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DEGRADATION OF FORESTLAND IN LAND-USE/COVER PATTERNS OF RUSSIA

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Table of Contents

Key Words

Land Degradation, Land Quality Indicators, Forest Land, Land Use, Land Cover, Forest Soils, Sustainable Development

Abstract

By manifesting the response of land to human activity and impacts, degradation of forestland indicates the locations where society is in conflict with sustaining the forest environment. The analysis of land degradation in various land-use/cover patterns of Russia's vast forest zone (about 1050 million ha, or 63% of the country) clearly demonstrates two human-induced problems, inappropriate technology and improper management, causing land degradation on 9% of the territory. The study illustrates the high vulnerability of forest soils (in comparison to steppe grassland soils) after conversion to intensive cultivation. Thus, a balanced combination of forest and cropland has been found to be the most sustainable land use in the forest zone.

Acknowledgements

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Introduction

Russia's potentially forested territory, termed forest zone, covers about 1050 million ha or 63% of the country. The territorial structure of this huge area comprises an intricate mosaic of various land-uses and land-covers[1] (LU/LC pattern). Major features of the LU/LC patterns are driven by a combination of physiographic peculiarities of the territory, such as relief, vegetation, soils and a variety of land-uses occurring in the area, for instance, cultivation, wood cutting, settlements, etc. These interrelated elements affect the environment, and changes in one area may have positive or negative reactions in others. Applying various land-use systems and changing them in historical perspective, humans have actively shaped the forest environment, converting forest into agricultural land, transforming natural forest into managed ecosystems, etc. However, these activities do not always enrich natural forest potentials, to allow the increasing and changing human needs to be met in a better way. Very often, particularly in the long run perspective, its create problems occur in sustaining production or the environment, suggesting a reassessment of the benefits which had been initially achieved.

Land degradation [4,6] affects land quality and/or functioning, often indicating a negative reaction of land on inappropriate human activity. As a concept, land degradation was primarily developed for agricultural land, referring to the deterioration of land productivity. Expansion of this concept to forestland recognizes that forest play a multi-functional role, for instance, in land protection, hydrological and geochemical cycles, climate impact, etc. It means that productivity decline, which is the main the criterion for quantifying degradation of agricultural land, does not encompass all aspects of the negative consequences for forestland. It leads to the conclusion that the concept of land degradation has to be adapted to the

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[1] Land use refers to the purpose for which humans exploit the land and includes the characteristics of the biophysical environment and socio-economic conditions. Land cover refers to characteristics of the land surface, i.e. the external features of land use.

complex functions of the forest environment. This concept will be valuable for the assessment of technology and management systems which are applied in the forest sector. For example, industrial harvest by clear-cutting causes replacement of naturally self-maintaining forest by man-managed ecosystems. In some regions [1] due to this technology, vast territories have lost the potential for afforestation or planted forest can produce only low-quality wood instead of real forest vegetation. The investigation of the dynamics of this development [2] has concluded that in the next century broad-leaved and coniferous broad-leaved forest will practically be replaced by anthropogenic ecosystems. Due to this perspective, to maintain the ecological balances on this huge territory appropriate land-use regulations have to be implemented that protect the ecological functions of forest. The alarming fact is that currently nobody can predict what the cost of current forest practices to future generations will be.

Obviously, land degradation has most severely developed on the territories where current land use does not fit environment conditions. Thus it could be applied as an obligatory information to indicate "hot" spots where society has harmfully intruded on the forest environment. It is important to implement preventive measures against land degradation at an early stage in the regions to avoid irreversible damage. Furthermore, the analysis of degradation in the context of the negative effects of human impacts might be applied as a helpful tool to find a balance between human activities and nature, optimizing structure and functioning within LU/LC patterns. Some authors have stipulated that maintenance of the productive potential of land resources, and checking of land degradation, are fundamental elements of sustainable land use [7].

