain, with its maximum in July. The quantity of water at the plot was calculated based on the average monthly rainfall data, obtained from the meteorological station Elantsy (Department for Hydrometeorology and Environmental Monitoring). The main restrictions of the study of erosion processes lie in the fact that the rainfall, rain intensity and droplet-size are not constant in natural conditions, as they are in the simulation (Agassi & Bradford 1999). The measurements of silt transfer were applied in a standardized way, so the results are comparable. Investigations were conducted in different land-cover types – one plot for each study site. During the experiment, three liters of water was poured onto the plot for fifteen minutes and the detaching silt matter was trapped and weighed to an accuracy of 1 g, after field air-drying.

The measurements recorded in the field (the estimation of degradation stage, phytomass quantification and the experimental measurements) were organized in a data-base (Table 3).

Table 3: Site characteristics. **Tabela 3:** Značilnosti rastišč.

№	Land-cover type	Slope	Degradation stage	Vegetation cover (%)	Transfer of silt matter (g/m^2 per quarter hour)	Above-ground herbaceous phytomass (t/ha)	Stock of tree phytomass (t/ha)
1	Sparse larch forest with *Poa*	8–10°	4	50	124	0.44	0
2	Sparse larch forest with forb	4–5°	4	40	12	0.64	0
3	Larch forest with *Rhododendron*	20–40°	3	80	4	0.68	259.4
4	Larch forest with forb and sagebrush	4–5°	2	80	20	0.60	204.8
5	Steppefied larch forest	6–20°	2	20	28	0.84	281.4
6	Larch forest with forb	11–20°	1	80	< 1	0.76	68.9
7	Sparse larch forest with *Cotoneaster* and *Poa*	0–25°	1	20	< 1	0.64	184.9
8	Larch forest with *Cotoneaster*	20–40°	2	20	< 1	0.52	70.2
9	Sparse larch forest	2–15°	4	80	8	0.60	187.9
10	Steppe with *Poa* and *Caragana*	6–40°	4	40	8	0.40	0
11	Forb steppe with *Caragana* and sagebrush	20–40°	3	20	< 1	0.60	0
12	Forb steppe with *Caragana* on the rocks	> 40°	2	60	20	0.40	0
13	Short grass steppe	< 1°	1	50	14	0.56	0
14	Lytomorphic vegetation on the rocks	> 40°	2	20	4	0.80	0
15	*Caragana* steppe with sagebrush	20–40°	3	50	12	0.52	0
16	*Caragana* steppe with forb	20–40°	3	30	12	0.56	0
17	*Fescue* steppe with *Chamaerhodos*	20–40°	4	30	28	0.76	0
18	Forb steppe	6–7°	3	70	28	0.60	0
19	*Stipa* steppe with tall grass	11–20°	3	90	<1	1.16	0
20	Forb (polydominant) steppe	< 1°	2	70	<1	0.62	0
21	Tall grass steppe	35°	3	65	28	0.60	0
22	Forb steppe with *Fescue*	1–5°	3	70	8	0.40	0
23	Forb steppe with *Stipa* grass	4–5°	2	70	8	0.48	0
24	*Stipa* grass steppe	20–40°	2	70	32	0.48	0
25	Forb steppe with sagebrush	2–5°	4	40	4	1.68	29.1
26	Sagebrush steppe	2-5°	4	70	4	0.60	0
27	Sagebrush steppe (fallow land)	< 1°	4	70	<1	0.84	0
28	Bent grass meadow with sedge	< 1°	4	70	<1	0.60	0
29	Turfy sedge marsh	< 1°	3	90	<1	1.48	0
30	Marsh with *Poa*	< 1°	3	100	<1	2.64	0
31	Settlements and recreational facilities	8–10°	5	20	36	0.44	0
32	Natural soil roads	1–10°	5	0	16–84	0	0

For estimation of ecosystem services, a non-monetary evaluation (Burkhard et al. 2009, 2012) was used. It is based on indicators, which allow assessment of the ecosystem capacity to provide different ecosystem services. The assessment matrix used a scale of five classes: 0 – no relevant capacity, 1 – low relevant capacity, 2 – relevant capacity, 3 – medium relevant capacity, 4 – high relevant capacity and 5 – very high relevant capacity. The classes were assigned to each land-cover type. We consider such ecosystem services as erosion regulation, provision of fodder and wild food (berries, mushrooms, edible plants, recreational fishing, etc.), recreation, landscape aesthetic and natural heritage. The services were valued using expert analyses, which were based on the field observations (Table 4).

