ISSN 2079-0961, Arid Ecosystems, 2020, Vol. 10, No. 2, pp. 127–134. © Pleiades Publishing, Ltd., 2020.
Russian Text © The Author(s), 2020, published in Aridnye Ekosistemy, 2020, Vol. 26, No. 2(83), pp. 48–56.

SYSTEMATIC STUDY OF ARID TERRITORIES

Adaptation of International Indicators of Land Degradation Neutrality for the Assessment of Forest Ecosystems in Arid Conditions in Russia

A. V. Ptichnikov[a, *] and A. A. Martynyuk[b]

[a] *Institute of Geography, Russian Academy of Sciences, Moscow, 119017 Russia*

[b] *All-Russia Research Institute for Silviculture and Mechanization of Forestry, Pushkino, Moscow oblast, 141202 Russia*

**e-mail: aptichnikov@igras.ru*

Received May 27, 2019; revised June 26, 2019; accepted July 2, 2019

Abstract—This paper addresses a large-scale problem: the degradation of protective forest plantings on arid lands in southern Russia. The degradation is primarily caused by a drastic reduction in the scope of forest-maintenance works carried out by forestry authorities due to cutbacks in funding and changes in ownership rights to lands with field-sheltering forest belts. The deterioration of forest plantings includes their pollution by domestic and industrial waste; damage caused by fire, illegal felling, diseases, and pests; the development of sod-formation processes in soils; and the thinning and decay of the forest cover. Currently, the sanitary condition of more than half of such plantings is unsatisfactory; they have reached their maximum age and have begun to decay. Due to the scale of the problem, it is suggested that the tools of the concept of land degradation neutrality (LDN) be used to monitor ongoing changes in such forest plantings and the use of accumulated practical experience to supplement the set of global LDN indicators with a number of national parameters, including the following forest taxation (valuation) characteristics: timber deposit, forest-cover percentage, and gross growth (taking into account the mortality). An additional indicator is also suggested: the biological diversity level (i.e., species diversity of the tree and shrubbery vegetation in protective forest plantings). LDN assessment should take into consideration the location of forest plantings on state-owned and private lands with various management goals.

Keywords: forests in arid climatic conditions, land degradation neutrality, protective forest cultivation, taxation (valuation) characteristics of forest plantings

DOI: 10.1134/S2079096120020109

INTRODUCTION

In 2016, the United Nations Convention to Combat Desertification (UNCCD) developed and published a scientific conceptual framework for land degradation neutrality (LDN) (Decision..., 2018). The framework proposes a minimum set of three key global LDN indicators. These indicators are considered the main prerequisites for the monitoring of national efforts to fulfill target 15.3 of the UN Sustainable Development Goals (SDGs) in the framework of the 2030 Agenda for Sustainable Development: "By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world." The above indicators are

- trends in land cover;
- trends in land productivity or functioning; and
- trends in carbon stocks above and below ground.

The combined use of these indicators is required to determine whether LDN has been achieved in a certain area. Land parcels or areas meet the neutrality criteria if none of the indicators shows degradation in a definite time.

According to Kust et al. (2018), the global LDN indicators proposed by the UNCCD cannot be directly applied to the territory of Russia. The main reasons behind this are the huge area of the country, the high diversity of the physico-geographical and socioeconomic conditions, and the existing multilevel state system for land inventory and monitoring.

The Russian Federation (RF) supports the SDGs, and its state policy is aimed at their implementation in the country. The RF has also signed and ratified the UNCCD, which, as noted above, stipulates the monitoring of the target 15.3 fulfillment. The UNCCD covers not only arid landscapes but humid ones as well, including forested lands. Therefore, the state forestry policy of the RF should contribute to the fulfillment of SDG target 15.3 (Ptichnikov et al., 2019).

The forest-fund lands occupy approximately two-thirds of the Russian territory; therefore, the adaptation (harmonization) of international LDN indicators for forestry management purposes is a top-priority objective.

One way to harmonize the national and global reporting frameworks regarding SDG target 15.3 is to supplement the national system with global indicators and to incorporate them into the national reporting system as general guidelines that can also be used to validate the objectivity of statistical data obtained with traditional methods (Kust et al., 2018).

The purpose of this study was to assess the feasibility of the adaptation of international LDN indicators for the assessment of forest health in the arid climatic conditions of Russia.