To investigate the LU/LC patterns a multi-sectoral analysis approach has to be used. One of the problems which make the task difficult to fulfill is the lack of a common information base. Traditionally, the inventory and analysis of the LU/LC patterns is carried out as separate compartments (cropland, forest, water, etc.) and by different institutions (agriculture, forestry, etc.). This approach creates a narrow and fragmental view of the territory for holistic understanding. The problem becomes much more complicated when taking into account the fact that various science disciplines and practices use different methods and terminology. Currently it seems that these problems can be partly overcome by applying geographical information systems (GIS) methods to allow the integration of different knowledge on the basis of spatial unity.

Objectives

The overall goal of the present study is to improve the understanding of the interaction between society and nature. The research uses data on degradation of forestland to indicate main human-induced damage to the forest environment occurring in the Russian forest zone. To achieve this task the following topics have been considered:

1. Overview of degradation of forestland within land-use/cover patterns of Russia;
2. Investigate major anthropogenic and natural driving forces causing negative developments in the forest zone of the country.

Materials and approach

The present study is based on a broad geographical analysis of a new digital georeferenced database on the land of Russia. The database has been created jointly by the United Nations Food and Agricultural Organization (Rome, Italy), the International Institute for Applied Systems Analysis (Laxenburg, Austria) and the Dokuchaev Soil Institute (Moscow, Russia). The database comprises of a set of spatially and temporally consistent digitized georeferenced coverages (relief, vegetation, soil including soil degradation attributes, land category, etc.) handled by GIS Arc/Info. An overlay of the coverages on land categories and soil (with soil degradation attributes) was used in the analysis.

The LU/LC patterns relevant to the research topic were distinguished by aggregation of the legend of the digitized Land Category Map [5]. The aggregation was aimed at differentiating type, degree/extent of human intervention for a number of broad land-use/cover categories. Soil and land degradation attributes [9] for the newly generated LU/LC pattern polygons were established by overlaying with the soil coverage.

Distribution of land degradation by land-cover pattern

Land degradation types, definition and causative factors are shown in the Table 1. Land degradation types can be grouped with regard to the distortion of major forest functions: forest protection function (water and wind erosion, terrain deformation, compaction); hydrological function (erosion, compaction, desertification, partly secondary salinisation and underfloods); local climate regulation function (desertification, surface corrosion, thermokarst); biodiversity and production function (disturbances of soil organic horizons due to wood cutting and fires). It is necessary to note, that this grouping is rather simplified because in reality most degradation types may affect several of the land functions. For instance, disturbances of the topsoil organic horizon may aggravate erosion and affect the hydrological function.

Analysis of human-induced factors (Table 1) causing increased of land degradation shows that they could be combined into two general groups. The first deals basically with inappropriate technologies in the harvest processes, type of machinery and wood transportation. The second deals mainly with improper management systems for forest protection against fires. In both cases land degradation gives a clear signal on the negative response of the forest environment to human intervention. Thus it can be concluded that degradation of forest could be used for detecting society-forest environment conflicts. This indicator can be applied as a powerful argument for recommendations to change land-use technologies, or improve management systems.

Degradation of forestland affects 92.7 million ha or 9% of the area of forest zone (Table 2). Consequently, 947 million of ha or 91% of the land of forest zone is still stable. The majority (92%) of forestland is stable because of protection by natural forest vegetation. 5% are stablized by planted forest and about 2% of stable land does not have vegetation (basically rock outcrops). These numbers manifest the very important fact that in more than 90% of the forest zone, the forest performs environmentally sound functions. Only 10% of the forest zone has been affected by different human activities. This share could be reduced by replacement of wood by other materials in construction, limitations on its use for fuel, etc. It should be mentioned that conventional assessments of forest resources are mainly concerned with the evaluation of the forest production function, i.e., accounting quantity and quality of timber or other forest products. This does not account for the ecological significance of forests and calls to re-evaluate the approach of the assessment of forest resources. Such an evaluation has to become more ecologically oriented.