Table 4: Indicators for assessment of ecosystem capacity to provide ecosystem service.
Tabela 4: Indikatorji za oceno ekosistemske zmogljivosti za zagotavljanje ekosistemskih uslug.

Ecosystem service	Indicators
Erosion regulation	Amount of transferred silt by rainfall
Fodder	Herbaceous phytomass (kg/ha), the presence of fodder plant species
Wild food	Presence of edible species
Recreation	Visual observations of the number of visitors and recreation facilities
Landscape aesthetic	Visual assessment of the attractiveness of the visible landscape
Natural heritage	Presence of endangered, protected, rare species or habitats

Percentage vegetation cover and loss of soil particles by water and wind can be used as indicators for the assessment of erosion regulating service (Kandziora et al. 2012). In this study, the amount of transferred silt by rainfall was applied as the indicator. A classification of values of soil erosion was obtained from experimental measurements of silt transfer. The following assessment scale was used: 0: 61–124 g/m^2 (such values can reach more than 20 t/ha of soil matter transfer per year); 1: 32–60 g/m^2; 2: 20–31 g/m^2; 3: 12–19 g/m^2; 4: 1–11 g/m^2; 5: <1 g/m^2.

4. RESULTS

The study shows a fast transformation of the research landscapes. The transformed area has increased by 6.3% (1.25 km^2) during the years 2003–2013. For example land-cover type 21 in Figure 3 (Tall grass steppe) was almost displaced by land-cover type 31 in Figure 3 (Settlements and recreation facilities).

Draft maps of phytomass stocks (Figure 5) and land-cover vulnerability to soil erosion (Figure 6) were compiled for the spatial analysis of investigated processes.