GENERAL DESCRIPTION OF FORESTS IN ARID AREAS

The Russian Federation includes 16 constituent entities in which the forest-cover percentage does not exceed 15% (so-called “sparsely forested” regions); 15 such regions are located in the southern part of European Russia (Republic of Dagestan; Republic of Kalmykia; Stavropol krai; and Astrakhan, Volgograd, Rostov, Orenburg, Saratov, Voronezh, Belgorod, Tambov, Lipetsk, Orel, and Kursk oblasts), and one of them (Altai krai) is in Asia. In three of these regions (Republic of Kalmykia, Astrakhan oblast, and Stavropol krai), the forest cover percentage does not exceed 2% (Martynyuk, 2014).

It has been proven by numerous studies that forests mitigate the disastrous effects of droughts and dry hot winds in arid climatic conditions, increase the yield of agricultural crops, and form a favorable microclimate for the population. Complexes of natural woodlands and artificial forest amelioration significantly increase the forest-cover percentage in respective areas and enhance their moisture circulation, heat exchange, and gas interchange (*Strategiya razvitiya* ..., 2008).

Let us examine the situation with forests in arid areas with the Southern Federal District of the Russian Federation as an example. The total forest area in the federal district is some 2.8 million ha. Protective forests constitute 99.9% of the local forests. Of these, 77% are valuable: primarily, antierosion forests; forests located in the desert, semidesert, forest–steppe, and steppe zones; state protective forest belts; and spawning belts (Martynyuk, 2017). Some 31% of forests in the federal district are of artificial origin (i.e., the results of forest cultivation). Overall, the local forests grow in arid natural–climatic conditions and perform crucial environment-forming, water protection, and other beneficial functions.

Unfavorable weather conditions pose a significant danger to forests, especially meteorological phenomena that may potentially produce, amid forthcoming climatic changes, new threats to the forest health, changes in the structure of forested lands, and forestry (Zamolodchikov, 2016). The most significant threats in this complex of factors are the effects of hurricane winds, changes in the water regime of forest plantings, and droughts. Should the global temperature regime and precipitation trends persist, an increasing number of regions located in the south of temperate latitudes (southern part of European Russia, the North Caucasus, and southern Siberia) may be affected by droughts and climate aridity caused by extremely high temperatures in the summer period (*Natsional’nyi dokald* ..., 2018).

FOREST CULTIVATION AS THE MAIN MEANS TO INCREASE THE FOREST-COVER PERCENTAGE IN ARID AREAS

One of the primary objectives for the improvement of social, economic, and environmental conditions in areas with arid climate is to increase their forest-cover percentage. The main goal of forestry and forest cultivation in arid regions is to form (maintain) sustainable forest plantings able to perform the environment-forming and environmental-protection functions as long as possible (Kulik et al., 2012).

Forest cultivation is the key priority of forestry management in southern regions of the RF. Forest cultivation (i.e., artificial afforestation of forestless areas) should be implemented to prevent water, wind, and other types of soil erosion, for the creation of protective forests, and for other purposes connected with the enhancement of forests’ potential (*Lesnoi* ..., 2017).

According to the forest-cultivation regulations (On approval ..., 2018), forest cultivation includes the afforestation of forest-fund lands (drained swamps, reclaimed lands, rezoned agricultural lands, etc.); the creation of protective forest plantings on agricultural, industrial, transport, and water fund lands and other land categories; the creation of forest plantings in the course of the reclamation of lands disturbed by industrial operations; and the creation of forest plantings in sanatorium and health resort zones and on other objects.

The result of forest cultivation in arid areas is the creation of forest plantings that perform protective functions (i.e., protective forests). The following main categories of artificial protective forest plantings are distinguished by the land-use type: state protective forest belts, field-sheltering forest belts, riverhead- and water-regulating forests on slopes; gully and ravine forest belts, mountainous ameliorative plantings, pasture-sheltering forest belts, etc. Protective forests on arid lands include inter alia state protective forest belts and forests located in the steppe, forest–