The most widespread degradation (Table 2) of forestland is surface corrosion (35.7 million ha) dealing with processes of frost mounds, frost mudboils, earth hummocks, solifluction, etc. The vast extent of this disturbance in the north of the European part, north of West Siberia, north and central parts of East Siberia and North East is explained by huge territories having permafrost (about 65% of the country) in Russia. In these territories thermokarst (4 million ha) has also been found.

Forest fires are the second largest cause of land degradation (14.1 million ha). Fires are widespread in East Siberia and the Far East. About 95 % of forest fires are caused by human carelessness [3]. Thus territories with insufficiently well-organized protection measures have been affected by fire damage. Better managed forests in the European part of Russia are hardly affected by forest fires. However, these forests are affected by degradation caused by wood clear-cutting (10 million ha).

Forestland is very strongly affected by soil compaction (12.6 million ha) and water erosion (8.7 million ha). Very often these types of land degradation are closely linked. It is a well-known fact, when top soil layers are reduced by water erosion, that more compacted underlying soil horizons are exposed.

Several classes of the LU/LC patterns were distinguished in the forest zone of Russia. They differ by type and degree/extent of human intervention, and are categorized according to use (wood cutting, cropping, etc.). These uses have been linked (with broad interpretation) to existing technology and management systems. The degree of intervention combines two factors: the intensity of human intervention, varying from unused to cultivated forestland; and extent of human intervention in terms of the share (in percentage) of degraded land in a LU/LC pattern. The lowest degree of intervention has been set at less than 4% (minimum value) of degraded land within the LU/LC pattern. Intervention from 4% to 9% corresponds to medium degree of human intervention, and values above 9% (the average amount of degraded land in the forest zone) represents a high degree of human intervention.

The most virgin forest class is represented by unused (elfin) woodland. This LU/LC pattern is found in the pre-tundra vertical vegetation zone occurring mainly in the Siberian mountains, covering more than 82 million ha. Because of its inaccessibility and lack of human habitation, the territory is unused. This LU/LC pattern demonstrates very little land degradation other than for permafrost (surface corrosion, thermokarst) and forest fires. The degree of human intervention is low (4% extent of degraded land).

Forest-tundra and forest represent two classes of natural use. The forest-tundra LU/LC pattern extends as a narrow belt between tundra and forest vegetation zones in the European and Asian parts of Russia and covers some 22 million ha. It is often used as pasture for winter grazing of deer. In some places, minerals, gas and oil extraction have been developed. Forest-tundra has a very limited extent of degraded land (4%) linked with permafrost. Most damage is caused by inappropriate construction technology, moving of machinery and distortion of surface peaty soil horizons. Because it is sparsely populated and lacks infrastructure, the degree of human intervention is low.

The forest LU/LC pattern (of natural use) is complex and combines different categories of forest: protected (group I[2]), limited exploitable (group II), reserved forest (group III), sparse forest and open woodland (forest-steppe zone). This LU/LC pattern is widespread over the country and occupies about 489 million ha. Exploitation is extremely varied depending on ownership (agricultural, industrial, communal, etc.), management, responsible institutions, legal status, etc. It is important to draw attention to the fact that 40% of this LU/LC pattern, located in Siberia, does not have any protection against fires, diseases, insects, etc. Due to a variety of inappropriately regulated human activities, forests of natural use suffer from various land degradation types. However, more than 80% of degraded land (9% in the pattern) are caused by two degradation types, namely surface corrosion and wood fires. The degree of human intervention is estimated as medium.

The class of exploitable forest comprises of matured forest located across the country with concentration in the European North, southern parts of the East Siberia and the Far East. It occupies about 404 million ha. Many different harvesting technologies are applied depending on forest peculiarities (structure, biological characteristics of the main tree species, age structure, canopy, etc.) and environment conditions (sloping, relief, etc.). Nevertheless, wood harvest is the main cause of land degradation. For instance, due to insufficient roads, industrial cutting in Siberia can only be performed in winter, when the topsoil organic horizons are frozen. Because of this, clear-cutting does not disturb the topsoil organic horizons. Physiographic conditions and the better developed infrastructure in the European part of Russia allows year-round industrial harvesting. These territories are very extensively

[2] according to Government system of forest account

affected by land degradation (more than 40% from total degraded) caused by wood cutting. Simultaneously, clear cuttings aggravate water erosion, desertification, etc., which have been found in this LU/LC pattern. The degree of human intervention is estimated as medium (6% of extent of degraded land within the LU/LC pattern).