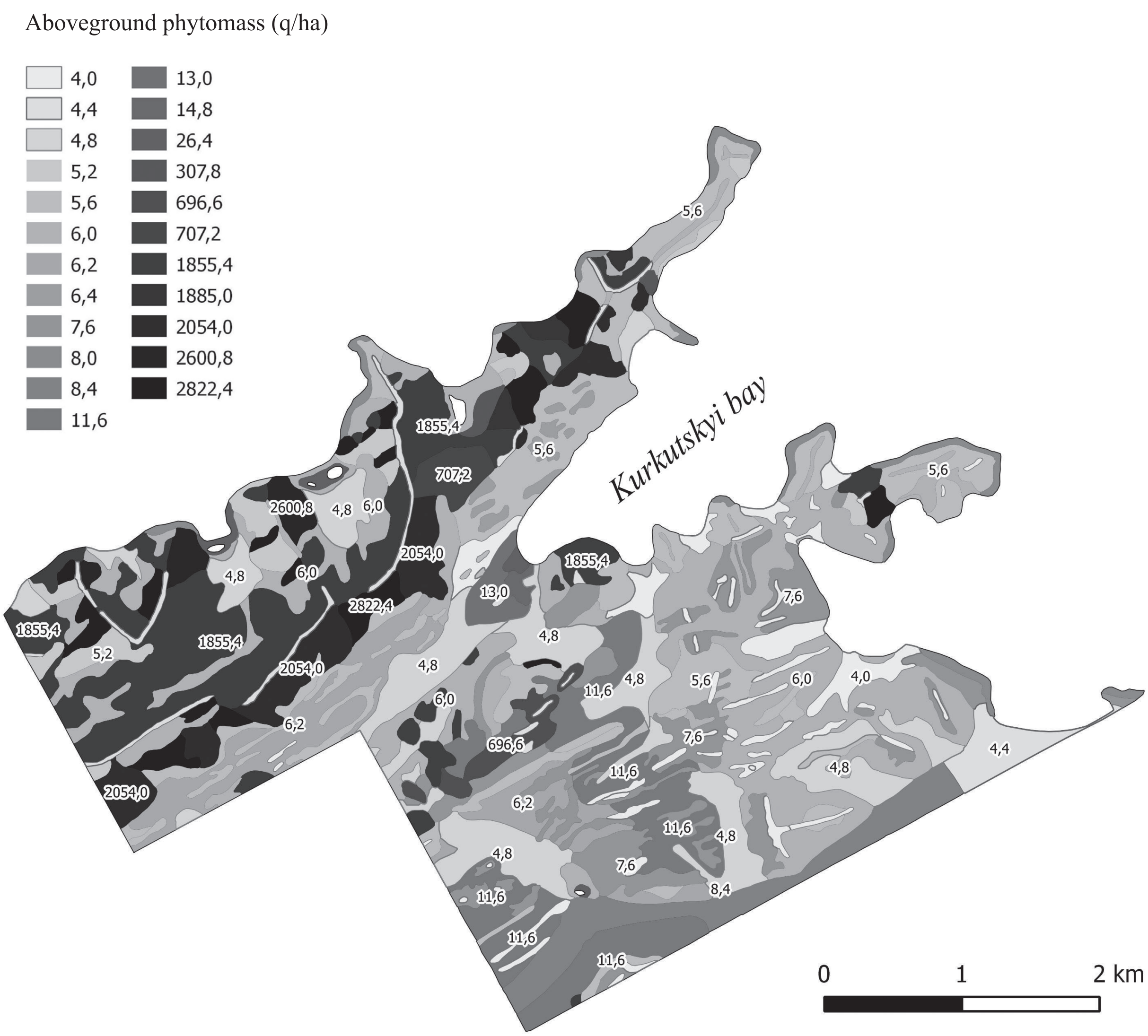


Figure 5: Draft map of the phytomass stocks (q/ha = 100 kg/ha).
Slika 5: Osnutek karte zaloge fitomase (q/ha = 100 kg/ha).

