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Soils of Russia: Correlated with the Revised Legend of the FAO Soil Map of the World and World Reference Base for Soil Resources

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Contents

Abstract

The *Soil Map of the Russian Soviet Federative Socialist Republic* (*SMR*; Fridlund, 1988) at scale 1:2.5 M was compiled through the joint efforts of many pedologists around the country. Practically all scientific pedological centers and institutes in Russia contributed to the map their expertise and scientific knowledge accumulated during more than two decades. The map legend comprises the latest soil-genetic classification concepts in which soil characteristics have been considered together with soil forming factors. The soil-geographical background of the map introduces a variety of geographical regularities of soil spatial distributions among which the soil zonality and the soil cover structure have been comprehensively represented.

Although the *SMR* is regarded as the major inventory document at the country scale, it is not widely known. The complexity of the legend and specific soil nomenclature have been the main factors confounding implementation of the map.

To make the *SMR* accessible, the correlation with the *Soil Map of the World* (*SMW*; FAO, 1988) and the *World Reference Base for Soil Resources* (*WRB*; FAO, 1998) was made as transparent as possible.

Preface

This research resulted from several discussions with Drs. W.G. Sombroek and R. Brinkman of the Food and Agriculture Organization (FAO) of the United Nations, and Dr. R. Oldeman of the International Soil Reference Information Center (ISRIC), that took place at ISRIC in 1988–1989. The discussions were initiated through research being carried out by the project on Global Assessment of Human-Induced Soil Degradation, which urgently required reliable soil information on the territory of Russia. It was recognized that many other environment-related activities were facing a similar problem.

The author, as coordinator of the USSR–Mongolian part, and Dr. E.N. Rudneva, as a collaborator on the compilation of the soil background, worked out the first version of the soil correlation based on the generalized version of the list of soils compiled for the scale 1:15 M for this region. However, neither the legend of the *SMR* nor the map itself was used for that first version. So the question of compiling, fully correlating, and updating the *SMW* for this region was raised again.

In 1993, FAO funded the updating of the soil information based on the procedure manual of the *Global and National Soils and Terrain Digital Database* (*SOTER*; ISRIC, 1993) and *SMR*. This task was successfully fulfilled and the results were transferred to FAO for digitizing. However, the compilation of a digital database could not be completed at that time.

In 1995, all materials were passed to the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, with the aim of finalizing this work in the form of a digital database. Considerable efforts by the Geographic Information System (GIS) group of the project Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia (LUC) at IIASA were put into checking, correcting, and linking the digital data, and making it consistent.

This report presents an important part of this effort that deals with soil correlation. After completion of a draft report by the author, the manuscript was carefully reviewed and edited by Mr. Maurice Purnell, a soil scientist working for FAO.

Acknowledgments

This work could not have been compiled in its present form without the strong support of the Food and Agriculture Organization (FAO) of the United Nations, which initiated and sponsored the updating of the soil information for Russia as part of the *SMW* (1974–1981). FAO also provided funding and technical competence to facilitate highly professional editorial work.

I am very much indebted to Mr. Maurice Purnell, whose expertise as editor of this report, as fellow soil scientist, and as consultant for FAO, has ensured the very high standards of this publication.

Many thanks are extended to Drs. W.G. Sombroek, R. Brinkman, and F.O. Nachtergaele from the Land and Water Development Division (AGLS) of FAO, Rome, and to Dr. R. Oldeman of ISRIC, Wageningen, Netherlands, for their support and consultation during the production of this work.

I am especially grateful to Dr. B.V. Sheremet for his cooperation in providing the improved version of soil correlation.

The author would also like to thank Dr. Günther Fischer, Leader of LUC Project (IIASA), for his helpful comments and suggestions, and Cynthia Enzlberger of IIASA for her help in reviewing and polishing earlier drafts, as well as preparing the final version of this report.

Finally, I am grateful to Forestry project leader Dr. Sten Nilsson and colleagues for their advice and improvements to this report.

About the Author

Vladimir Stolbovoi is a doctor in soil geography. He has intensive experience in both academic and applied soil classification, mapping, and interpretation. He has gained extensive experience through field research in European Russia, Siberia, Central Asia, Syria, Cuba, and the Seychelles. He was coauthor of the *Global Assessment of Soil Degradation* (GLASOD; ISRIC/UNEP, 1990) for the Former Soviet Union and Mongolia, led an updating of the *SMW* for the USSR and Mongolia, and coordinated research of the Fomer Soviet Union's European Republics within the project Assessment of Soil Degradation in Central and Eastern Europe (SOVEUR). Since January 2000, Dr. Stolbovoi has been carrying out development of the European Geographic Soil Information System on Russia and countries of the European New Independent States (NIS). He is author of more than 100 publications.

Vladimir Stolbovoi joined IIASA's LUC Project in 1995 to develop a comprehensive digital georeferenced database on the land of Russia. Since 1998, he has been working with IIASA's Forest Resources Project, where he has contributed to the analysis of forest land, land use, full carbon account, and elaboration of the integrated land information system for Russia.

About the Editor

In 1976, Mr. Maurice F. Purnell took up the position of Senior Officer for Soil Resources at FAO's headquarters in Rome after a long career as a soil surveyor and project manager in FAO field projects in Ghana, Brazil, Burundi, Myanmar, and Sudan.

He was particularly active in developing FAO's revised legend of the *SMW*, *Land Evaluation Procedures*, *Guidelines for Soil Profile Description*, and *Guidelines for Land Use Planning*.

Since his retirement in 1992, Mr. Purnell has remained actively involved in FAO as a freelance consultant and editor of various soil-related publications.

About FAO

FAO has been collaborating with IIASA, ISRIC, United Nations Environmental Program (UNEP), and other international organizations and national institutes with the objective of updating the *SMW* according to the principles developed in *SOTER*. These regional soil and terrain datasets will provide up-to-date information on physical and environmental conditions worldwide.

The *SOTER* for Northeast Africa was published in 1999, and the *SOTER* for South America and the Caribbean is due for release shortly. *Soils of Russia* describes the work undertaken in a larger context of building up revised soil and terrain databases for the former Soviet Union, China, and Mongolia. It fits well with more detailed work presently undertaken by FAO and ISRIC in collaboration with national soil institutes in Eastern Europe, as well as with efforts of the European Soils Bureau in the same region.

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Glossary

A2 horizon: Equivalent to the FAO E horizon.

Accumulative: Refers to soil horizons where soil-forming processes lead to accumulation of substances (clay, sesquioxides, organic matter, carbonates) both by movement (illuvial) or by neoformation *in situ*.

Automorphic: Soils clearly manifesting climate influence with normal atmospheric moistening; formed from loams on the uplands.

Autonomous relief positions: Soils formed on the uplands that are geochemically independent.

CEC: Cation exchange capacity.

Cha:Cfa ratio: Ratio between humic and fulvic acids in the organic matter.

cmol(+) kg-1: SI unit equivalent to milliequivalents per 100 g of soil.

Curdled, curd-like: Irregular, platy soil structure caused by freezing.

Differentiated: Indicates that the soil profile horizons vary as a result of soil formation (in clay content, sesquioxides, structure, etc).

Facial subtypes of soils: Refers to specific features of the soil hydrothermic regime caused by climate differences within one soil zone in continentality (latitude) or temperature (altitude).

Far East: Traditional geographic name (not an administrative unit) for the huge territory in the eastern part of the country from the Chukotka peninsula to Khabarovsk and Vladivostok.

Iced permafrost: As distinct from dry permafrost.

Meadow: As part of a soil name, term indicates a hydromorphic soil water regime in the forest-steppe and steppe zones. "Meadow" implies groundwater at less than 3 m deep, and "meadowish" implies groundwater at more than 3 m. Contact-meadow soils have perched water above the contact between two different textures.

Podbur: Soils having a spodic B horizon and lacking an albic E horizon. Some features of heluviation of iron oxides and bleaching might be observed in topsoil.

Podzolized: In the original sense, term means bleached by leaching of the iron and aluminium sesquioxides and organic matter, without necessarily any accumulation of the organic matter or the iron and aluminium in a spodic horizon, although rusty stains and thin bands are common. (FAO Podzols must have a spodic horizon.)

R_2O_3: Sesquioxides of iron and aluminium.

Residual calcareous: Carbonates remaining from the parent material or rocks after leaching.

Retinization: Gelic soils with a second humus horizon formed above a permafrost layer; the second horizon has humic acids whereas the topsoil has mainly fulvic acids.

Spot soils: Gelic soils without any clearly distinguished pedogenetic horizons; a component of cryogenic complexes (patterned cover) occurring in the center of the polygons.

Acronyms

FAO	Food and Agriculture Organization of the United Nations
GLASOD	*Global Assessment of Soil Degradation* (ISRIC/UNEP, 1990)
GUGK	Central Administration of Geodesy and Cartography
IIASA	International Institute for Applied Systems Analysis
LUC	Modeling Land-Use and Land-Cover Changes in Europe and Northern Asia project
SMR	*Soil Map of the Russian Soviet Federative Socialist Republic* (Fridlund, 1988)
SMW	*Soil Map of the World* (FAO/UNESCO, 1971–1981)
SMW legend	The revised legend of the *Soil Map of the World* (unless otherwise stated)
WRB	*World Reference Base for Soil Resources (FAO, 1998)*
SOTER	*Global and National Soils and Terrain Digital Database* (ISRIC, 1993)
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VASHNIL	All-Union Academy of Agricultural Sciences

1
Introduction

1.1 The *Soil Map of the World for Russia*

The *Soil Map of the World* at scale 1:5 M (FAO/UNESCO, 1974) is one of the most important documents aimed at standardizing soil information for communication between scientists and practical specialists in different countries. The legend of this map is regarded as a general scientifically based language for such communication and exchange of experience. It forms a bridge between different national pedological schools using various traditions and methods.

The *Soil Map of the World* (hereafter, *SMW*) is based on a very broad international consensus, which fixed the state of knowledge of soil distribution at a given historical time. This map was compiled in 1971–1981, and, during the intervening years, great progress has been achieved in various branches of soil science and in the methods used. For example, tremendous efforts to improve soil diagnostic practice and soil classification resulted in a revised legend of the *SMW* (FAO, 1988).

Parallel to the *SMW* legend development, great efforts have been introduced during the last two decades aimed at approaching an international agreement on the major soil groups to be recognized at a global scale, as well as on the criteria and methodology to be applied for defining and identifying them. The intention was to facilitate the exchange of information and experience, to provide a common scientific language, to strengthen the applications of soil science, and to enhance communication with other disciplines. This work has resulted in the *World Reference Base for Soil Resources* (hereafter, *WRB*; FAO, 1998), which has been adopted by the XV Congress of the International Union of Soil Science (IUSS) at Monpellier, France, in 1998. The *Soils of Russia* provides correlation with the document, and assumes that the *WRB* will be widely used in the future.