The LU/LC pattern cropland in combination with forest occupies a small part of the middle taiga zone (about 1%) and partly south taiga zone with complicated physiographical condition (intersected relief, flat relief with numerous lakes, swamps, etc.). It is located in the European part of the country, southern parts of Siberia and the Far East and occupies about 31 million ha. In the places with intersected relief and excessively drained conditions, the cropland is localized on the flat interfluves with low erosion potential. The LU/LC pattern is characterized by a variety of activities, however, land-use impacts are very restricted because of environment conditions and land degradation is low (4%). Mainly three degradation types occur: water erosion (25% of degraded land), desertification (25% of degraded land), and disturbances caused by forest fires. It is important to emphasize, that the combination of forest with cultivated fields seems to be the most favorable condition monitored in land degradation in the forest zone. The degree of human intervention is close to low.

The last class distinguished is cropland which has replaced forest. This LU/LC pattern occupies about 15% (near 19 million ha) of the south taiga zone of the European part of Russia and the southern parts of Siberia and the Far East. Physiography is characterized by plain relief with flat or gently sloping conditions. Cultivation is rather intensive because of relatively dense population which causes a high degree of land degradation (94% of LU/LC pattern). This LU/LC pattern suffers from two main types of land degradation - compaction (about 70%) and water erosion (about 30%). The degree of human intervention is high.

Development of compaction and erosion depending on origin of soils

Observation of the distribution of land degradation by LU/LC patterns occurring in the forest zone of Russia clearly indicates that the degradation of forestland highly depends on types and degree of human intervention. Two major societal causes aggravating negative developments have been found: inappropriate technology and improper management. It has been recognized that the major features of spatial distribution of the LU/LC patterns are driven by geographical factors: climate, relief, soils, permafrost, etc. However, the extent of soil degradation does not completely follow the type and degree of human intervention. It leads to the conclusion that the environment specific to the forest zone has also influenced and controlled these negative developments. To understand the effect of natural factors in degradation of forestland, soil vulnerability to water erosion and compaction has to be analyzed.

As mentioned above, water erosion and soil compaction are closely linked. For instance compaction may be aggravated by erosion by reducing topsoil and exposing more compacted subsoil. On the other hand, compaction prevents water infiltration resulting in accelerated run-off. The scale of water erosion can be attributed firstly to a humid climate, where water erosion causing soil detachment and transport, is very high. Secondly, traditionally cultivated land in the forest zone occupies externally drained slopes. Flat interfluves are covered by swamps and bogs and unsuitable for cultivation. Slope cultivation requires land protection measures which obviously can decrease erosion to some extent but very seldom prevents it completely. Thus, the development of compaction and water erosion in the forest zone are strongly pre-conditioned by physiographic and geographic features.

The nature of forest soils is another important factor influencing erodibility. Soil erodibility is the integrated effect of processes that relate to the resistance of the soil to particle detachment by rainfall and subsequent transport. Figure 1 shows the extent of water erosion and compaction on the cultivated soils formed under forest and steppe vegetation. As can be seen, 61 % of cultivated soils (cropland) which formed under forest are affected by compaction, and 27% of the soil is influenced by water erosion. Cultivated soils developed under steppe grassland contain only 30% of compacted and 7% water eroded soils, i.e., they are only half and one-fourth affected compared to soils originating from forest. These figures completely correspond to differences in erodibility of major arable soils of Russia (Fig. 2). As can be seen, Podzoluvisols, which primarily formed under forest vegetation, manifest erodibility at the levels between 3 and 3.5 t/ha for medium textured soils and from 2 to 2.5 t/ha for fine textured soils. Chernozems, originally developed under steppe vegetation, are characterized by erodibility from 1.5 to 2 t/ha (medium textured soil) and 1 to 1.5 t/ha (fine textured soil). These values are about half compared with Podzoluvisols. Greyzems, formed in a forest-steppe environment and having mixed features of forest and steppe soils, demonstrate a medium level of erodibility. Consequently, the erodibility of medium textured Greyzems varies from 2.5 to 3 t/ha, and of fine textured from 1.5 to 2 t/ha. We conclude that the greater extent of water erosion and compaction of the cultivated soils primarily formed under forest compared to soils developed under steppe vegetation can be explained by differences in their nature. A more detailed explanation of the mechanisms causing this difference can be found from soil physics and chemistry.