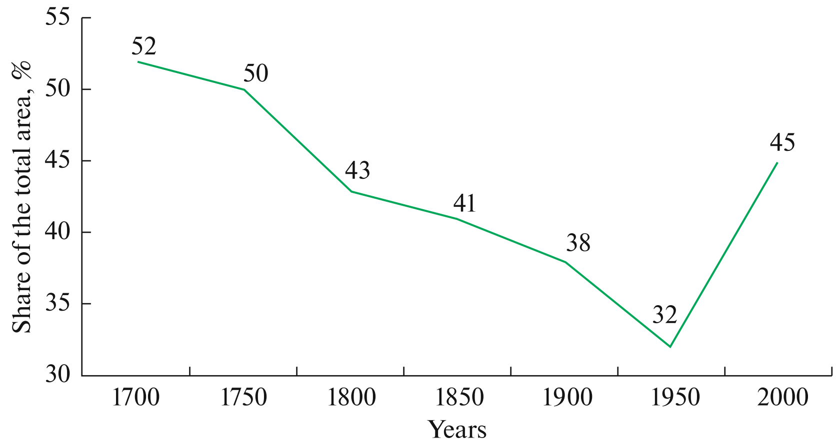

Fig. 1. Forest cover percentage dynamics in European Russia for the last 350 years (*Natsional'nyi atlas*..., 2000).

steppe, desert, and semidesert zones (i.e., in regions with arid climate).

Today, state protective forest belts are of great recreational significance and feature high recreational attractiveness. In recent years, the forestry authorities have recognized state protective forest belts as an important element of the territorial environmental frame. Biogeocoenoses with rich flora and fauna have formed within them. Field-sheltering forest belts are linear plantings created in plain areas and on flat watersheds (both on irrigated and rain-fed lands). They can protect arable lands and cultivated crops from adverse natural factors. Antierosion forest plantings are soil-protective forest plantings in the form of coulisses, belts, curtains, and forest tracts preventing soil wash away, washout, and deflation.

RESULTS AND DISCUSSION

Changes in the Forest-Cover Percentage in European Russia and Actual Forest-Cultivation Programs

The forest-cover percentage is the key forestry management parameter in arid areas and is directly related to the fulfillment of Russia's obligations under SDG target 15.3. In SDG terms, an increase in the forest-cover percentage indicates a decrease in the share of degraded lands in arid areas and vice versa: a decrease in this parameter indicates an increase in the share of such lands.

Accurate data on the forest-cover percentage for the country are available for the period starting from the mid-1950s; at that time, the state began to produce an inventory of its forest fund. The historical data indicate that the average forest-cover percentage in the central part of European Russia (i.e., in Kyivan Rus) was some 50%. In the 16–19th centuries, the slash-and-burn agriculture system and subsequent exhaustive forest mining during the industrial upsurge period have reduced the average forest-cover percentage in European Russia to 33%. In the once-forested areas of central and mid-Volga governorates, the forest-cover percentage has dropped to 15%; in forest–steppe and southeastern governorates, it has fallen to 5% or less. In that period, the steppe border has advanced at least 100 km to the north (*Lesnaya Entsiklopediya*, 1985). In the 20th century, the total forest-cover percentage in European Russia has increased due to social disturbances, reforms, and wars, primarily, via the colonization of arable lands by trees and shrubs. By 1956, the entire forest fund of the country had been surveyed, and the average forest cover percentage was 39.5%; it was 45.3% in 1998 and 45.4% in 2003 (Fig. 1) (*Lesnaya Entsiklopediya*, 1985).

The forest-cover percentage on arid lands increased as a result of various forest cultivation programs implemented by the state. Since the end of the 18th century, 5.2 million ha of protective forest plantings have been created on the agricultural lands of southern Russia (Martynyuk, 2014).

The creation of state protective forest belts commenced in 1949 in accordance with the Decree of the Council of Ministers of the USSR and the Central Committee of the All-Union Communist Party of Bolsheviks of October 20, 1948, "The Plan for Field-Sheltering Forest Plantings, the Introduction of Grassland Crop Rotations, and the Establishment of Ponds and Reservoirs to Ensure Heavy and Sustainable Crops in Steppe and Forest–Steppe Districts of the USSR," which is also known as "The Nature Transformation Plan." Under this famed plan, 2.1 million ha of protective forest plantings were created in southern regions of Russia during the 1950s (*Strategiya razvitiya*..., 2008).