There is no direct information about what sources were used in the USSR to compile the original *SMW* in the 1970s. It might be assumed that it was a composition of several sources; for instance, the soil maps compiled by N.N. Rozov

(1964) and V.A. Kovda and E.V. Lobova (1975). However, there are several opinions concerning these materials. First, the maps were based on the authors' soil classifications, which were not officially accepted. The first national soil classification of the USSR was published only in 1977 (Kolos), and, therefore, could not have been used. The earliest material, *Guidelines to Soil Classification and Diagnostics* (Kolos, 1967), appeared after publication of Rozonov's map in 1964. The analysis of the second map (Kovda and Lobova, 1975) shows that soil classification and nomenclature is quite original and did not follow the Russian traditional school. Secondly, the maps were compiled by a very limited group of scientists, and, therefore, many of the local sources of soil data have not been involved.

At the national level, before the collapse of the USSR in 1992, the development of pedology in Russia was characterized by intensive accumulation of empirical soil-mapping knowledge and clarification of fundamental issues (genesis, diagnostics, classification, cartography, etc.).

At present, a great amount of new materials are being collected that significantly change conceptions of soils diversity and soil geography of the country. Vast amounts of new soil data have been obtained for northern Eurasia, including Siberia and the Far East. For the forested territories, complete soil maps were compiled at scale 1:100,000. For agricultural regions, soil maps were produced at scale 1:10,000 and 1:25,000. These maps were used for compilation of the district maps at scale 1:300,000 and applied to the *State Soil Map* at scale 1:1 M. Finally, all current knowledge on the soil environment of the country was scientifically summarized in one product: the *Soil Map of the Russian Soviet Federative Socialist Republic* at scale 1:2.5 M (hereafter, [*SMR*]; Fridland, 1988).

All recent developments at the national and international levels are applied to the present process of updating the *SMW*. For the Russian territory, the updating is based on two documents: the *SMR* (Fridland, 1988) and the program of the *Soil Map of the USSR* at scale 1:2.5 M (hereafter, *SMR* program; Fridland, 1972a). However, neither of these documents is widely known or accessible inside or outside the country. This fact has necessitated a fuller treatment of certain aspects of the description of the map legend.

The study relies on two basic documents: the revised legend of the *SMW* (FAO, 1988) and the *SMR* program at scale 1:2.5 M (Fridland, 1972a). In addition to the correlation mentioned above, the study provides synonyms to the classifications used in the *WRB* (FAO, 1998), which may be widely used in the near future.

This report has been planned as an explanatory text to the Digital Soil Database for Russia at scale 1:5 M, which was published by FAO as a CD-ROM (FAO, 1999). It is structured and written in the form of a reference book, and is aimed at assisting specialists dealing with soils, environment, and land resources analysis of Russia. I believe that the report contributes to a better understanding of Russia's natural environment, of which many specific features are still unknown.

2 Objectives

The central aim of this report is to give a clear description of the correlation between the soils of the *SMW* legend and the *SMR* legend. The report provides an account of the following themes and includes tables showing the results:

- An introduction to the *SMR* legend.
- Procedures adopted for correlation between the *SMR* and the *SMW* legends.
- Correlation of the *SMR* and *SMW* legends.

3

The *Soil Map of the Russian Soviet Federative Socialist Republic (SMR)*

3.1 Definition of Soil Horizons

The soil classification used for the *SMR* is based partly on soil horizons identified in the field and laboratory; these soil horizons are therefore listed below together with their definitions and symbols. These horizon notations are necessary for the understanding of the correlation between the *SMR* and *SMW* in Section 7. They are not shown on the map or in the legend.

Traditionally, the identification of soils has dealt with their horizons and profile definition. Despite the fact that many Russian documents have been produced that attempt to standardize soil descriptions (including translations), and despite the fact that in some investigations the FAO system has been implemented, no universally accepted system has been officially established. This can be largely explained by the tremendous extent of the country, great variety of geographical features, huge number of soil classes, and the division of soil surveys among different organizations, such as agriculture, irrigation, forest survey, etc., all of which have their own priorities and preferences.

The first attempt to combine all existing knowledge on soil diagnostics was made in the framework of the *SMR* program. The advantage of this system is that it deals with all the soils of Russia in one standard way. The definition of the soil horizons that have been developed as diagnostics for the soils in the *SMR* is presented below.

The *SMR* program assumed that genetically different soil types have specific combinations of genetic horizons. In principle, a soil profile would have a few main horizons that determine the soil genetic type. The following main horizons are distinguished in the *SMR* program:

O organic horizons. By volume, they contain more than 70% of organic matter with different rates of decomposition. Any minerals present are mostly a mechanical admixture. The horizons are usually at the soil surface or, if buried, anywhere within the soil profile. These horizons may form the entire soil profile (in the case of peat soils). Organic horizons are subdivided as follows:

- **O1** horizons formed mainly of well-preserved or slightly decomposed plant remains, which retain the main features of their initial composition.
- **O2** horizons formed mainly of moderately decomposed plant residues, partially retaining their initial features (such as portions of plant fabric).
- **O3** horizons formed by well-decomposed plant residues that have completely lost their initial features.

AO the upper organo-mineral horizons containing considerable quantities (30-70% by volume) of organic matter at different stages of decomposition. They usually have a mechanical mixture of organic and mineral material, which, however, could be easily separated.

A1 the upper mineral horizons, which are usually the most dark-colored within the soil profile. They contain well-humified organic material, which is formed in situ and closely linked to the mineral phase.

A2 usually underlying horizons O, AO, or A1, but in heterogeneous profiles may occur under any horizon of the overlying profile. They are the most bleached and colorless horizons in the soil profile, and do not have the gleying characteristic of the G horizon.

B mineral horizons, underlying horizons AO, A1, or A2 (or O horizon if the above-mentioned are lacking). They are identified by any differences of color, structure, or texture in comparison with the overlying horizon A and underlining horizons G and C.

G mineral gley horizons that reveal uniform or alternating bright blue, blue-grey, green, or rusty colors throughout the dominant part (not less than 70%) of the freshly cut surface. They include:

- **G1** gley horizons with uniform or alternating bright blue and dark blue colors;
- **G2** gley horizons mottled with blue, grey-blue, and rusty tints;
- **G3** mineral horizons, that have olive, green, or greyish-green colors.

C parent material, mostly unchanged by soil formation.

D underlying rock, different from the soil parent material, underlies the soil profile, and has no features caused by soil forming processes.

S horizons, cemented in both moist and dry conditions, may form an impermeable layer and resist sheet erosion. They are formed by the concentration of various chemical compounds (oxides of iron, silica, carbonates of calcium and magnesium, salts, etc.) cementing the soil mass.

K fragile, porous crusts, not more than 5 cm thick, forming the surface of the profile.

Any of the main horizons (O1, O2, A1, A2, B, G1, S, etc.) may be further subdivided into subhorizons according to differences in the specific characteristics within the given horizon. In this case, the horizon code bears an additional subscript Arabic figure ($O1_1$, $O2_2$, $A2_1$, $A2_2$, etc.).

The transitional horizons that show properties of both the overlying and underlying horizons are labeled with codes referring to both of them. The code index for the dominant horizon comes first (for example A2B1, or B1A2).

The transitional horizons in which the features of overlying and underlying horizons are expressed equally, are marked with indexes of both horizons separated by a slash (A2/B1, A1/B1).

Buried soil horizons are shown in square brackets [A1].

Frozen, impermeable, or ice-cemented soil horizons found at the time of soil profile description are labeled with the code for the main horizon accompanied by a special sign ($\perp$).

Horizons that have temperatures below freezing at the time of description but are not impermeable are marked with the main horizon code plus the prefix of a down arrow ($\downarrow$).

Characteristics of the main horizons, such as soluble salts, carbonates, morphologically expressed solonetz features, etc., are shown with lowercase Latin letters located to the right of the main code. As shown below, the lowercase letters indicate features (characteristics) of genetic soil horizons (with examples of their application given in parentheses):

- ca (Bca, Aca, Cca) - carbonates of calcium or magnesium;
- pca (Bpca, Apca) - calcareous gravel among noncalcareous matrix;
- cs (Bcs) - visible gypsum formations;
- s (Bs) - visible features of soluble salts;
- fe (A1fe, Cfe) - ferralitic composition of the mineral mass (lower than 5% content of primary minerals, except for the most resistant ones, such as quartz, rutile, etc.); the clay fraction is dominated by kaolinite, halloysite, iron, and aluminium oxides;
- fa (A1fa, Bfa) - ferralitized composition of the mineral mixture (together with various primary minerals, a considerable part of the mineral mass is kaolinite, halloysite, iron, and aluminium oxides);
- sl (Bsl) - solonetz horizons and properties;
- m (Bm) - mineral horizons whose main morphological features were formed as a result of initial material transformation in situ (m for metamorphosed);
- n (Bn) - presence of hard nodules (of any composition) which may be derived from the soil mass;
- a (A1a, A2a) - horizons showing considerable changes in their morphology due to human impact (ploughing, irrigation, compaction due to vibration, application of manure, peat, etc.);

- g (A2g, Bg) - morphological features of gley that are not enough to describe this horizon as G1, G2, G3;
- h (Bh) - illuvial humus horizons of dark brown and reddish-brown color;
- f (Bf) - illuvial-ferruginous horizons with bright yellow, red, and brownish yellow colors;
- t (Bt) - horizons of finer texture than overlying ones, with visible signs of transport of fine material in the form of clay skins along cracks, pores, and aggregate surfaces;
- p (BCp) - presence of stones coarser than 1 cm (gravel, stones and boulders, etc.) in quantities of more than 10% by volume;
- h (A2h, Bh) - horizons that do not come to the surface, do not directly contact horizons O and AO, are a darker color of black or grey in comparison with the overlying horizon, and are not buried (including a second humus-accumulation horizon, accumulations of grey and dark-grey humus above an impermeable barrier including permafrost, and illuvial humus horizons in neutral and alkaline soils);
- z (A1z, Oz) - numerous traces of soil fauna activity (coprolites, cysts of insects, krotovinas, etc.);
- v (Av, O2v) - horizons containing 50% or more of living parts of plants (steppe web, sod, meadow-sod, moss, etc.);
- su (BCsu) - mineral, black and dark-grey colored horizons, smelling of sulphuretted hydrogen, H2S, and containing iron sulfides;
- d (BCd) - signs of dynamic intermixing of soil mass;
- ve (Ave, Bve) - signs of compaction.

If the lowercase letter is underlined, it indicates that a particular diagnostic feature reaches the maximum expression within that horizon.