It is well known that soil erodibility highly depends on soil characteristics such as particle size distribution, structural stability, organic matter content, nature of clay minerals, and chemical constituents, which determine water stable structure [8]. Water-stable macro-aggregates (>0.25 mm) are formed by processes of adhesion of micro-aggregates (<0.25 mm) and mineral particles when the soil has a high humus content, humic acids prevailing in the soil organic composition, saturation of exchange complex by calcium, etc. Forest soils have low humus content, dominant fulvic acids in soil organic composition, and unsaturated exchange complex by calcium. To improve these conditions, usually large amounts of organic fertilizers, liming, etc. have to be applied. Macro-aggregates in forest soils are formed during the winter season. When freezing, mineral soil particles and micro-aggregates are compacted by growing ice crystals. However, the adhesion of macro-aggregates is provided by water films and becomes unstable when additional water is supplied. During water logging in the spring season, the macro-aggregates are detached and the soil mass becomes dispersed. This leads to a decreasing infiltration rate, an increase in both runoff and water erosion.

Figure 3 illustrates the composition of water-stable aggregates in forest loamy Podzoluvisols and steppe loamy Chernozems. The diagram shows that Chernozems have much more water-stable macro-aggregates as compared with Podzoluvisols. It is important to note that the amount of micro-aggregates is more than 5 times in Podzoluvisols as compared with Chernozems. Figure 4 shows the dependence of the infiltration rate on the composition of micro-aggregates (silt fraction) and aggregates in soils. As can be seen, the infiltration rate in Chernozems containing less than 10% silt particles can be expected at the level of 60 mm/hour. The infiltration rate of Podzoluvisols containing 50% of silt particles is estimated to be 0.6 mm/hour i.e., 100 times less. Thus it is absolutely clear that soil erodibility of forest soils will be much more than for soils formed under steppe grassland.

Conclusions

It is estimated that:

- 93 million ha (about 9%) of the land of Russia's forest zone is affected by various types of degradation. More than 90% of the forest zone is still stable and performing a very important environmental role. Beyond purely economic factors, more attention to the ecological functions of forests is required when assessing the forest resources.
- Land degradation data manifest such geographically explicit data sets the negative impacts of human-induced activities on land. They allow to delineate areas, detect

causes and understand mechanisms of society-forest environment conflicts. The information can help to establish suitable and functional land-use structures in various LU/LC patterns.

- Inappropriate technology and improper management are major societal causes of land degradation of the Russian forest zone. Improvements in both aspects could contribute considerably to sustaining development of the forest zone.
- Natural factors (climate, relief, soils, permafrost, etc.) are the main driving regularities of the spatial distribution of the LU/LC patterns within the forest zone, providing differentiation by types and degree of human intervention across the country. Due to low organic content, prevalence of fulvic acids in humus composition, an exchange complex unsaturated by calcium, etc., forest soils are vulnerable to intensive agricultural use. Lacking a water-stable structure, they are strangely affected by compaction and water erosion. This negative inspect of cultivation on forestland could be partly avoided by maintaining forests within cropping areas.