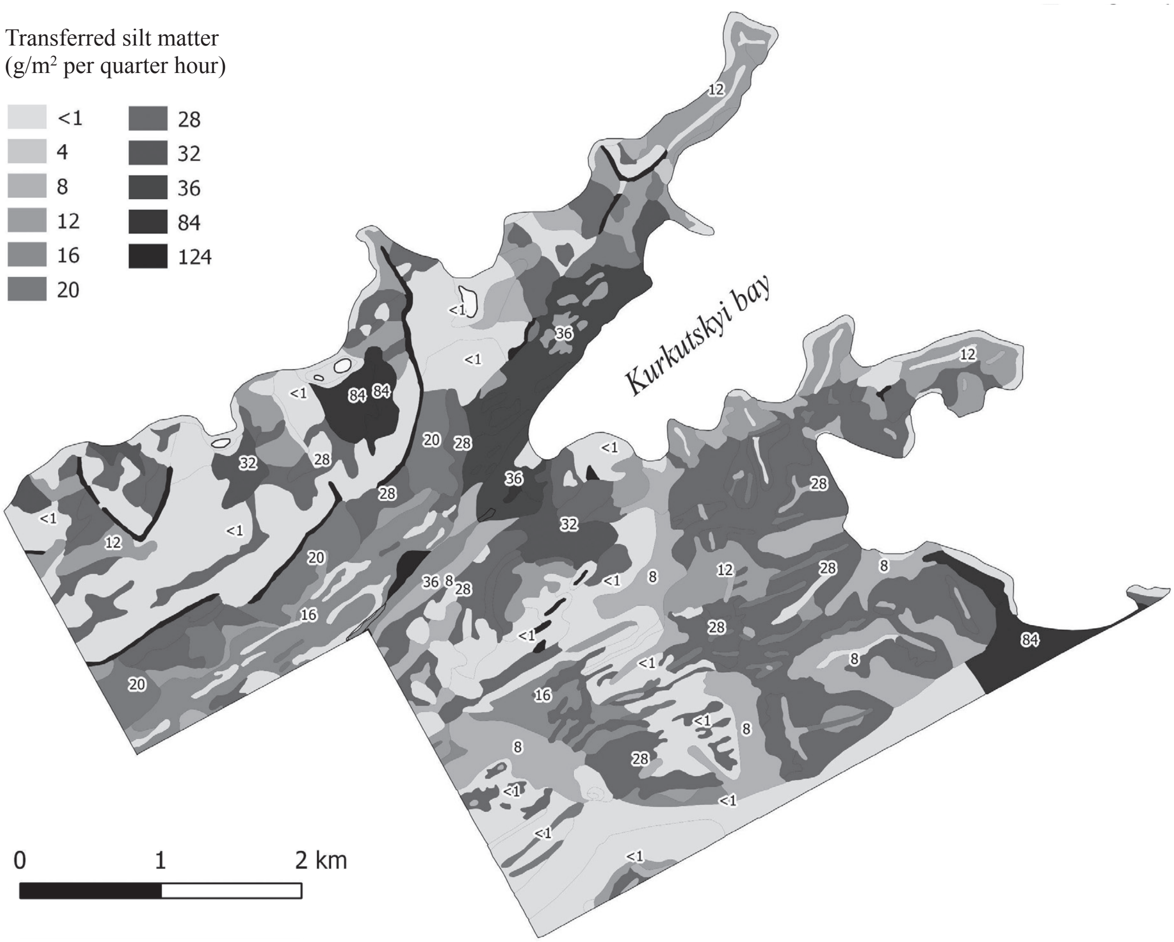


Figure 6: Draft map of the vulnerability of land-cover types to soil erosion.
Slika 6: Osnutek karte ranljivosti tipov pokrovnosti tal zaradi erozije tal.

According to the maps (Figure 2, 5) and the data-base (Table 3), the values of above-ground herbaceous phytomass of the steppe habitats varied from 400 to 2640 kg/ha. Marshes (sedge complexes of intermountain basin and valleys – land-cover types 29, 30) had the highest phytomass values among herbaceous communities. Apical stony and sloping grass-forb landscapes (land-cover types 10, 12, 22) and areas of settlements and recreation facilities (land-cover type 31) had the lowest values. Forest steppes were characterized by low crown density and non-large stand density, which was represented mainly by larch. Phytomass stock ranged from 307.8 to 2822.4 kg/ha. Maximum values corresponded to the forest steppe with larch on steep slopes (land-cover types 3–5).

The maximum values of the soil matter transfer (up to 124 g/m^2) corresponded to areas with strong anthropogenic pressure (4–5 stage of degradation), with the lower value of vegetation cover (from 0 to 45%) and above-ground herbaceous phytomass (400 –600 kg/ha) (Figure 6, Table 3). The minimum values of the soil matter transfer (less than 1 g /m^2) corresponded to the forest steppes (land-cover types 6, 7, 8) with low anthropogenic impact (1 stage of degradation), some plain steppes (19, 20, 27) with high vegetation cover and medium anthropogenic pressure (2–3 stage of degradation), minor areas of meadows and wetlands (28, 29, 30) with strong anthropogenic impact (3–4 stage of degradation).

Different ecosystems vary in their resistance to impact. The rainfall simulation revealed different levels of vulnerability to soil erosion, for example, for land-cover type 15 (*Caragana* steppe with sagebrush) on the undisturbed area, trapped silt was 12 g/m^2 and for an anthropogenically dis-

Table 5: Assessment matrix of some ecosystem services.
Tabela 5: Matrika ocen nekaterih ekosistemskih uslug.