In recent decades, some 140000 ha of state protective forest belts with a total length of some 5000 km have been created in 19 regions of the country. The belts were established along watersheds dividing river basins and along river banks to protect the rivers from

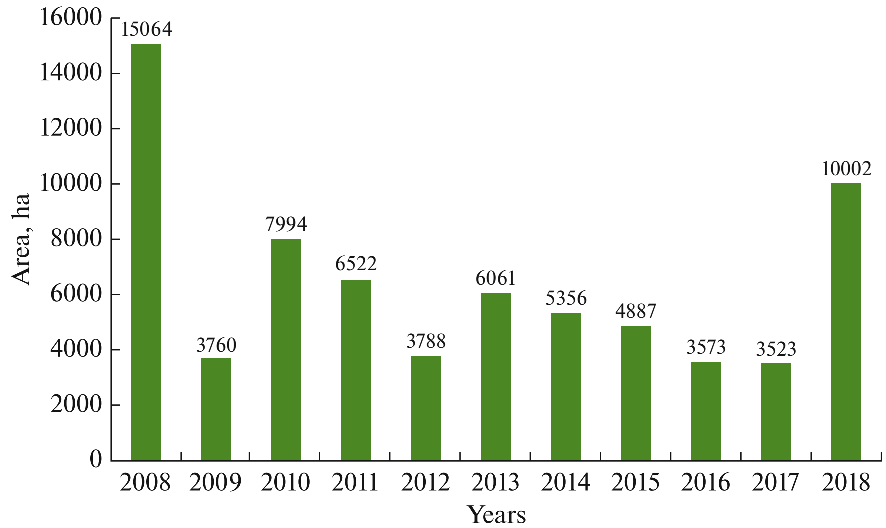

Fig. 2. Protective forest cultivation dynamics in the RF (Martynyuk, 2017, with supplements).

silting and pollution. State protective forest belts became the frame for the protective-forest planting (PFP) system. The majority of such plantings currently belong to the federally owned, state forest fund. In most cases, they constitute well-formed forests that perform key climate-regulating and wind-sheltering functions. In some places, the natural overgrowth of unused fields progressing from forest edges of such belts is observed (Fig. 2) (Martynyuk, 2014).

Since the 1980s, the quantities of newly created PFPs have been decreasing. In the last 10 years, the amount of protective-forest cultivation have decreased by almost four times (Martynyuk, 2017). In 2008–2017, the number of forest–cultivation works had dropped to the minimum and were performed on lands designated for various uses with a total area of 3500–8000 ha. In many constituent entities of the Russian Federation, such works ceased almost completely, including those in regions where soils must be protected against erosion (Astrakhan, Volgograd, Tambov oblasts, etc.).

It is only in recent times that the state of protective-forest cultivation has slightly improved. In 2018, protective-forest cultivation was performed in areas totaling 10000 ha, and the amount of forest-cultivation works increased by 2.8 times in comparison with 2017.

THE STATE OF PFPs IN ARID AREAS AND THE NEED TO ASSESSMENT THEM WITH LDN TOOLS

According to the data obtained by the All-Russia Research Institute for Silviculture and Mechanization of Forestry, roughly half of the existing protective plantings require reconstruction or complete replacement due to their very unsatisfactory condition or attainment of the maximum age (Martynyuk, 2014). The main reason behind PFP degradation is a lengthy (over 20 years) period in which forestry maintenance works were not performed due to a lack of funding. Many PFPs are polluted by domestic and industrial waste and damaged by fires, illegal felling, diseases, and pests. Processes of forest-cover thinning are progressing in them; in addition, in most cases, newly created PFPs are single-species plantings or narrow belts of three to four rows consisting of poplar and birch trees; this contributes to intense sod formation in the soil and thus, a worsening of the conditions for natural reforestation. In Voronezh and Belgorod oblasts alone, where the existing PFPs are in need of large-scale forestry works, the total area that should be covered by such works amounts to 103776 ha. The highest amounts of work relate to maintenance cutting and sanitary cutting (57.4% and 28.0% of the total area, respectively) (Chekanyshkin and Lepekhin, 2015).