References

1. Efremov, D. F., 1997: Green desertification, Proc. of the IBFRA conference, Duluth USA (in publication).
2. Isakov Y.A., H.S. Kazanskay, A.A. Tishkov, 1986: Zonal regularities of ecosystems dynamics. Moscow, Nauka, 150 p.
3. Land of Russia - 1995, Problems, Figures, Commentaries, 1996: Moscow, 79p.
4. Lynden G.W.J. van (Ed.), 1995: Guidelines for the Assessment of the Status of Human-Induced Soil Degradation in South and Southeast Asia (ASSOD), ISRIC, Wageningen, 20 p.
5. Map of Land Categories of USSR. Scale 1:4M. 1989: Compiled by: L.F. Yanvareva (editor-in chief), K.N. Martynyuk, N.M. Kiseleva. GURK, Moscow.

6. Oldeman, L.R., R.T.A. Hakkeling and W.G. Sombroek, 1991: World Map of the Status of Human-Induced Soil Degradation. An Explanatory Note, second revised version. Global Assessment of Soil Degradation, 27p.
7. Pieri, C., J. Dumanski, A. Hamblin, and A. Young, 1995: Land Quality Indicators. World Bank Discussion Paper, 315, p. 63.
8. Revut, I.B., 1972: Soil physics, Leningrad, Kolos, 368 p.
9. Stolbovoi, V., G. Fischer, 1996: Georeferenced Soil Degradation Database for Russia, Proc. of 9th Conference of the International Soil Conservation Organization (ISCO), Bonn, Germany 26-30 August 1996, p. 235.

Table 1. Land degradation types, definition and causative interpretation

Type of degradation	Definition	Causes
Water erosion	Loss of topsoil by sheet erosion	Inappropriate technology causes unobstructed flow of run-off water, weak soil structure
Water & wind erosion	Combined action of water and wind depending on seasons humidity	Inappropriate technology causes ineffective seasonal protection against water and wind action
Wind erosion	Loss of topsoil by wind action	Inappropriate technology causes insufficient soil protection by vegetation
Terrain deformation	Development of gully or rill erosion or mass movements	The same
Compaction	Deterioration of soil structure by trampling	Inappropriate technology, repeated use of heavy machinery, overgrazing and overstocking.
Underfloods	Human-induced hydromorphism	Inappropriate technology causes rising watertable, increased flooding
Secondary salinization	Increase of the salt content of the topsoil	Inappropriate technology causes improper irrigation
Desertification	Decrease of average soil moisture content	Inappropriate technology causes changes in the local hydrology
Disturbances due to wood cuttings	Distortion of the topsoil organic horizons	Inappropriate technology, clear cutting, skidding, etc.
Disturbances due to fires	Distortion of the topsoil organic horizons	Inappropriate management, insufficient forest protection
Surface corrosion	Solifluction, landslides	Inappropriate technology causes distortion of the thermoisolating topsoil
Thermokarst	Development of thermokarst caves very often filled with water	Inappropriate technology causes distortion of thermobalance of subsurface permafrost

Table 2. Types and extent of degraded and stable land in land-use/cover patterns of forest zone (FZ) of Russia.