Land-cover type	Ecosystem services					
	Erosion regulation	Fodder	Wild food	Recreation	Landscape aesthetic	Natural heritage
1. Sparse larch forest with *Poa*	0	0	1	3	5	4
2. Sparse larch forest with forb	3	0	1	5	5	4
3. Larch forest with *Rhododendron*	4	0	1	4	5	4
4. Larch forest with forb and sagebrush	2	0	1	4	5	4
5. Steppefied larch forest	2	0	1	3	4	4
6. Larch forest with forb	5	0	1	2	5	4
7. Sparse larch forest with *Cotoneaster* and *Poa*	5	0	1	5	5	4
8. Larch forest with *Cotoneaster*	5	0	1	4	4	4
9. Sparse larch forest	4	0	1	5	5	4
10. Steppe with *Poa* and *Caragana*	4	1	0	1	4	5
11. Forb steppe with *Caragana* and sagebrush	5	1	0	1	4	5
12. Forb steppe with *Caragana* on the rocks	2	1	0	1	5	5
13. Short grass steppe	3	1	0	1	5	5
14. Lytomorphic vegetation on the rocks	4	0	0	2	5	5
15. *Caragana* steppe with sagebrush	3	1	0	1	4	5
16. *Caragana* steppe with forb	3	1	0	5	5	5
17. *Fescue* steppe with chamaerhodos	2	2	0	3	4	5
18. Forb steppe	2	2	0	5	5	5
19. Forb steppe with tall grass	5	3	0	2	2	5
20. Forb (polydominant) steppe	3	2	0	1	2	1
21. Tall grass steppe	2	2	0	1	4	5
22. Forb steppe with *Fescue*	4	1	0	5	4	5
23. Forb steppe with *Stipa* grass	4	1	0	3	3	5
24. *Stipa* grass steppe	1	1	0	4	5	5
25. Forb steppe with sagebrush	4	3	0	5	3	5
26. Sagebrush steppe	1	2	0	1	2	5
27. Sagebrush steppe (fallow land)	5	2	0	1	2	1
28. Bent grass meadow with sedge	5	2	0	3	4	5
29. Turfy sedge wetland	5	0	0	2	4	5
30. Wetland with *Poa*	5	0	0	1	3	5
31. Settelments and recreational facilities	0	0	0	5	2	0
Water body (Lake Baikal)	-	0	5	5	5	5
Natural soil roads	0	0	0	2	0	0

turbed patch – 84 g/m². For land-cover type 26 (Sagebrush steppe), trapped silt changed from 4 to 16 g/m².

A matrix of some ecosystem services was compiled (Table 5) to show dependence between the studied types of ecosystems and the ecosystem services they provide. The map of the erosion regulation service is shown in Figure 7. We identify the variation in the capacity to provide this service among the studied steppe and forest steppe types, which generally have a lower capacity than forest ecosystems around Lake Baikal (Vanteeva & Solodyankina 2014). Forest steppes, minor areas of wetlands and some forb steppes with Tall grass, have a high relevant capacity to provide this service. Disturbed landscapes and some steppe on steep slopes (e.g. *Stipa* grass steppe – land-cover type 24) have the lowest capacity.

The study area has a low potential to provide such services as fodder for livestock and wild food and a high potential to provide cultural services. Lake Baikal and its scenically attractive landscapes increase the attractiveness for tourism.