If several lowercase letters refer to the same horizon, they are separated by commas (B1m,f,g).

If a horizon contains soluble salts, then the presence of carbonates and gypsum is not indicated.

If gypsum is morphologically identified, the presence of carbonates is not indicated.

A successive designation of soil genetic horizons makes a profile formula; the horizon codes and symbols are separated by a hyphen: O-A2-A2B-B-BC-C.

If a horizon is replaced by another one, the symbol of the substituted horizon is written in parentheses: O-A1-A2(A1A2)-B-BC-C.

When the presence of a certain horizon is not obligatory for a particular soil, the formula cites it in parentheses: O-A1-A2-(A2B)-B-BC-C.

When parent material layers are present, and their thickness is comparable to that of the soil horizons, the layers are designated with Roman numerals (II, III, etc.). The designation of layers starts with Figure II, on the assumption that the overlying layer would be Figure I, which is dropped when the profile is indexed: A1-B1-IIB2-IIBC.

3.2 The Legend of the *SMR*

The legend of the *SMR* at scale 1:2.5 M consists of three groups of data:

I. Classification and mapping of soils;

II. Texture and petrography of parent materials;

III. Soil topography.

3.2.1 Soils

Classification

The soils shown on the *SMR* represent different taxonomic levels. Some of them are identified as soil genetic types (e.g., Sod-gleyic soil, Solods, etc.), while others refer to subtypes (e.g., Dark-grey, Grey, Light-grey forest soil; Chestnuts dark, Chestnuts light soil, etc.) and genus (Podzolic soil with second leached horizon; Meadow-chernozems solodized, Chestnuts solonetzized, etc.). The soil species, being the lowest soil classification taxon, are shown only for Podzolic soils (based on the depth of the lower boundary of podzolic horizons) and Chernozems (based on high, medium, and low humus content), for which the systematic classification is most developed. There are a few soils that have no clear place in the soil classification (Pine forest sands, High-mountain desert soil, etc.).

The subtypes of Chernozems and Chestnuts soils are shown as individual mapping units in steppe and dry steppe zones.

Thus, a number of new soil types, subtypes, and genera were shown on the *SMR*.

In the naming of soils, preference was given to traditional terms and short symbolic terms. The use of landscape terms and terms based on presumed soil genesis have played a subordinate role. Landscape terms were used for soils of inadequately studied territories and also for explanatory and traditional reasons (Grey forest soil, Meadow soil, etc.).

Cartographic design

The features used for cartographic design of the mapping units are as follows.

Soils occurring as simple homogeneous soil mapping units, or those forming the dominant components of complex heterogeneous soil mapping units, are represented by different colors, and corresponding symbols (letters and numbers) form the index on the map. Soils that occur as secondary components within complex soil mapping units are shown by colored figure signs.

All the soils that represent automorphic genetic types (Podzol, Grey forest soil, Chernozems, Chestnuts soil, etc.) are colored pink, brown, yellow, and other colors derived from the red and yellow spectrum. The Alluvials, Meadow and Bog soils, and Solonetz and Solonchaks have green, blue, and violet colors derived from the blue and violet spectrum.

The intensity of color corresponds to the natural darkness of the soil (mainly due to higher humus content);

The soil subtypes are marked by different tints in accordance with the color of the main soil type.

The alpha-numeric index code consists of three parts:

- A capital and a small letter, more rarely two capitals and two small letters, indicate the soil types;
- Small superscript letters (one or two, more rarely three) on the right of the main part of the index, indicate the soil subtypes;
- Subscript letters or numbers indicate soil genera or species.

However, it should be noted that there is not full correspondence between the alpha-numeric index and the taxonomic units, because of the space requirements for indexing.

Composition of the soil mapping units

The mapping units of the *SMR* are either homogenous (simple) or heterogeneous (complex).

Homogenous mapping units are shown where one soil comprises more than 85% of a mapping unit, or slightly less than 85% if the other soils are not contrasting. Such soil mapping units have the color of the dominant soil marked with its index code. The minimum size of simple mapping units is defined as 15 mm^2, with width not less than 2 mm.

Heterogeneous mapping units include soil sequences, mosaics, complexes, and altitude- or exposure-differentiated soil patterns. (For more detailed information, see Fridland, 1972b.)

Soil sequences are regular alternations of rather large areas of significantly different soils, formed of similar parent material, and revealing genetic relationship; the repeated differences are determined by local changes of hydrothermal regime and vegetation, mostly due to meso-relief.

Soil mosaics are similar to the soil sequences but formed on different contrasting parent materials. The genetic links between the components are not close, and the spatial soil pattern is not regular.

Soil complexes represent an alternation of small (5–30 m^2) spots of different soil types or, more rarely, subtypes, interdependent in their genetic development and mostly linked to the elements of micro-relief. The agricultural value of these components may differ greatly, but the potential land utilization is determined by the properties of the soil complex as a whole. Two big groups of soil complexes are distinguished on the *SMR*: cold regions (arctic, tundra, and the northern taiga) and hot regions (steppes and semideserts).

The soil sequences and mosaics are shown on the map by the colors, alphanumeric symbols, and colored out-of-scale signs. The background color and symbol reflect the dominant soil in the mapping unit, while the colored signs show the subordinate components. The minimum size of the mapping unit of this type is 80 mm^2, with a width not less than 5 mm, to provide space for a symbol and a colored sign.

The complex mapping units are shown by color lithographic cross-hatching. The shape of the cross-hatching reflects the genetic and geometric (spatial) pattern of the soil complex, while the color and symbol show the dominant soil component. The complete list of components for each soil complex is given in the map legend.

3.2.2 Texture and petrography of parent materials

The parent materials are either unconsolidated (loose) or hard rocks. Texture classes for deposits are represented by:

- clays and loams;
- clays and loams with debris;
- sandy loam and sands;
- sandy loam and sands with boulders;
- layered deposits;
- loose volcanic;
- hard rock with debris.

The textures of Alluvial soils and parent materials as well as the texture of Peat-boggy soils are not shown.

A system of black-hatched patterns throughout the unit is used for soils formed on loose deposits. The soils formed on hard rock are shown with signs reflecting the rock petrology (igneous or metamorphic; acid, medium or basic; calcareous limestones, shales, sandstones). In addition, such important properties as stones and boulders on the surface are noted.

3.2.3 Soil topography

The soil topography is represented by two general groups: plains and mountains.

The soils of plains are not marked by any particular sign on the map, other than those showing the main characteristics of any given soil mapping unit (color, symbol, hatching, signs). They comprise soils of level, undissected, or rolling lowlands, and also soils of more dissected, rolling and hilly upland plains, and plateaus. Their typical range in elevation is 100–200 m.

The mountain soils are shown by colored angle cross-hatching. The altitude exceeds 500 m, the relative change in elevation is considerable, and the main elements of relief are steep slopes.

3.3 Additional Explanatory Maps

Two additional explanatory maps at scale 1:15 M accompany the *SMR*. They have been developed to illustrate the main agricultural uses plus the structure of soil cover patterns, and the soil ecological regions of Russia.

The first map shows agricultural use and the structure of soil cover patterns. Agricultural use is considered for 11 economic regions within natural agricultural zones. The map displays the percentages of land use in the region by main categories (cultivated, perennial crops, forage land, and pastures). It also contains information on the percentage of zonal soils, loamy-sand and sandy automorphic soils, sands, wet and bog soils, meadow-steppe soils, soils with solonetz properties, Alluvial soils, and Solonchaks.

The structure of soil-cover patterns demonstrates major forms of soil cover combinations, their causes, and spatial geometry: soil sequences (caused by meso-relief), mixed-sequence mosaics (caused by meso-relief plus contrasting parent materials), and soil complexes caused by micro-relief and vegetation heterogeneity. Two types of soil cover patterns (altitudinally differentiated and exposure-differentiated) were identified for the mountainous regions.

The second explanatory map illustrates the soil-ecological regions of Russia. It shows nine lowland zones and 50 lowland soil provinces, indicating the characteristics of the main climatic and soil temperature-moisture regimes. It also includes five mountain zones and 17 soil provinces with data on climatic parameters (average temperature in July, sum of temperatures above 100°C, annual precipitation, and annual moisture coefficient).

4

Correlation of the *SMR* and the *SMW* Legend

4.1 Generalization Procedure

The problem of aggregation (generalization) always arises when it is necessary to transform a map at a larger scale to a less detailed map of smaller scale. In this case, the aggregation is caused by the differences in scales between the original *SMR* at scale 1:2.5 million and the *SMW* at scale 1:5 million. Generalization procedures and some new approaches to solve the problem have been discussed in Stolbovoi and Sheremet (2000). Usually, generalization deals with two main kinds of aggregation: 1) a generalization of the substantive content or attributes, and 2) a generalization of the geometry of the mapping units or polygons.

The first aspect of generalization is rather complicated and is more akin to an art than a science. Usually the process of deleting and combining soils is based on arguments, not always clearly defined, such as taxonomic unity of the aggregated classes, their representativeness, purposes which the aggregated product will serve, professional skill of the author, etc.

The second aspect, the generalization of mapping units, is caused by the fact that some polygons that exist at a larger scale cannot be shown on a smaller scale. This generalization requires the manipulation of the geometry of the polygons. In this study the geometry was generalised in accordance with a traditional rule of observational cartography that the minimal size of a mapping polygon should not be less than 1 cm^2.

In practice, the generalization was done in two steps. In the first step, all soil groups of the *SMR* were correlated with the *SMW* soil units. A full list of the correlated soils can be found in Appendix 1. Next, all soil polygons of the original *SMR* were described by attributes according to the FAO basic guidelines for compilation of the *SMW* (FAO/UNESCO, 1974) and the *SMW* revised legend (FAO/UNESCO, 1988). Thus, each soil polygon of the *SMR* was provided with a set of the following characteristics:

Table 4.1. Composition of complex mapping units (% of polygon).

Dominant soil	Associated soil	Inclusions
100	0	0
90	0	10
80	0	10+10
70	0	10+10+10
70	30	0
60	30	10
60	20+20	0
50	20+20	10
50	30	10+10
45	30	5+5+5+5+5
40	30	10+10+10
40	20+20	10+10
35	20+20	5+5+5+5+5
30	20+20+20	10
30	20+20	10+10+10
30	20+20+20	5+5
25	20+20+20	5+5+5
24	20+20+20	4+4+4+4

- soil name, including ranking of dominant, associated, and included soils;
- texture classes;
- slope classes;
- phases.

In the second step, neighboring soil mapping units were combined if they contain genetically, morphologically, and analytically related soils. Naturally, this procedure caused a decrease in some soils when their extent was less then 4% of the newly united polygon area. In order not to lose important information when combining a soil, a soil phase of significant practical meaning was shown.