Another significant problem of PFPs is the degradation of protective-forest belts on agricultural lands. During the Soviet period, field-sheltering forest belts were maintained by the forestry authorities. Plenty of former agricultural lands have become privately owned since then; as a result, the forestry authorities ceased the maintenance of field-sheltering forest belts, while the private owners (farmers and agricultural complexes) either refuse to maintain field-sheltering forest belts or drastically reduce the number of maintenance works. As a consequence, large areas of forest-sheltering belts became, in fact, ownerless. For instance, only 17% of forest belts in Krasnodar krai currently belong to the region; the rest of them are privately owned. Forests belts occupy over 120000 ha in Krasnodar krai and can increase the grain harvest by up to 12% and the harvest of industrial crops by up to 35%. However, the forest belts currently do not fulfil their functions. Half of the protective plantings require forestry maintenance and improvement of their sanitary state on an urgent basis. Some 95% of the plantings belong to the third age period, i.e., they are older than 16 years and in need of reconstruction (Filed protective..., 2016). Illegal felling incidents occur, including especially large-scale ones. The owners (leaseholders) of agricultural lands have to perform sanitary felling and maintenance; however, no liability is prescribed for the nonperformance of such works. According to Sergeeva (2018), it is necessary to make an inventory of protective plantings on lands belonging to all categories to assess their condition (Fig. 3).

The above facts indicate that there are severe problems, both quantitative and qualitative ones, affecting PFPs on arid lands. The situation implies the need to assess the state of PFPs and natural forest ecosystems in arid areas with LDN approaches.

Fig. 3. State of a forest belt on agricultural lands in the Republic of Adygea (Sergeeva, 2018).

LDN MONITORING OF FORESTS IN ARID AREAS

LDN assessment of forests growing in arid areas requires the precise determination of the land categories eligible for this assessment. The forests of the Southern Federal District are located both on forest-fund lands and agricultural lands (field-sheltering belts and other PFP categories). Therefore, the monitoring for SDG target 15.3 should be applied both to forest-fund lands encompassing a broad range of categories (from forested to unforested lands) and agricultural lands covered by tree and shrubbery vegetation and the presence of greenery on them.

Analysis of the LDN indicators and respective forest taxation (valuation) indicators used at the federal level makes it possible to establish the following correspondence between these sets of parameters (Table 1).

FOREST-COVER PERCENTAGE AND ITS DYNAMICS

The forest-cover percentage is the key LDN indicator for forests growing in arid areas. The forest-cover percentage and its dynamics over time constitute, in fact, a direct and most important parameter for the assessment of the SDG indicator of 15.3 (the proportion of land that is degraded to the total land area). The statistical data on forested areas of the RF and their distribution by constituent entities of the RF are published on a regular basis in national and regional reports and available in the State Forest Register. Changes in the forest-cover percentage are directly linked to changes in the forested area. Changes in the forested area can be caused by

- forest drying due to climatic changes;
- changes in the forest structure caused by anthropogenic impacts (grazing, illegal felling, invasions of species);
- forest mortality caused by adverse factors (fires, industrial emissions, pests, and diseases).

The state statistical reports provide summary data on the forest-cover percentage for entire constituent entities of the RF; therefore, a more accurate dynamics analysis is required for arid areas of these constituent entities. Analysis of the PFP areas and protective-forest belts must take into account the ratio of the arable land area and the PFP area. A PFP-to-arable-land ratio of 5% or higher ensures an optimal yield of many

Table 1. Approximate correspondence between LDN indicators and forest taxation parameters (based on *Entsiklopediya Lesnogo*..., 2006)

Trends in land cover	Forest yield (m^3/ha)
	Forest cover percentage
	Dynamics of felling, fire, insect damage, and withering areas
	Forest cultivation dynamics (for unforested lands belonging to the forest fund and agricultural lands)
Trends in land productivity or functioning	Gross growth (taking into account the mortality)
	Biological diversity level (e.g. the Shannon species diversity index)
Trends in carbon stocks above and below ground	Estimated parameters

cultivated crops. If this ratio decreases , a reduction in yields is observed.

LAND PRODUCTIVITY

In relation to forests, the land-productivity indicator may characterize the productivity of forests and tree and shrubbery vegetation. Forest productivity is determined by the amount of various resources produced by the forest in a period of time per unit area. The productivity categories include biological productivity (the amount of biomass produced by the forest in a period of time per unit area) and timber productivity (the amount of timber produced by the forest in a period of time per unit area) (*Entsiklopediya Lesnogo…*, 2006).