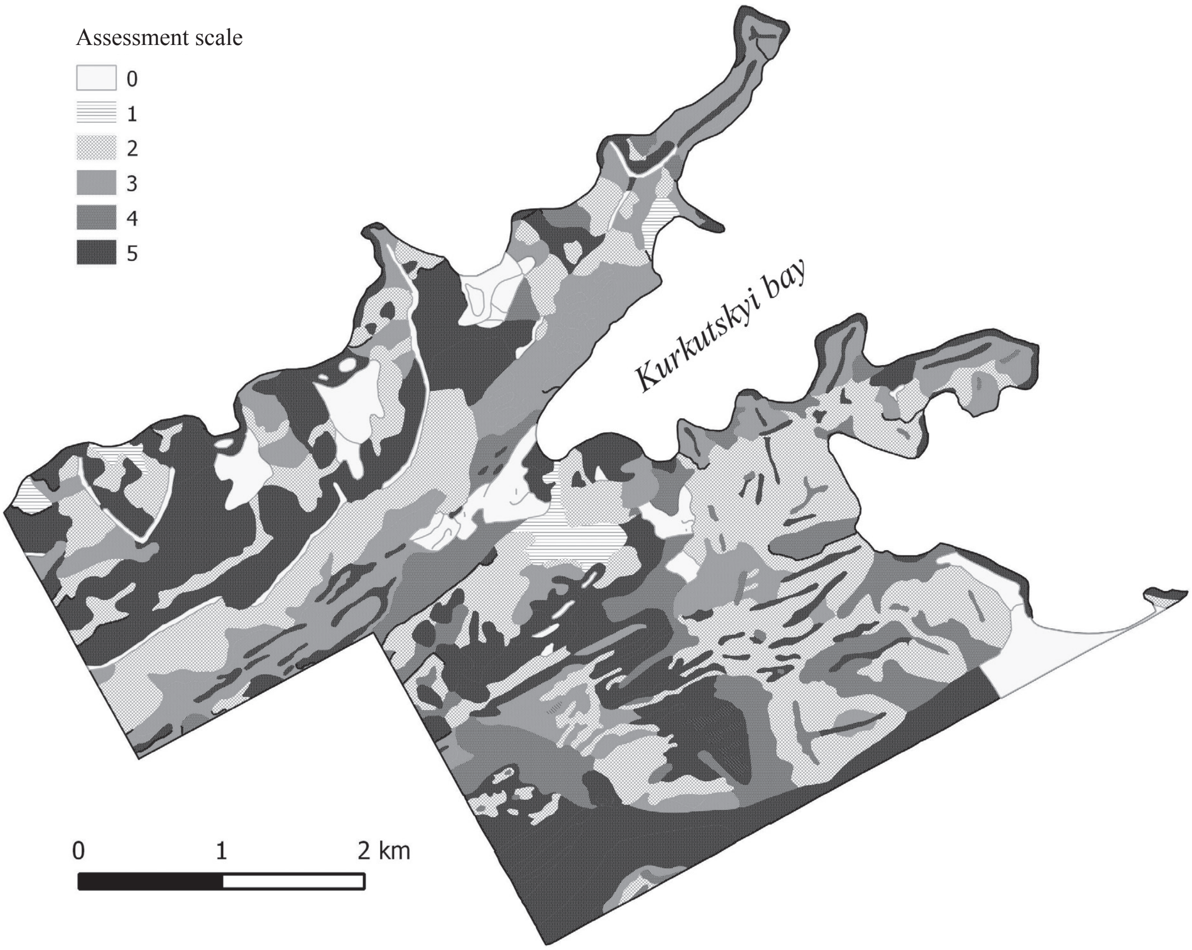


Figure 7: The erosion regulating ecosystem service assessment. (0 – no relevant capacity, 1 – low relevant capacity, 2 – relevant capacity, 3 – medium relevant capacity, 4 – high relevant capacity and 5 – very high relevant capacity)
Slika 7: Ocena ekosistemskih uslug, ki jih uravnava erozija. (0 – brez ustrezne kapacitete, 1 – nizka ustrezna kapaciteta, 2 – ustrezna kapaciteta, 3 – srednja ustrezna kapaciteta, 4 – visoka ustrezna kapaciteta in 5 – zelo visoka ustrezna kapaciteta).

5. DISCUSSION

In this research we determine landscape values to provide ecosystem functions and services for the Priol'khonie steppes and forest steppes. Investigation of the functioning of these ecosystems and the directions of their alterations is needed because of their ecological and economical value and vulnerability to impacts.

The investigation showed strong landscape transformation, leading to changing in ecosystem properties and functioning. During fieldwork, changes in the species composition of vegetation that lead to a decrease in phytomass production were recorded. For example, in forb steppes (land-cover types 11, 19, 20, 21, 24) some species, such as *Stipa* spp. and *Festuca* spp., which are more productive, were gradually displaced by *Carex duriuscula* C.A. Mey and *Carex pediformis* C.A. Mey.

On the most disturbed areas (4, 5 stages of degradation), synanthropic species, such as *Urtica dioica* L.*, Alopecurus pratensis* L*, Taraxacum officinale* F.H.Wigg.*,* dominate. Species with wide ecological amplitude, such as shallow-rooted species (*Potentilla acaulis* L., etc.), species with vegetative reproduction (*Carex duriuscula* C.A. Mey, etc.), flagellate or rosette shoots species (*Veronica incana* L., *Thymus baicalensis* L., etc.) are spreading in the vegetation cover at stages 3, 4 of degradation (Ponomarenko & Solodyankina 2013).