When a map unit was complex, including more then one soil, it was composed of a dominant soil (the most extensive one) and of an associated soil, or soils, covering at least 20% of the polygon. Important soils that covered less than 20% of the polygon area were called inclusions. The average number of soils in a mapping unit varied from two to three. However, in some cases, it was as high as six or seven. The compilation of complex polygons was made on the basis of an accurate calculation of their composition; this was done in accordance with the recommendations of FAO/UNESCO (1971–1981) shown in *Table 4.1*.

4.2 Texture Classes

Texture reflects the relative proportions of the fractions of clay, silt, and sand in a soil. Difficulties in creating the data on soil texture were caused by the different information on texture shown on the *SMR* and required by the *SMW*. Practically new data on the texture of soils in Russia was collected for a large number of the soil map polygons. Where literature sources did not exist, expert judgment, based on information shown on the *SMR*, was applied.

Another problem is the differences in defining textural fractions between the Russian and FAO soil maps. This raises the problem of data compatibility. In general, these differences are shown in *Table 4.2*. It is apparent that fewer textural fractions are defined in the FAO soil map than are proposed in the Russia map. This is because the FAO system portrays a much larger (global) scale. On the other hand, the differences are not very great, and the generalized textural classes could be correlated adequately for practical tasks at a global scale. For more precise analysis for scientific research, this correlation needs to be done in greater detail.

As shown in *Table 4.2*, three textural classes were distinguished:

- Coarse-textured (corresponding to FAO sands) loamy sands and sandy loams with less than 15% clay and more than 70% sand;
- Medium-textured (corresponding to FAO sandy loams) sandy clay loams, silt loams, silt, silty clay loams, and clay loams with less than 35% clay and less than 70% sand; the sand fraction may be as high as 85% if a minimum of 15% clay is present;
- Fine textured (corresponding to FAO clays) silty clays, sandy clays, clay loams, and silty clay loams with more than 35% clay.

These texture classes were established for the dominant soil and refer to the texture of its upper 30 cm.

4.3 Slope classes

The slope conditions shown on the *SMR* do not meet the FAO requirements. It was therefore necessary to create these characteristics, as was done for texture. The principal problem was that the topographic maps at scales 1:2.5 M and 1:5 M are very rough for this task. For example, the basic map at scale 1:2.5 M, published by GUGK in 1976 and used for compilation of the *SMR*, has contour intervals of 50 m up to 300 m above mean sea level, 100-m-intervals from 300 m to 800 m in elevation, then 200-m-intervals and 250-m-intervals above elevations of 1,000 m. To meet the FAO requirements, a number of calibration plots were established at positions of different relief around the country. Topographic maps at scale 1:100,000 have been analyzed on these plots. This procedure facilitates correlation between

Table 4.2. Correlation of particle size distribution between FAO and Russian systems.

Name of texture fraction	Particle size (mm), FAO system (1988)	Particle size (mm), Russian system (1967)
Gravel, fine gravel	≥2	≥1
Sand		
Coarse		–0.5
Medium	–0.06	–0.25
Fine		–0.05
Silt		
Coarse		–0.01
Medium	–0.002	–0.005
Fine		–0.001
Clay	≤0.002	≤0.001
General classes		
Coarse	–0.06	0.05
Medium	–0.002	–0.001
Fine	≤0.002	≤0.001

the actual slope conditions and the density of contour lines on the basic map at the scale 1:2.5 M. This correlation was applied to create slope classes that referred to the prevailing slopes in a soil mapping unit.

These slope classes correspond to FAO:

- level to gently undulating: dominant slope ranging between 0% and 8%;
- rolling to hilly: dominant slope ranging between 8% and 30%;
- steeply dissected to mountainous: dominant slopes are over 30%.

4.4 Phases

Phases are features of the land that are significant for its use and management. They are not necessarily related to soil formation. It is assumed in the original manual of the *SMW* (FAO/UNESCO, 1977) that phases usually cut across soil boundaries and, hence, have not been used to define individual soil units, particularly when some phases are not related to present soil formation. This means that in the *SMW*, phases could be shown by signs without precisely defining their spatial dimensions. This approach was absolutely correct and could be achieved when compiling traditional paper maps. It is not acceptable when digitizing the final product, because each characteristic belongs to a specific polygon and is stored in an attribute file. Thus, phases were created as an additional attribute outlined on the original soil map as separate polygons. The total list of phases for Russia are given in Appendix 2.

5

Soil Resources of Russia

The correlation procedure identified 19 FAO major soil groupings (*Figure 5.1*) out of the 28 described by FAO (1988). These are listed in *Table 5.1* (together with their subdivisions).

The total land area, covered by soils and other surface formations excluding water, is 16,704.4 km^2 (1,670,440,000 ha). The accuracy of the area estimate is within 3% (Stolbovoi and Sheremet, 1997).

The most extensive major soil grouping on the territory of Russia is Podzols. It occupies more than 371 million ha, or about 22% of the total land area.

The second most extensive major soil grouping is Gleysols, with about 275 million ha, or more than 16% of the total land area.

Two major soil groupings, Cambisols and Podzoluvisols, cover about 210 million ha each, or about 12.5% each.

Leptosols cover an extent of more than 144 million ha, or about 9% of the land area.

More than 118 million ha (about 7% of the land area) are covered by Histosols.

The most agriculturally valuable major soil grouping – Chernozems – occupies about 94 million ha, or less than 6% of the land area.

Four major soil groupings also favorable for agriculture are Fluvisols, Greyzems, Phaeozems, and Kastanozems. Together they occupy about 160 million ha, or approximately 10% of the land.

Other major soil groupings, together with nonsoil formations, occupy about 90 million ha, or a little more than 5% of the total land area.

The newest observations of soil reserves of Russia (Stolbovoi and Sheremet, 1997) have shown that practically 80% of the country is under the dominant influence of cold and humid soil-forming environments. We found (Stolbovoi, 2000) that 74% of the country includes regions where permafrost occurs; more precisely, 9% occurs as isolated permafrost patches, 21% is discontinuous sporadic permafrost, and 44% is continuous permafrost. Cold and humid climate drives major soil-forming processes in general, and metabolisms of organic material in particular. We understand the latter to mean a wide spectrum of biochemical and geochemical transformations and cycles of organic substances in terrestrial ecosystems, including processes of biotic and abiotic assimilation and dissimilation, absorption and migration, leaching and sedimentation, etc. These processes are responsible for the main features of carbon distribution in soil profiles and landscapes, and they define the size of pools and fluxes.

Cold climate, deep soil freezing during severe winters, and slow and shallow thawing in summer are unfavorable for microbiological activity, and considerably lower the organic decomposition rate. It results in the accumulation of abundant underdecomposed vegetation residuals, and a variety of peat and peat-muck topsoil horizons, which, in turn, play an important thermo-insulation role and preserve low temperatures in deeper soil. This mechanism inhibits the penetration of biochemical processes into cool mineral soil. It is well documented by numerous field observations in the European north (Ignatenko, 1977), the Taymyr region of Russia (Vasilievskaya, 1980), etc.

Humid refers to the climates where the amount of atmospheric precipitation considerably exceeds evaporation capacity. Excessive moisture leads to the development of wetlands (about 221 million ha), wet tundra (about 253 million ha), and boreal coniferous forest (more than 540 million ha), where surface drainage and temperature permit trees to grow (Nilsson and Shvidenko, 1998; Stolbovoi, 2000; Vomperski, et al., 1998).

Humid climate conditions have a different effect on organic soil formation depending on texture, hydraulic conductivity of the substrata, internal and external soil drainage, chemical characteristics, and composition. The huge extent of coarse-textured siliceous parent materials in the forest zone of Russia is favorable for excessive drainage and a water percolation regime. These factors support an intensive migration of the soluble organic substances, particularly, organic complexes with ligands: iron, aluminum, and other strongly bound elements that have resulted from physical and chemical weathering of parent materials. Due to the low absorption capacity of parent rocks, the accumulation of organic acids on topsoil is not evident, and dissolved organic material migrates to deep soil horizons, groundwater, and streams.

Fine-textured deposits enhance effects of low temperature, leading to more rapid and deep freezing during autumn-winter and slow and shallow spring/summer thawing compared with coarse-textured soils. In actual fact, the forest penetrates the north due to warmer, coarse-textured soils. There is evidence of a limitation of root development caused by the dense clay accumulation. The factors listed above are not favorable for the formation of deep organo-mineral horizons. On the other hand, decomposed organic products tend to associate with clay minerals through bridging by polyvalent cations (clay-metal-humus), hydrogen bonding, ligand exchange, etc., and this definitely supports humus immobility and accumulation.

Soils on slightly drained plains or depressions with shallow groundwater are manifested in conditions of excess wetness. Long periods of saturation result in the reduction of iron oxides and formation of redoximorphic features – that is, olive and blue colors. An intensive development of plant root systems is constrained by the lack of oxygen. This evidence shifts the biological activity toward the aerated surface and leads to the accumulation of the organic matter in the form of peaty and muck horizons.

Extremely poorly drained flat interfluves and depressions with shallow groundwater are favorable for bog formation, which have been associated with an intensive organic (peat) accumulation. Clay and metal complexes are present in very low amounts in relation to the humus component. In these soils, humic substances are presented in the form of insoluble macromolecular complexes.

Of the nine FAO major soil groupings not listed above, most are more typically tropical soils, but three may, in fact, exist in Russia. There are Anthrosols of various kinds that are too fragmented to appear on the map, and, therefore, are not described in this report. Limited areas of Gypsisols are included within the Calcisols in semidesert regions.

There may be small areas of various kinds of Luvisols that are unrecognized as such, but these areas are rarer than might be expected. This is so because the generally quartzitic parent materials and the prevalent specific forest litter in a cold, humid climate favor the movement of organic matter and sesquioxides and the destruction and leaching of clay (podzolization in the original sense) when drainage is good, or gleyization and organic matter accumulation when drainage is poor. The soils, therefore, typically form Podzoluvisols on fine-textured substrates, Podzols on sandy parent materials with excessive drainage and a low level groundwater table, and such soils as Gleysols and Histosols under poorly drained plains with water saturation for long periods every year. Argic horizons, or at least textural B horizons, of clay accumulation by neoformation and eluviation are fairly common, but Luvisols are not.