Land use/cover (LU/LC)	Forestland converted to cropland				Timber cutting (groups III & II)		Use of natural				Unused (Elfin) woodland		Total D&S	
Types of	Totally		Partly				Forest		Forest-tundra					
Degradation (D), stabilization (S)	Million ha	% of LU/LC	Million ha	% of LU/LC	Million ha	% of LU/LC	Million ha	% of LU/LC	Million ha	% of LU/LC	Million ha	% of LU/LC	Million ha	%
Water erosion	5.3	30	0.3	25	2.0	8	1.1	2	0.0	0	0.0	0	8.7	9
Water and wind erosion	0.2	1	0.1	8	0.4	1	0.4	1	0.0	0	0.0	0	1.1	1
Wind erosion	0		0.1	8	0.3	1	0.2	0	0.0	0	0.0	0	0.6	1
Terrain deformation	0		0.0	0	0.1	0	0.2	0	0.0	0	0.0	0	0.3	0
Compaction	12.3	69	0.0	0	0.2	1	0.1	0	0.0	0	0.0	0	12.6	14
Desertification	0		0.3	25	1.5	6	2.1	5	0.0	0	0.0	0	3.9	4
Secondary salinisation	0		0.1	8	0.1	0	0.7	2	0.0	0	0.0	0	0.9	1
Disturbances due to cuttings	0		0.0	0	10.0	41	0.0	0	0.0	0	0.0	0	10	11
Underfloods	0		0.0	0	0.1	0	0.6	1	0.0	0	0.0	0	0.8	1
Disturbancies due to fires	0		0.3	25	4.0	16	9.3	21	0.0	0	0.5	16	14.1	15
Surface corrosion	0		0.0	0	4.7	19	28.2	62	0.6	75	2.2	69	35.7	39
Thermocarst	0		0.0	0	1.0	4	2.3	5	0.2	25	0.5	16	4	4
Total D and % of the LU/LC	17.8	94	1.2	4	24.3	6	45.2	9	0.8	4	3.2	4	92.7	9
Artificially stable	not cal-culated		7.7	25	26	7	16.9	3	0	0	0.1	0	≅50	5
Stable by vegetation	not cal-culated		22.4	75	345	90	414.6	96	19.6	94	74.5	95	≅876	92
Stable unvegetated	not cal-culated		0	0	13	3	4.8	1	1.2	6	3.5	5	≅22	2
Total S and % of the LU/LC	not cal-culated	≅6	30.1	≅96	383.4	≅94	436.4	≅91	20.7	≅96	78.1	≅96	≅947	≅91
Total LU/LC and % of the FZ	18.9	2	31.3	3	403.8	38	489.1	47	22.4	2	82.4	8	1049.6	

Figure 1. Soil compaction and erosion in soils of forest and grassland origin.

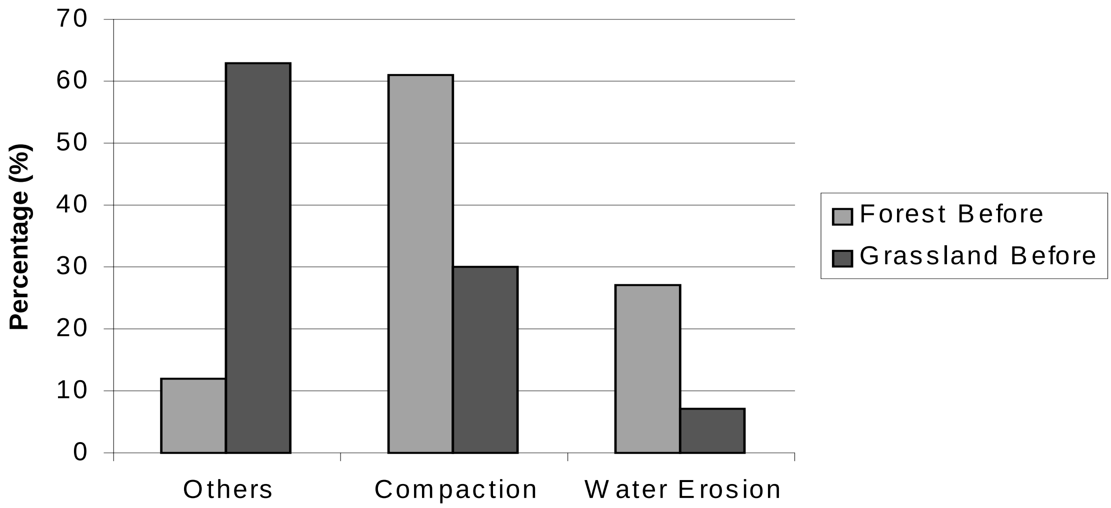

Figure 2. Erodibility (t/ha) of some medium and fine textured soils of Russia. *[based on 8]*