It is reasonable to use the biological productivity of forests for LDN purposes. Forest productivity is described by a special taxation parameter: growth (gross growth). Two oppositely directed processes are ongoing in forest stands: an increase in timber volume due to growth (by the volume of growing trees) and its decrease due to tree and shrubbery-vegetation mortality and intermediate felling. The total growth characterizes the increase in the volume without allowance for mortality.

The following main factors affect the growth value: the biological features of tree species; the forest-stand origin, age, growing conditions, normality, and sanitary state; and forestry activities.

Data on forest growth (productivity) are available in the State Forest Register (*Gosudarstvennyi…*, 2013), statistical data published by the Federal Forestry Agency in its departmental documents (*Doklad…*, 2015), specialized regional reference books, and databases. Remote-sensing data, including those obtained in the framework of Biomassar Program (Gauthier et al., 2015), constitute an additional important data source.

BIODIVERSITY AND LDN

One of the main differences between forests and other land types is the high biological diversity level in forest ecosystems; this applies even to actively used and artificial forests. In reality, an increase in forest productivity (e.g., in monodominant protective forest plantings) is often accompanied by a decrease in its initial biological diversity. In such cases, it is impossible to state that the effect caused by the productivity growth is unequivocally positive; it is necessary to take into account a contributing factor: biodiversity conservation in forest ecosystems. In strategic goal 4-2, the UNCCD refers to the need to monitor trends in abundance and distribution of selected species (both plants and animals). Therefore, we propose that an assessment of forest biodiversity and its dynamics be included in the LDN assessment at the local level.

As a first step, it is recommended that the species richness of the tree and shrubbery vegetation in PFPs and protective-forest belts be assessed. The majority of PFPs and protective forest belts were created with timber species featuring tolerance and a high root-taking capacity: *Robinia pseudoacacia* and white acacia. However, without proper forestry maintenance, such plantings start to degrade and decay as early as at the age of 15 years. Black walnut, English oak, and Strandzha oak are used to enhance the sustainability of such plantings; these species increase the species diversity and even make it possible to procure commercial timber in the course of maintenance felling. Such plantings are more attractive as animal and bird habitats, and their longevity is significantly higher. After the completion of maintenance felling, the forest belts perform their functions more efficiently. This will make it possible to raise the grain crop yield to 2.5 centners/ha and to transform the border zones of forest belts overgrown with shrubs and underwood into arable lands. Therefore, an increase in the plantingsto-fields ratio to 5 ha per 100 ha of arable lands is recommended.

All other conditions being equal, PFPs with higher species diversity are more sustainable. The preferential use of local long-living tree and shrub species adapted to arid climates may be used as another indicator of more sustainable approaches to the PFP creation.

The assessment of the PFP-to-arable land ratio, the PFP species composition, and the PFP age appears to be an important element of the LDN assessment of forest plantings in the arid zone.

CONCLUSIONS

A significant problem is observed on the arid lands of Russia: the degradation of PFPs and natural forests, including state forest belts and field-sheltering forest belts, throughout vast areas of arid lands in southern Russia. The degradation is primarily caused by a drastic reduction in the scope of forest-maintenance works performed by forestry authorities due to cutbacks in funding and changes in ownership rights to lands with field-sheltering forest belts.

The problem is in the worsening of the sanitary condition of such forest plantings, including their pollution by domestic and industrial waste; damage caused by fires, illegal felling, diseases, and pests; the development of sod formation processes in the soils; and the thinning and decay of the forest cover. Due to the scale of the problem, it is suggested that LDN tools be used to monitor ongoing changes in PFPs. Concurrently, it is necessary to supplement the set of global LDN indicators with a number of national parameters.

LDN assessment should take into consideration the location of forest plantings on state-owned and private lands with various management regimes. Currently, some 70% of forests on forest funds lands in the arid zone are of natural origin, while almost all forest plantings on agricultural lands are man-made and result from forest cultivation. Natural forests are more resistant to environmental factors, while artificial forests are significantly more susceptible to degradation in the absence of proper maintenance.

Analysis of the forest cultivation dynamics in arid conditions shows that the majority of protective forests were created in the 1950–1960s. In the last 30 years (up until 2018), a downward trend was observed in relation to the areas affected by protective forest cultivation. The situation started to improve only in the last year. Forest degradation has been registered as well: the sanitary condition of more than half of protective forest plantings is unsatisfactory; they have reached the maximum age and begun to decay. All of these data indicate a negative forest land degradation dynamics over the last 30 years; this trend affects a significant area of forest plantings in arid conditions.