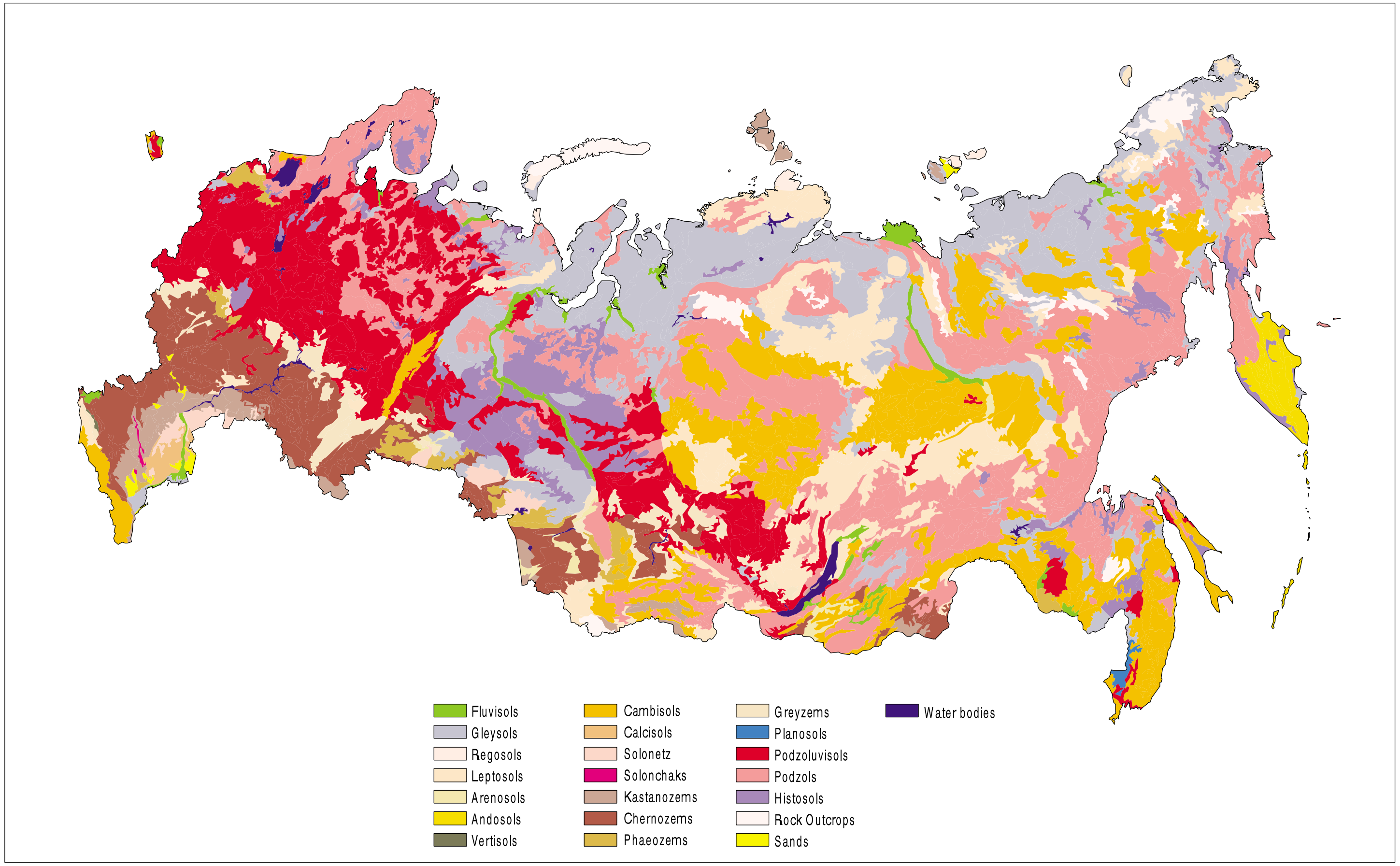

Figure 5.1. Major soil groupings of Russia.

Table 5.1. Extents of FAO major soil groupings and soil units in Russia.

Major soil groupings and soil unit (FAO, 1988)	Extent million ha	Percent of total land area of country	Percent of major soil grouping
FLUVISOLS	57.37	3.43	
Eutric	3.25	0.19	5.60
Calcaric	0.18	$\leq$0.10	0.30
Dystric	30.38	1.82	53.00
Umbric	22.33	1.34	38.91
Thionic	1.42	0.08	2.47
GLEYSOLS	275.19	16.47	
Dystric	70.06	4.19	25.46
Mollic	9.25	0.55	3.36
Umbric	46.85	2.80	17.04
Gelic	149.03	8.92	54.16
REGOSOLS	4.35	0.26	
Haplic	0.33	$\leq$0.10	5.60
Gelic	4.35	0.30	94.60
LEPTOSOLS	144.54	8.65	
Dystric	7.32	0.44	5.07
Rendzic	87.00	5.21	60.19
Mollic	3.77	0.23	2.61
Umbric	5.62	0.34	3.89
Lithic	34.42	2.06	23.81
Gelic	6.41	0.38	4.44
ARENOSOLS	5.58	0.33	
Cambic	5.58	0.33	100.00
ANDOSOLS	15.64	0.94	
Haplic	11.18	0.67	71.47
Vitric	2.73	0.16	17.47
Gelic	1.73	0.10	11.06
VERTISOLS	0.21	0.01	
Eutric	0.21	0.01	100.00
CAMBISOLS	212.03	12.69	
Eutric	25.45	1.50	12.00
Dystric	68.98	4.10	32.50
Humic	0.60	$\leq$0.00	0.30
Calcaric	5.44	0.33	2.57
Chromic	1.31	0.08	0.62
Gleyic	6.69	0.4	3.16
Gelic	103.56	6.20	48.80
CALCISOLS	4.57	0.27	
Haplic	1.75	0.11	38.37

Table 5.1. Continued.

Major soil groupings and soil unit (FAO, 1988)	Extent million ha	Percent of total land area of country	Percent of major soil grouping
Luvic	2.82	0.17	61.63
SOLONETZ	11.16	0.67	
Haplic	2.56	0.15	22.95
Gleyic	8.60	0.51	77.05
SOLONCHAKS	0.98	0.06	
Haplic	0.64	0.04	65.14
Gleyic	0.34	0.02	34.86
KASTANOZEMS	25.80	1.54	
Haplic	17.28	1.03	66.97
Calcic	0.15	0.00	0.58
Luvic	8.37	0.50	32.46
CHERNOZEMS	92.84	5.60	
Haplic	30.41	1.82	32.80
Calcic	26.48	1.59	28.50
Luvic	27.51	1.65	29.60
Glossic	8.44	0.51	9.10
PHAEOZEMS	26.26	1.60	
Haplic	7.81	0.10	29.70
Calcaric	0.09	0.40	0.30
Luvic	17.62	1.05	67.10
Gleyic	0.74	$\leq$0.10	2.80
GREYZEMS	44.96	2.69	
Haplic	44.54	2.67	99.06
Gleyic	0.42	0.03	0.94
PLANOSOLS	2.26	0.14	
Mollic	2.26	0.14	100.00
PODZOLUVISOLS	207.37	12.41	
Eutric	119.41	7.15	57.59
Dystric	24.07	1.44	11.61
Stagnic	8.04	0.47	3.88
Gleyic	55.71	3.34	26.87
Gelic	0.13	0.00	0.06
PODZOLS	371.13	22.22	
Haplic	147.82	8.85	39.83
Cambic	117.67	7.04	31.71
Ferric	62.41	3.74	16.82
Gleyic	26.79	1.60	7.22

Table 5.1. Continued.

Major soil groupings and soil unit (FAO, 1988)	Extent million ha	Percent of total land area of country	Percent of major soil grouping
Gelic	16.42	0.98	4.42
HISTOSOLS	118.86	7.11	
Terric	8.58	0.50	7.20
Fibric	90.78	5.40	76.40
Histosols	19.50	1.20	16.49
Sands	3.55	0.21	100.00
Rock Outcrops	41.94	2.51	100.00
Glaciers	3.85	0.23	100.00
Total	1670.44	100.00	

6

Description of the FAO *SMW* Soil Units and the Correlated Soil Groups of the *SMR*

6.1 Fluvisols

Fluvisols occupy 57.56 million ha, or 3.4% of the land of Russia (*Table 5.1*). Such soils are widespread, (*Figure 6.1*) particularly in West Siberia, southern Siberia, and the northern European part of the country.

This major soil grouping corresponds to a wide range of so-called intrazonal alluvial soils in Russia. The soils are developed in flood plains and characterized by regular flooding (but not necessarily every year), and deposition of fresh alluvial material on the soil surface. These processes determine the specific features of alluvial soils, the character of their water regime, and genesis.

Fluvisols are generally formed on alluvial deposits. They have fluvic properties and have no diagnostic horizons other than an ochric, mollic, or umbric A horizon; a histic H horizon; a sulfuric horizon; sulfidic material within 125 cm of the surface; or salic properties.

The following FAO soil units of the Fluvisols have been identified, and the corresponding soil groups in the *SMR* are indicated.

- Fluvisols Eutric (FLe)
  - – Alluvials slightly acid and neutral
  - – Alluvials saline
- Fluvisols Calcaric (FLc)
  - – Alluvials calcareous
- Fluvisols Dystric (FLd)
  - – Alluvials acid
- Fluvisols Umbric (FLu)
  - – Alluvials meadow

  - Alluvials boggy meadow
- Fluvisols Thionic (FLt)
  - Marshy saline and Alluvials solonetzic

6.1.1 Fluvisols Eutric (FLe)

This soil unit occupies 3.25 million ha, which corresponds to 0.2% of the land area of the country, or 5.6% of the area of the Fluvisols major soil grouping. These soils have a base saturation (by NH_4O_{Ac}) of 50% or more between 20 cm and 50 cm from the surface, but are not calcareous at the same depth. Additionally, these soils have no sulfuric horizon, no sulfidic material within 125 cm of the surface, and no salic properties.

The Fluvisols Eutric correlate with the Alluvials slightly acid and neutral soils. Some Alluvials saline soils are included in the mapping unit, though they correlate with salic Fluvisols.

Alluvials slightly acid and neutral soils have the profile A1-B-CDg. The humic horizons vary in color from light grey to dark grey and have a thickness of 5–25 cm. The A1 horizon is succeeded by a transitional B horizon. The parent material is layered or laminated. The texture varies from sands to clay loams. The soil reaction is slightly acid or neutral. Saline Alluvial soils are characterized by their alkaline soil reaction and the presence of soluble salts.

6.1.2 Fluvisols Calcaric (FLc)

This soil unit occupies 0.18 million ha, which corresponds to $<$0.1% of the country area, or 0.3% of the Fluvisols major soil grouping. This unit correlates with Alluvials calcareous.

These soils have the profile A1ca-Bca-CDgca.

They are very similar to the Alluvials slightly acid and neutral soils, however, as they have a slightly alkaline pH and effervescence reaction with 10% HCl.

These soils are widely spread in dry steppe, semidesert, and desert bioclimatic zones.