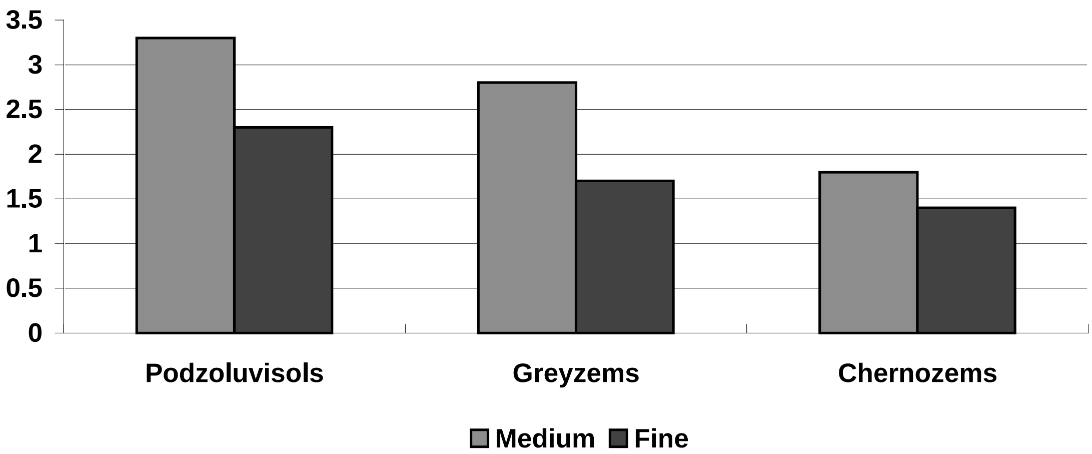

Figure 3. Water stable aggregates composition *[based on 8]*

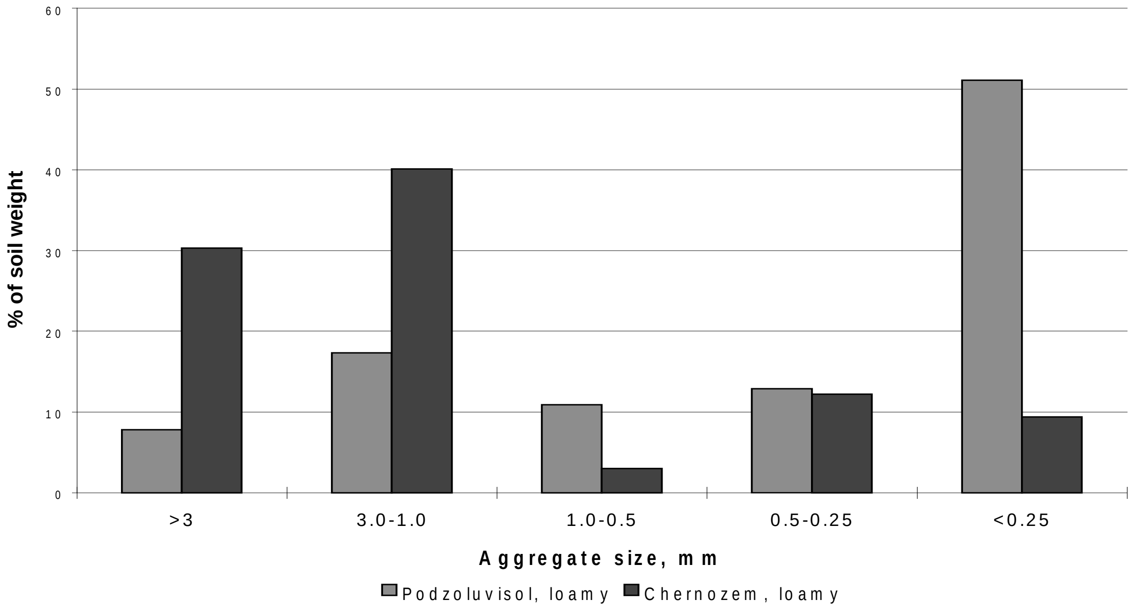

Figure 4. Dependence of infiltration rate upon composition of microaggregates and aggregates in soils *[based on 8]*