The taxation (valuation) indicators of forest plantings, such as the timber deposit, forest-cover percentage, dynamics of damage inflicted to forests, and forest-cultivation dynamics, are optimal for the assessment of the LDN indicator “trends in land cover.” Such taxation indicators as gross growth (taking into account the mortality) are satisfactory characterized by the LDN indicator “trends in land productivity or functioning of the land.” The biological diversity level (e.g., the species richness of the tree and shrubbery vegetation, including field-sheltering belts) can be used as an additional indicator characterizing the land productivity on a gross scale. The wide use of remote-sensing data is advisable for LDN analysis.

FUNDING

This article is based on a study supported by the Russian Science Foundation, grant no. 18-17-00178 (Development of the Fundamental Land Degradation Neutrality Concept to Assess the Effectiveness of Sustainable Land Use and Adaptation to Climatic Changes). The collection and primary processing of archive materials were performed as a part of the State Assignment of the Institute of Geography, Russian Academy of Sciences, state registration no. 0127-2019-0010 (Development of Scientific Bases for Sustainable Management of Natural–Anthropogenic Systems on the Basis of Balanced Land Use Models).

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflicts of interest.

Statement on the welfare of animals. This article does not contain any studies involving animals performed by any of the authors.

REFERENCES

Chekanyshkin, A.S. and Lepekhin, A.A., Protective forestation in Central Chernozem region, *Lesn. Zh.*, 2015, no. 4, pp. 9–17.

Decision 7/COP.13: The future strategic framework of the Convention, The UNCCD 2018–2030 Strategic Framework. https://www.unccd.int/sites/default/files/relevant-links/2018-08/cop21add1_SF_EN.pdf. Accessed March 2, 2019.

Doklad o sostoyanii i ispol’zovanii lesov Rossiiskoi Federatsii za 2015 god (A Report on the State and Use of Forests of Russian Federation in 2015), Moscow: Rosleskhoz, 2015.

Entsiklopediya lesnogo khozyaistva (Encyclopedia of Forestry), in 2 vols., Moscow: Vseross. Nauchno-Issled. Inst. Lesovod. Mekh. Lesn. Khoz., 2006.

Federal target program “Conservation and recovery of soil fertility of agricultural lands and agrolandscapes as a national heritage of Russia in 2006–2010 and until 2030,” 2019. http://fcp.economy.gov.ru/cgi-bin/cis/fcp.cgi/Fcp/ViewFcp/View/2013/192/. Accessed March 7, 2019.

Filed protective forest belts became ineffective: An interview with head of Administration of Krasnodarles A.I. Funtikov, Russian Agrarian Portal, 2019. https://agroportal-ziz.ru/articles/polezashchitnye-lesnye-polosy-stali-neeffektivny. Accessed March 1, 2019.

Gauthier, S., Bernier, P., Kuuluvainen, T., Schvidenko, A.Z., and Schepaschenko, D.G., Boreal forest health and global change, *Science*, 2015, vol. 349, no. 6250, pp. 819–822.

Gosudarstvennyi lesnoi reestr 2013. Statisticheskii sbornik (State Forest Cadastre of 2013: Statistical Handbook), Moscow: Roslesinforg, 2014.

Kulik, K.N., Rulev, A.S., Zhdanov, Yu.M., Yuferev, V.G., Kretitnin, V.M., Isupov, B.A., Tubalov, A.A., Kosheleva, O.Yu., Dorokhina, Z.P., Koshelev, A.V., and Yuferev, M.V., *Adaptivno-landshaftnoe obustroistvo zemel’ sel’skokhozyaistvennogo naznacheniya lesostepnoi, stepnoi i polupustynnoi zon evropeskoi chasti Rossiiskoi Federatsii: monografiya* (Adaptive-Landscape Organization of Agricultural Lands in Forest-Steppe, Steppe, and Semidesert Zones of European Part of Russian Federation: Monograph), Volgograd, 2012.

Kust, G.S., Andreeva, O.V., and Lobkovskii, V.A., Neutral balance of land degradation as a new approach for decision making in the land use and land policy, *Probl. Postsov. Prostranstva*, 2018, no. 5 (4), pp. 369–389.