The recorded values of above-ground herbaceous phytomass varied from 400 to 2640 kg/ha, which are less than the results of Molozhnikov (1986), which range from 500 to 3,500 kg/ha on the same territory. Ranges of values have large overlap and some differences can be explained by climatic variations, or increased impact since 1986. Generally, in North Eurasian steppe, aboveground herbaceous phytomass varies from 300 to 13,700 kg/ha, with a mean value of 2,000 kg/ha (Bazilevich & Tishkov 2015).

The study area is subject to erosion, which is why measurements of silt transfer were carried out. We show that different ecosystems vary in their erosion regulation capacity and resistance to impact (Table 3). Measured amounts of transferred silt range from 0.01 to 20 t/ha of soil matter transfer per year. The lower end of the range corresponds to a minor area of meadows, wetlands and forest steppes. Generally, in natural steppe, the amount of transferred silt by water erosion varies from 0.5 to 1 t/ha of solid matter transfer per year (Isachenko 1991). So, a considerable amount of soil (5480 – 8220 t/yr from 19.86 km^2 of study area) is transferred by water.

Qualitative assessment of other ecosystem services showed that the capacity of the study area is high for providing cultural services and low for fodder and wild food production.

6. CONCLUSION

Functioning of the Priol'khonie steppe and forest steppe landscapes (even undisturbed) is characterized by special aspects, such as exposure to inter-rill and rill erosion, low phytomass and specific climate conditions. Characteristics of ecosystem function significantly vary in the steppe and forest steppe of the Priol'khonie (Table 3). That is why draft maps of phytomass stocks (Figure 5) and the vulnerability of land-cover types to soil erosion (Figure 6) were compiled. A matrix (Table 5) was compiled for the assessment of the provision of ecosystem services, which shows how the ecosystem capacity varies according to ecosystem functioning and land-cover types.

The rate of landscape alteration is 1.25 km^2 during 10 years (dwelling and recreation facilities), which leads to loss of ecosystem services.

7. ACKNOWLEDGMENTS

The study was supported by Russian foundation for basic research. We thank Stephen Venn, University of Helsinki, and two unknown reviewers for their advice, and for polishing the language.

8. REFERENCES

Agassi, M. & Bradford, J.M. 1999: Methodologies for interrill soil erosion studies. Soil & Tillage Res. 49: 277–287.

Berkin, N.C., Makarov, A.A. & Rusinek, O.T. 2009: Baykalovedenie: manual. Irkutsk State University Publisher, Irkutsk, 291 pp. [in Russian].

Burkhard, B., Kroll, F., Müller, F. & Windhorst, W. 2009: Landscape's capacities to provide ecosystem services – a concept for land-cover based assessments. Landscape Online 15: 1–22.

Burkhard, B., Kroll, F., Nedkov, S. & Müller, F. 2012: Mapping ecosystem service supply, demand and budgets. Ecological Indicators 21: 17–29.

Catorci, A., Cesaretti, S. & Gatti, R. 2009: Biodiversity conservation: geosynphytosociology as a tool of analysis and modeling of grassland systems. Hacquetia 8: 129–146.

Deák, B., Valkó, O., Kelemen, A., Török, P. Miglécz, T., Ölvedi, T., Lengyel, S. & Tóthmérész, B. 2011: Litter and graminoid biomass accumulation suppresses weedy forbs in grassland restoration. Plant Biosystems 145: 730–737.

Ganquelin, T., Jalu,t G., Iglesias, M., Vallet, F., Fromard, F. & Dedoubat, J. 1996: Phytomass and carbon storage in the *Stipa tenacissima* steppes of the Baza basin, Andalusia, Spain. Journal of Arid Environments 34: 277–286.

Grismer, M. E. 2011: Rainfall simulation studies – a review of designs, performance and erosion measurement variability. URL: http://ucanr.org/sites/ californiaagriculture/files/145682.pdf.

Isachenko, A. G. 1991: Landscape science and physical-geographical regionalization. Vysshaya Shkola Publishers, Moscow, 366 pp. [in Russian].

Kachergis, E., Rocca, M. E. & Fernandez-Gimenez, M. E. 2011: Indicators of ecosystem function identify alternate states in the sagebrush steppe. Ecological Applications 21: 2781–2192.