6.1.3 Fluvisols Dystric (FLd)

This soil unit occupies 30.38 million ha, which corresponds to 1.8% of the land area, or 53.0% of the Fluvisols major soil grouping area. These soils have a base saturation (by NH_4O_{Ac}) of less than 50% between 20 cm and 50 cm from the surface, and do not have a sulfuric horizon or sulfidic material within 125 cm of the surface.

This unit correlates with Alluvials acid soils, which have layered soil profiles with varying humic and mineral horizons and acid soil reaction.

6.1.4 Fluvisols Umbric (FLu)

This soil unit occupies 22.33 million ha, which corresponds to 1.3% of the land area, or 38.9% of the Fluvisols major soil grouping. These soils have an umbric A horizon or a dystric histic H horizon, and do not have a sulfuric horizon, sulfidic material within 125 cm of the surface, or salic properties. This soil unit corresponds to Alluvials meadow soils and Alluvials boggy meadow soils.

Alluvials meadow soils have a profile A1-B-Bg-CDg. The 30–50 cm humic horizon is dark grey or brownish grey and has 3–5 cm of sod in the upper part. It is loamy, with granular structure, rusty spots and veins, on flat relief. The second group (O-G-Gt-G) is formed from loams and clay-loams in conditions of poor external drainage (flat relief) or sometimes where stratified rock layers are close to the surface. It is characterized by a thin (3–4 cm) O horizon that is poor in oxalate-soluble and total Fe_2O_3, and which is distinguished (but only chemically) beneath the litter horizon. The Gt horizon has weak micro-morphological features of illuviation.

These soils are found in the middle and northern taiga and forest-tundra; the first group dominates in the European part of Russia, the second in West Siberia.

Alluvials boggy meadow soils are characterized by gley features, and often have an organic peaty horizon at the top. The B1 is a transitional horizon with spots of gley and iron staining. The Bg is a bluish-grey gley horizon, which commonly has layers that vary in extent of gleying. The CD is layered alluvium with thin layers of buried peat.

These soils are formed in central flood plains with deposits of relatively small quantities of clayey and loamy alluvium. The vegetation typically consists of humid meadows of the forest and steppe zones.

6.1.5 Fluvisols Thionic (FLt)

These soils occupy 1.42 million ha, which corresponds to 0.1% of the land area of the country, or 2.5% of the Fluvisols major soil grouping. They have a sulfuric horizon or sulfidic material, or both, at less than 125 cm from the surface.

This soil unit correlates with saline and alkaline Marsh soils. They form on marine shores periodically flooded with brackish marine waters.

6.2 Gleysols

This major grouping occupies 275.19 million ha or 16.5% of the land area (*Table 5.1*). It is widespread (*Figure 6.1*) particularly in the northern part of Siberia and Far East, and is very common in West Siberia.

These soils are developed under excess water and formed from unconsolidated material, exclusive of coarse-textured material and alluvial deposits with fluvic properties. These soils show gleyic properties within 50 cm of the surface and have no diagnostic horizons other than an A horizon, a histic H horizon, a cambic B horizon, a calcic horizon, or a gypsic horizon. They do not have the characteristics that are diagnostic for Vertisols or Arenosols, including salic properties or plinthite within 125 cm of the surface.

This major soil grouping is not distinguished as a separate class in the soil classification of Russia. In general, it corresponds to so-called azonal soils that also can occur in any natural zone. However, their characteristics (humus content, reaction, base saturation, etc.) strongly depend on the zonal conditions. The FAO soil units and correlated equivalent classes from *SMR* are described below:

- Gleysols Dystric (GLd)
  - Gleyzems peaty and peat boggy
  - Gleyzems taiga differentiated
  - Gleyzems taiga
  - Sod-gleys podzolized
- Gleysols Mollic (GLm)
  - Meadows solonetzic and solonchakous
  - Meadow-boggies
  - Meadow-boggies solonetzic and solonchakous
- Gleysols Umbric (GLu)
  - Sod-(muck-)gleys
  - Meadows
- Gleysols Gelic (GLi)
  - Gleyzems arctic
  - Gleyzems arctotundra muck-gley
  - Gleyzems peat and peaty-humic tundra
  - Gleyzems weak-gley, peaty-muck tundra
  - Gleyzems differentiated peaty-muck tundra
  - Gleyzems peaty and peat tundra
  - Gleyzems peaty-muck taiga
  - Gleyzems weak-gley, peaty-humic taiga

6.2.1 Gleysols Dystric (GLd)

This soil unit occupies 70.06 million ha, which corresponds to 4.2% of the land area, or 25.5% of the major soil grouping. The soils have a base saturation (by NH_4O_{Ac}) of less than 50% between 20 cm and 50 cm from the surface, no diagnostic horizons other than an ochric A horizon and a cambic B horizon, and no andic properties or permafrost within 200 cm of the surface.

The Gleysols Dystric correlate with Gleyzems taiga, Gleyzems taiga differentiated, Gleyzems peaty and peat boggy, and Sod-gley podzolized soils.

Gleyzems taiga (synonyms: taiga gley and undifferentiated slightly gley soils) are characterized by two types of soil profiles: O3-G-Bh,t-C and O-G-Gt-G. The first group (O3-G-Bh,t-C) is formed from clay-loamy parent materials, with slow internal drainage of the topsoil. The soil profile consists of raw humus organic horizons O3 (5-12 cm) and mineral gleyed layers with varying internal structure and degrees of gleying. The upper part of the mineral layer is saturated with exchangeable bases. It contains a significant amount of colorless humus compounds. These soils are not differentiated by clay content or minerals, Al_2O_3 nor, usually, Fe_2O_3. In the first group, gleying is localized in the topsoil above stratified, finely dispersed material, with the maximum of oxalate-soluble Fe. The subsoil is ungleyed and has features of clay illuviation. A vast amount of Mn-Fe concretions is deposited along the boundary with the gley layer. The mineral soil is gleyed and the degree of gleying increases downward to a maximum in the parent material; it is medium- to heavy-textured, and sometimes stratified on flat relief. The second group (O-G-Gt-G) is formed from loams and clay-loams in conditions of poor external drainage (flat relief), and sometimes where stratified rocky impermeable layers are close to the surface. It is characterized by a thin (3–4 cm) O horizon that is poor in oxalate-soluble and total Fe_2O_3 and which is identified (only chemically) beneath the litter horizon. The Gt horizon has weak micro-morphological features of illuviation. These soils are found in the middle and northern taiga and forest-tundra; the first group dominates in the European part of Russia, the second in West Siberia.

Gleyzems differentiated taiga (synonyms: differentiated taiga gley and weak gley, including podzolized taiga soils) have the profile O-GA2-Bg(G)-G(C). The O horizon (5-12 cm thick) overlies the gleyed mineral horizon, which is characterized by one or more of the morphological features described below.

The degree of gleying may gradually decrease downward to nongleyed parent rock. Sometimes the horizon underlying the O horizon is a lighter color.

Alternatively, very well expressed gleying properties increase downward. The topsoil is permeated with a significant amount of colorless humus (down to a depth of 20-30 cm). Two variants of a weak mineral profile are distinguished that are not visible in the morphology: 1) a variant differentiated by the distribution of total and oxalate-soluble Fe_2O_3 or Al_2O_3, or both; 2) a variant podzolized by interdependent Fe_2O_3 and clay eluvial-illuvial distribution.

These soils are formed on loams and stony-loams in the middle and northern taiga and forest-tundra of the European part of Russia, and also in Siberia and the Far East.

Gleyzems peaty and peat-boggy (synonyms: taiga differentiated gleyed peaty soils, Gleyzems, and peaty differentiated slightly gleyed soils, including taiga podzolized soils) have the profile O-GA2-Bg(G)-G(C). They are similar to differentiated taiga gley soils but differ by having more distinctive features of wetness, gleying, and weak bog formation. This results in the formation of a peaty horizon to a depth of 15–25 cm.

The soils are found in depressions of the relief under dark, sphagnum moss and in coniferous forests with hydrophilic bushes in the taiga parts of Siberia.

Sod-gley podzolized soils have the profile A1v-A1-A2g,n-Bt,g-G2. The litter horizon O, or muck O3 horizon, is 5–30 cm thick, depending on the degree of waterlogging, and is underlain by a dark grey or steel-grey colored humus horizon A1 (20–30 cm thick) with granular structure when it is loamy. Sometimes it contains solid concretions and features of gleying. The A2g horizon has podzolization features, expressed by bleaching in the lower part of the A1 horizon or by bleaching of the particle surfaces. The transitional B horizon (25–50 cm) is dirty-brown colored, often has hard iron concretions, and is always gleyed – but the degree of gleying varies (blue-grey stripes, rusty stains, continuous gley horizon). Gleying may be expressed not in the whole soil profile, but only in the topsoil (surface waterlogging) or in a lower layer within the parent rock (ground waterlogging). When the texture is loamy, the structure is curd-like or granular. Manganese stains and concretions are common. The C horizon can be strongly gleyed or even an aquifer, but an absence of gleying features also is possible. These soils are characterized by high humus content (3–14%). Humic acids linked with calcium prevail. The topsoil reaction is neutral and the subsoil is slightly alkaline. Base saturation is high (70–90%).

These soils are influenced by seasonal surface waterlogging and relatively high ground water levels. They develop from calcareous parent rocks under coniferous (spruce) and mixed forests with mossy grass and grass groundcover in poorly drained or depressed relief or under meadow vegetation in the northern, middle, and southern taiga subzones.

6.2.2 Gleysols Mollic (GLm)

This soil unit occupies 9.25 million ha, which corresponds to 0.6% of the total land area, or 3.4% of the major soil grouping area.

These soils have a mollic A horizon or eutric histic H horizon, they do not have andic properties, and they do not have permafrost within 200 cm of the surface.

This soil unit corresponds to Meadow-boggies, Meadows solonetzic and solonchakous, and Meadow-boggy solonetzic and solonchakous soils.

Meadow-boggy soils have the profile (O)-Av-A1g-Bg-G. The upper part of the profile may contain a thin peat layer (up to 10 cm thick) succeeded by some 15–20 cm of muck or sod. The lower part of this horizon has distinct gley features. The transitional horizon contains a considerable amount of humus. It is profoundly gleyed and gradually passes into a gley parent material. The soils are characterized by high base saturation; the pH varies from acid to slightly alkaline (in calcareous varieties). These soils are formed under grass in depressions of lowlands or on river and lake terraces. They are periodically flooded and the ground water table is at 1–2 m. Such soils are found in forest steppe and some drier zones.