Lesnaya entsiklopediya (Forest Encyclopedia), Vovob’ev, G.I., Anuchin, N.A., Atrokhin, V.G., and Vinogradov, V.N., Eds., in 2 vols., Moscow: Sovetskaya Entsiklopediya, 1985.

Lesnoi kodeks Rossiiskoi Federatsii (Forest Code of Russian Federation), Moscow: Eksmo, 2017.

Martynyuk, A.A. and Erusalimskii, V.I., Input of the All-Russian Research Institute of Silviculture and Mechanization of Forestry into development of protective forestry, in *VNIILM—80 let nauchnykh issledovanii* (The All-Russian Research Institute of Silviculture and Mechanization of Forestry—80 Years of Scientific Studies), Pushkino: Vseross. Nauchno-Issled. Inst. Lesovod. Mekh. Lesn. Khoz., 2014, pp. 99–114.

Martynyuk, A.A. and Filipchuk, A.N., Dynamics of climate and forest: possible consequences and action plan, *Aktual'nye Napravleniya Nauchn. Issled. XXI Veka: Teor. Prakt.*, 2017, vol. 5, no. 1 (27), pp. 276–279.

Natsional'nyi Atlas Rossii. Tom 3. Naselenie i Ekonomika (National Atlas of Russia, Vol. 3: Population and Economy), Moscow: Roskartografiya, 2009. https://национальныйатлас.рф. Accessed March 20, 2019.

Natsional'nyi dokald "Global'nyi klimat i pochvennyi pokrov Rossii: otsenka riskov i ekologo-ekonomicheskikh posledstvii degradatsii zemel'. Adaptivnye sisitemy i tekhnologii ratsional'nogo prirodopol'zoavniya (sel'skoe i lesnoe khozyaistvo)" (National Report "Global Climate and Soil Cover of Russia: Assessment of Risks and Ecological-Economic Consequences of Land Degradation. Adaptive Systems and Technologies of Rational Nature Management in Agriculture and Forestry"), Bedritskii, A.I., Ed., Moscow: GEOS, 2018.

On approval of The rules of afforestation, the parts of the afforestation project, and the its development procedure, Order of the Ministry of Natural Resources of Russian Federation no. 700 of December 28, 2018. http://docs.cntd.ru/document/552196662. Accessed March 15, 2019.

Ptichnikov, A.V., Karelin, D.V., Kotlyakov, V.M., Pautov, Yu.A., Borovlev, A.Yu., Kuznetsova, D.A., Zamolodchikov, D.G., and Grabovsky, V.I., Indicators in estimation of land degradation neutrality for Russian boreal forests, *Dokl. Earth Sci.*, 2019, vol. 489, no. 1, pp. 1345–1347.

Pyatyi natsional'nyi doklad. Sokhranenie bioraznoobrazniya v Rossiiskoi Federatsii (Fifth National Report on Conservation of Biological Diversity in Russian Federation), Moscow: Inst. Geogr., Ross. Akad. Nauk, 2016.

Resolution of the Council of Ministers of the USSR and the Central Committee of the CPSU (b) of October 20, 1948 "On the planning of field protective forest belts, use of herbaceous crop rotations, pound and reservoir organization to maintain high and stable harvests in steppe and forest-steppe regions of European part of the USSR." https://ru.wikisource.org/wiki/Постановление_Совета_Министров_СССР_и_ЦК_ВКП(б)_от_20.10.1948_№_3960. Accessed March 9, 2019.

Sergeeva, M., Forest belts: current state and legal principles of functions and control in Adygeya Republic, *Ustoich. Lesopol'z.*, 2018, no. 4 (56), pp. 21–27.

Strategiya razvitiya zashchitnogo lesorazvedeniya v Rossiiskoi Federatsii na period do 2020 goda (The Strategy of Protective Forestation in Russian Federation until 2020), Kulik, K.N., Eds., Volgograd: Vseross. Nauchno-Issled. Inst. Agrolesomelior., 2008.

Web-Atlas "Environment and population health in Russia," 2019. http://www.sci.aha.ru/. Accessed March 9, 2019.

Zamolodchikov, D.G. and Kraev, G., Impact of climate change on Russian forests: registered consequences and forecasts, *Ustoich. Lesopol'z.*, 2016, no. 4 (48), pp. 23–32.

Translated by L. Emeliyanov