Kandziora, M., Burkhard, B. & Müller, F. 2012: Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators – A theoretical matrix exercise. Ecological Indicators 28: 54–78.

Kasyanova, L. 2004: Plant ecology of the Baikal region (water exchange). Science, Moscow, 288 pp. [in Russian].

Kelemen, A., Török, P., Valkó, O., Miglécz, T., Tóthmérész, B. 2013: Mechanisms shaping plant biomass and species richness: plant strategies and litter effect in alkali and loess grasslands. Journal of Vegetation Science 24: 1195–1203.

Mace, G. M., Norris, K. & Fitter, A. H., 2012: Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology and Evolution 27: 19–26.

Maynard, S., Davidson, A., James, D., Mooney, S., Petter, M., McPherson, D. & Walker, M. 2013: Ecosystem functions the SEQ Ecosystem service Framework. URL: http://www.ecosystemservicesseq.com.au/ecosystem-functions.html.

Molozhnikov, V., 1986: Plant communities of the Baikal region. Science, Novosibirsk, 272 pp. [in Russian].

Olkhon District' Administration 2012: Olkhon District' Administration report for the year 2012. URL: http://www.adm-olkhon.ru/news/one-1820.html.

Pleshanov, A., Bardunov, L., Makryiy, T. et al. 1990: Unique wildlife of Lake Baikal basin. Science, Novosibirsk, 224 pp. [in Russian].

Ponomarenko, E. A. 2003. Biocomplexes of the Priol'khonie and Olkhon Island (Lake Baikal) and their anthropogenic transformation. PhD. thesis, Ulan-Ude, 216 pp. [in Russian].

Ponomarenko, E. A. & Solodyankina, S. V. 2013: Transformation of the coastal ecosystems of Lake Baikal under the influence of recreational activities. The Bulletin of Irkutsk State University 1: 147–160. [in Russian].

Bazilevich, N. I. & Tishkov, A. A. 2015: Productivity of ecosystems in North Eurasia. URL: http://biodat.ru/db/ prod/index.htm. [in Russian].

Public Cadastral map. 2013: Federal Service for State Registration, Cadastre and Cartography. URL: http://maps.rosreestr.ru/PortalOnline. [in Russian].

Savenkova, T. 2001: Protected areas of Lake Baikal basin. Institute of Geography SB RAS Publishers, Irkutsk, 185 pp. [in Russian].

Semenova, L. N. 2000: The study of landscape-geochemical conditions of the Kurkutskyi bay coast (Lake Baikal). In: Landscape ecology and land use planning. Abstracts of National Conference (Irkutsk, September 11-12, 2000). Publisher of SB RAS, Novosibirsk, pp. 176–177 [in Russian].

Semenov, Y. M., Antipov, A. N., Bufal, V. V. et al. 2004: Ecologically oriented land use planning in the Baikal region. Olkhon district. Institute of Geography SB RAS Publishers, Irkutsk, 147 pp. [in Russian with English summary].

Vanteeva, Y. V. & Solodyankina, S. V. 2014: Assessment and mapping of landscape productivity in Northern Pribaikalie. Geography and Natural Resources 3: 63–69 [in Russian, with English summary].

Yevstropieva, O. V. 1999: Transformation natural complexes in the recreation areas. Geography and Natural Resources 1: 130–133. [in Russian].

Zagorskaya, M. V. 2004: Landscape structure of central Ol'khon region. Geography and Natural Resources 4: 58–68 [in Russian, with English summary].

Zamolodchickov, D. G., Utkin, A. I. & Chestnich O. V. 2003: Conversion rates stocks plantations in phytomass for the major tree species of Russia. Forest Inventory and Forest Management 1: 119–127 [in Russian].

Zamolodchickov, D. G., Utkin, A. I. & Korovin, G. N. 2005: Conversion coefficients phytomass/reserves related to dendrometric parameters and stand composition. Russian Forest Sciences 6: 78–81. [in Russian, with English summary].

Received: 5 February 2014
Accepted: 4 June 2015
Co-ordinating Editor: Stephen Venn