Meadow solonetzic and solonchakous soils (synonyms: meadow alkaline and saline) with profile A1(sl)- A1B(sl)-Bca,(cs),(s),(g)-Cg, ca,(cs),(s), differ from the Meadow soils in that they have a horizon with a nut (subangular blocky) or nutty-prismatic structure, and contain exchangeable sodium. Either the humic or the transitional horizon may have solonetz features, sometimes with solod bleaching above them. The solonetz features are usually accompanied by salinization of the middle and lower parts of the soil profile. In saline soils, gypsum may also be found at a depth of 30–80 cm, but there is no close correlation in depth between soluble salts and gypsum accumulation. The alkaline and saline Meadow soils are found in the same landscapes as the calcareous Meadow soils.

Meadow-boggy solonetzic and solonchakous soils (synonyms: alkaline and saline Meadow-boggy) differ from those described above due to the presence of soluble salts. Such soils occur in the same territories as meadow boggy soils.

Meadow differentiated (including solodized) soils have a profile A1-A2(A1A2)-Bt, (g)-Bca, (g)-Cg. They differ from typical Meadow soils in having a bleached platy A2 horizon or bleached material. These soils usually have exchangeable sodium. Differentiated Meadow (including solodized) soils occur together with calcareous Meadow soils.

6.2.3 Gleysols Umbric (GLu)

This soil unit occupies 46.85 million ha, which corresponds to 2.8% of the land area of the country, or 17.0% of the major soil grouping.

These soils have an umbric A horizon or a dystric histic H horizon, and they do not have andic properties nor permafrost within 200 cm of the surface.

These soils correlate with Sod-gleys and Meadows soils.

Sod-gleys have the profile O-O3-A1(g,n)-Bg,(n)-C(g)(G2). The thickness of the litter horizon O, or muck O3 horizon (5–30 cm), depends on the degree of overwetting. Sod-gleys are underlain by a dark grey or steel-grey colored humic horizon A1 (20–30 cm) with granular structure when it is loamy, which sometimes contains solid concretions and features of gleying. The transitional Bg horizon (25–50 cm) is dirty-brown colored, often with hard iron concretions, and always gleyed – but the degree of gleying varies (blue-grey stripes, rusty stains, or continuously gleyed horizon). Gleying can be present not throughout the profile, but only in the topsoil (surface waterlogging) or in a lower layer within the parent material (ground waterlogging). When the texture is loamy, the structure is curd-like or granular. Manganese stains and concretions occur. Cg horizons may be strongly gleyed or may even be an aquifer (G2), but an absence of gleying features is also possible. These soils are characterized by high humus content (3–14%), with humic acids linked to calcium prevailing. The topsoil reaction is neutral and subsoil is slightly alkaline. Base saturation is high (70–90%).

These soils are developed under coniferous (spruce) and mixed forests with mossy-grass and grass groundcover on depressed or slowly drained relief positions over calcareous parent rocks. Such sites are characterized by seasonal surface waterlogging and relatively high ground water levels. They form meadow vegetation in the northern, middle, and southern taiga subzones.

Meadows soils have a strongly differentiated profile A1-A1B-Bg,ca-Cg,ca. They have a well-developed, powdery-crumby-granular humic A1 horizon. Rusty spots are common within the transitional brownish-grey A1B horizon with nutty or coarse-crumby structure. The Bg,ca horizon is brown, calcareous, and has rusty spots. The Cg,ca horizon is the gleyed calcareous parent material. Meadow soils are formed under conditions of excessive soil surface wetness that is permanently linked to fresh ground water at a depth of 1–3 m. They are characterized by seasonal changes in moisture flows: abundant downward ground water flow in spring, and predominantly upward flows during summer and autumn. These soils occur in depressions of poorly drained plains under meadow grasses.

6.2.4 Gleysols Gelic (GLi)

This soil unit occupies 149.03 million ha, which corresponds to 8.9% of the land area, or 54.2% of the major soil grouping area. All the soils have permafrost within 200 cm of the surface.

This soil correlates with Gleyzems arctic, Gleyzems arctotundra muck-gley, Gleyzems and weak-gley humic tundra, Gleyzems peaty and peat (shallow and deep peat) tundra, Gleyzems differentiated peaty-muck and peat tundra, Gleyzems peaty and peaty-muck tundra, Gleyzems peaty-muck taiga, and Gleyzems weak-gley peaty-muck taiga.

Gleyzems arctic have the profile O1(2)-G-⊥G, and the thawing depth is not more than 50 cm. Organic horizons O1(2) are thin (a few centimeters) and saturated with water. The reaction is near neutral. They are formed under grain-moss arctic peatlands in the southern part of the arctic zone.

Gleyzems arctotundra muck-gley have the profile O3-G-⊥G. The peaty-muck horizon O3 (1–5 cm) is underlain by a mineral, blue-grey colored layer, which is homogeneously gleyed down to the lower boundary of seasonal thawing (60–80 cm). The profile is undifferentiated in clay content and sesquoxide distribution. The reaction is acid to slightly acid and slightly base-unsaturated. Such soils exist mainly in humid arctic tundra.

Gleyzems and weak-gley humic tundra have the profile O1(2)-Gd-⊥G. The upper peaty or peaty-muck horizon is from 5–15 cm (peaty) to 30–40 cm (peat) thick, and is underlain by a strongly gleyed mineral layer, sometimes thixotropic. Permafrost exists at the depth of 60–100 cm. The soil profile is thoroughly acid, with no clay content or sesquioxides differentiation, but with common features of cryogenic deformation of soil horizons. They are generally in the temperate continental permafrost subarctic tundra and forest- tundra zones.

Gleyzems peaty and peat (shallow and deep peat) tundra have the profile A1-Bg-⊥C. The A1 horizon (1–3 cm) is underlain by a mineral layer with features of weak local gleying (small mottles on brown ungleyed background). The permafrost is at a depth of 40–60 cm. The mineral layer is undifferentiated by clay content or sesquoxides content. The upper layer is slightly acid with incomplete base saturation, while the lower horizon is neutral with full base saturation. Such soils are limited to the continental arctic tundra.

Gleyzems differentiated peaty-muck and peat tundra have the profile O-G-3A2-G-2B(G1B)-⊥G. The peaty and peaty-muck O horizon (5–10 cm) is underlain by gleyed mineral material over permafrost at a depth of 1.0–1.5 m. The upper part of the mineral horizon (up to 50–60 cm) is periodically oxidized and eluvial, as compared with the lower one, which is continuously anaerobic and is illuvial above the permafrost. There is clear differentiation in clay content, iron and aluminium oxides, and also in the amount of organic matter accumulated above the permafrost (frost retinization). The profile is acid throughout and significantly base-unsaturated. These soils generally overlie mild continental permafrost and deep permafrost in the southern tundra and forest-tundra with dissected relief.

Gleyzems peaty and peaty-muck tundra have the profile O1(O2)-Gd↓G. The raw humus organic horizon O (5–15 cm) overlies a thoroughly homogeneous gleyed and chemically undifferentiated mineral layer that is sometimes thixotropic, underlain by permafrost at the depth of 80–100 cm. Seasonally frozen layers are fully thawed out by the end of the warm period. Such soils occur in the continental permafrost regions in the middle and southern tundra of the Kolsky peninsula.

Gleyzems peaty-muck taiga (synonyms: peaty-muck taiga Gley, peaty-muck humus taiga Gleyzems) have the profile O1(2)-G(Gd)-G(C). The O1(2) peaty-muck horizon (10-15 cm) is interbedded with undifferentiated (morphologically and chemically), gleyed mineral layers with dirty grey, brown, and light brown colors. Thixotropic and cryogenic deformation phenomena are common. Permafrost at 60–100 cm depth constrains soil profile development. The reaction is acid or slightly acid. The soils are formed on loamy-clay rocks (sometimes stones) in the middle and northern plains and mountainous taiga of East Siberia and the Far East.

Gleyzems weak-gley peaty-muck taiga have the profile O3-Gd-G(C). The Humus-peaty humic O3 horizon (10-15 cm) is interbedded with undifferentiated (morphologically and chemically), very wet mineral gley layers of dirty-grey or brown color. Soil development is limited by permafrost (usually to about 1 m). Features indicative of cryogenic mixing are common in the soil profile. The soil reaction is acid to slightly acid. The soils are developed on loamy and stony-loamy parent materials in plains and mountainous middle and northern taiga of East Siberia and the Far East.

6.3 Regosols

This major grouping occupies 4.37 million ha, or 0.3% of the land area of Russia (*Table 5.1*). It occurs in the northern Taimyr peninsula, in the southern part of the Novaya Zemlya islands, and the northern part of the Novosybirsk islands (*Figure 6.1*).

In general, Regosols are formed from loose material underlain by hard rock. They are formed on unconsolidated parent materials, exclusive of coarse-textured deposits more than 100 cm deep (Arenosols) that show fluvic properties (Fluvisols); additionally, they have no diagnostic horizons other than an ochric or umbric A horizon, they do not have gleyic properties within 50 cm of the surface, they do not have characteristics that are diagnostic for Vertisols or Arenosols, and they do not have salic properties.

This major soil grouping does not appear in the soil classification of Russia. It corresponds to a broad collection of weakly developed soils that are dispersed among other kinds of soils. Only one FAO soil unit and correlated class from *SMR* are recognized.

- Gelic Regosols (RGi)

  – Arctic soils (Cryozems)

The Regosols Calcareous (RGc) soil unit occupies 0.02 million ha, which corresponds to $<$0.1% of the land area of the country. It corresponds to the Arctic calcareous soils (Cryozems).

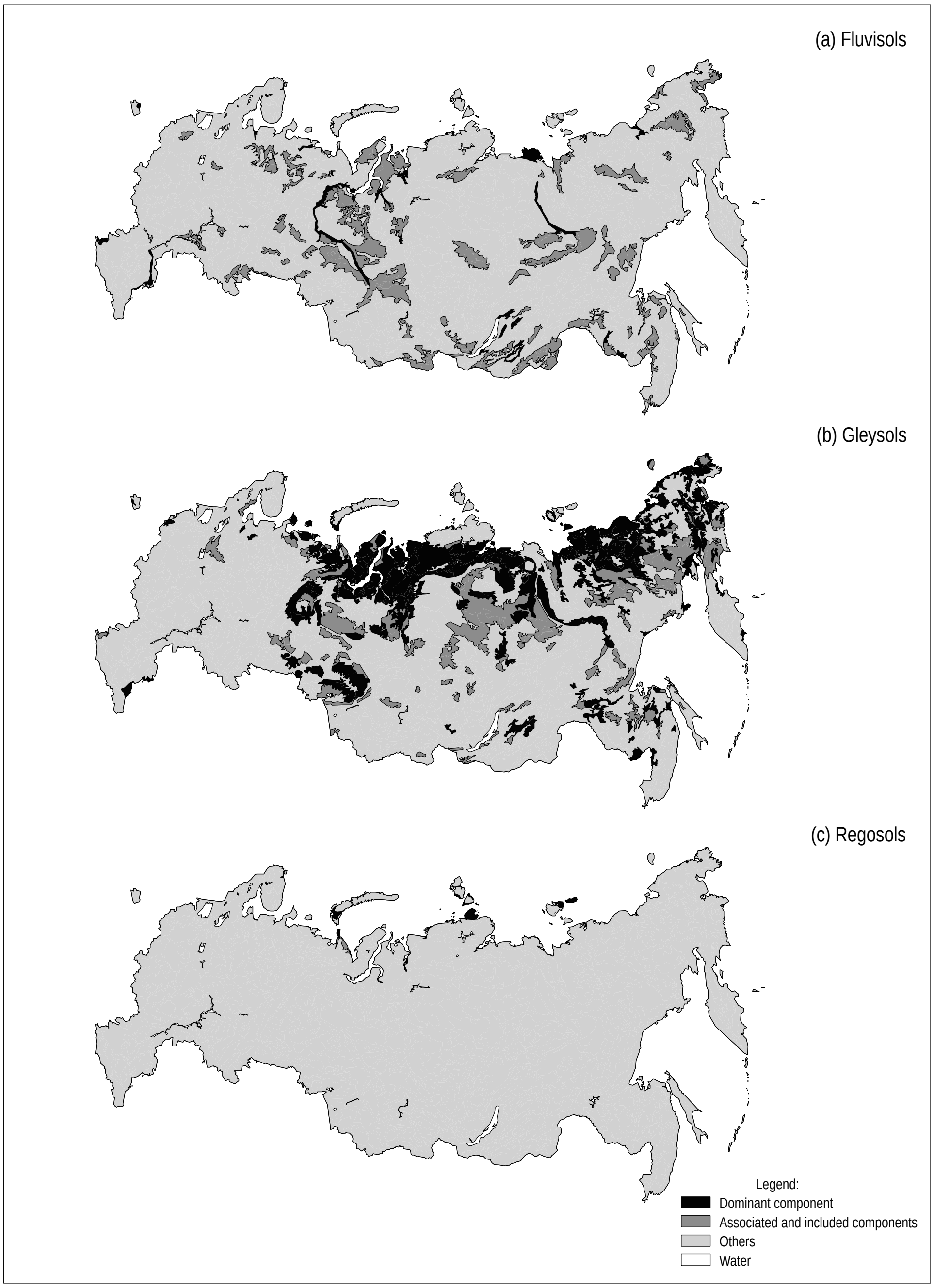

Figure 6.1. Major soil groupings of Russia: (a) Fluvisols, (b) Gleysols, and (c) Regosols.

Arctic calcareous soils (Cryozems) have the profile A1ca-Cca ↓Cca. A very shallow (1-2 cm) humic horizon with humus content of about 1% overlies an undifferentiated ungleyed layer. Dry or slightly iced permafrost is present. These soils have weakly alkaline pH and efferverscence with 10% HCl. Such soils are common in “pockets” and spots in the sparse vegetation patches in the northern and central part of the arctic zone.

The Gelic Regosols (RGi) soil unit occupies 4.35 million ha, which corresponds to 0.3% of the land area of the country. It corresponds to the Arctic desert, Arctic cryozems, and Arctic hydromorphic non-gleyic sols.

Arctic desert soils have the profile C(Cp)-C?-Cca. These soils manifest undifferentiated non-gleyic mass without an organogenepoius horizon, and have dry permafrost and desert pavements on the soil surface. These soils usually have carbonates and soluble salts. Such soils are common in the northern and central part of the arctic zone. Arctic soils (Cryozems) have the profile A1-C ↓Cca. A very shallow (1-2 cm) humic horizon with humus content of about 1% overlies an undifferentiated ungleyed layer. Dry or slightly iced permafrost is present. These soils have weakly alkaline pH and usually efferverscence with 10% HCl. Such soils are common in “pockets” and spots in the sparse vegetation patches in the northern and central part of the arctic zone.

Arctic hydromorphic non-gleyic sols have a profile similar to those of Arctic soils and saturated with water. Soil profile do not manifests gleyic properties.

Such soils are common in northern and central part of the arctic zone.

6.4 Leptosols

This major soil grouping occupies 144.54 million ha, or 8.7% of the land area (*Table 5.1*). It is widespread (*Figure 6.1*) particularly in the Ural and Altai mountains, East Siberia, and the northeastern part of the country.

In general, Leptosols are shallow, weakly developed soils and are defined in the following way: They are either limited in depth within 30 cm of the surface by continuous hard rock, highly calcareous material (calcium carbonate equivalent of more than 40%), or a continuous cemented layer; or they have less than 20% of fine earth over a depth of 75 cm from the surface; or they have no diagnostic horizons other than a mollic, umbric, or ochric A horizon, with or without a cambic B horizon.

This major soil grouping is not distinguished in the soil classification of Russia. In general, it corresponds to a broad collection of shallow soils that are dispersed among other soil types. The following FAO soil units and their correlated classes from *SMR* are defined.

- Leptosols Dystric (LPd)

  - High mountain baldy-soddy
- Leptosols Rendzic (LPk)
  - Muck-calcareous tundra
  - Muck-calcareous
  - Sod-calcareous
- Leptosols Mollic (LPm)
  - Chernozems shallow
  - Mountain forest chernozemic
  - Mountain meadow-steppe
  - Mountain-meadow chernozem-like
- Leptosols Umbric (LPu)
  - Mountain forest-meadows
  - Mountain-meadow soddy
- Leptosols Lithic (LPq)
  - Mountain primitive (less than 10 cm deep)
- Leptosols Gelic (LPi)
  - Spot soils (saline, arctic, and tundra) with permafrost.

6.4.1 Leptosols Dystric (LPd)

This soil unit occupies 7.32 million ha, which corresponds to 0.4% of the land area of the country, or 5.1% of the major soil grouping area. The soils have an ochric A horizon and a base saturation (by NH_4O_{Ac}) of less than 50% in at least some part of the soil; they do not have hard rock or a continuous cemented layer within 10 cm nor permafrost within 200 cm of the surface. This soil unit correlates to High mountain sod-baldy soils.

High mountain sod-baldy soils have the profile O-A1p-Bp- BCp-Cp. The O horizon (1–2 cm) is distinguished by weakly decomposed litter material. The A1p horizon (3–13 cm) has a brownish-grey or dark-brown color, loose structure, and stony loam texture. The muck in these horizons contains about 11% humus. The ratio between humic and fulvic acids (Cha:Cfa) is 0.7–0.8. The Bp horizon (15–20 cm) has a loamy-skeletal texture with abundant gravel and rock fragments. The yellowish-brown-colored fine earth fills the space between rock fragments and covers the upper surfaces of stones and boulders. The undersides of rock fragments and gravel are usually covered by iron-humus films. The fine earth contains 1.5–4.0% humus. The BCp horizon is a gradual transition to eluvial and eluvial-deluvial material derived from hard rocks. Gley properties are absent or weak, and cryoturbation, solifluction, and frost sorting are well developed. Base saturation is high.

Such soils are formed in cold, dry climates of highlands under driade and cobresia grasslands, and are widespread on well-drained surfaces of the Altai, Sayan, and Trans-Baikal mountains.

6.4.2 Leptosols Rendzic (LPk)

This soil unit occupies 87.0 million ha, which corresponds to 5.2% of the land area of the country, or 60.2% of the major soil grouping area. The soils have a mollic A1 horizon that contains or immediately overlies calcareous material with a calcium carbonate equivalent of more than 40%; they do not have hard rock or a continuous cemented layer within 10 cm nor permafrost within 200 cm of the surface.

This soil unit correlates with Muck-Calcareous tundra, Muck-calcareous, and Sod-calcareous soils.

Muck-Calcareous tundra soils have the profile O3-Bpca-BCcap-Ccap. The organic peaty humus O3 horizon (up to 10 cm thick) covers a very stony layer with a small amount of dark-colored silt material. Pieces of calcareous rock are covered by dark films of organic-mineral compounds. Silt of the organic horizon is leached of carbonates, while that of the subsoil is partly leached or still contains carbonates. The profile is very stony and shallow. The permafrost is dry or absent.

These soils are formed on exposed solid calcareous rocks in the tundra zone.

Muck-calcareous soils have the profile O-AO-A1pca-BCcap-Dca. They have a shallow 20–30 cm profile. The O horizon, characterized by weakly decomposed peaty litter (3–5 cm), overlies a thin (1–2 cm) organo-mineral AO horizon, consisting of differently decomposed fractions of organic matter with small additions of silt and calcareous debris material. The muck organic horizon A1pca is easily distinguished. It is dark grey or dark brown, rich in calcareous debris, though silty material is often leached of carbonates. Rock pieces are strongly effervescent. The transitional horizon to parent rock, Bccap, is lighter in color, and the silt and calcareous debris material are strongly effervescent. This merges into weakly weathered calcareous eluvium at the depth of 20–30 cm, which is underlain by massive calcareous rocks (horizon Dca). The Apca horizon has a well expressed microstructure, a soil reaction near neutral, a humus content from 8% up to 22%, a Cha:Cfa ratio close to one (0.8–0.9), high base saturation (95–98%), and a fairly high cation exchange capacity (35–50 cmol[+] kg–1). The profiles do not show any differentiation in texture or total chemical composition. Such soils are common in humid regions and forest-tundra, and in the northern and middle taiga. They are formed on calcareous rocks under dark and light (larch) coniferous forests with moss groundcover, in plains or mountains of the northern taiga and forest-tundra regions. The humid and moderately cold climate, together with a percolating water regime, favors rapid carbonate leaching. Therefore, typical forms of calcareous Muck soils are quickly transformed into podzolic soils with residual carbonates.

Sod-calcareous soils have the profile O-AO-A1pca-Bcap-Ccap-Dca. The litter horizon (O1, 1–5 cm) is often present, consisting of decomposed leaf fall. The AO horizon contains a significant amount of mineral particles. The humus horizon (10–35 cm) is dark with granular structure and contains calcareous debris. The transitional Bcap horizon has reddish-brown or greyish-brown color and granular-subangular blocky structure. It is enriched in clay, compacted in its upper part, and has an angular blocky (beech-nut) structure in leached and podzolized soils. The thickness of the Bcap horizon varies significantly (5 cm to 40 cm) and depends on the degree of soil profile development. The Ccap horizon consists of calcareous eluvium that is weakly transformed by pedogenesis. A Dca horizon is often absent due to the thin loose eluvium layer and close-bedded hard calcareous rocks. These soils are similar to calcareous peaty Muck (by soil reaction, strong aggregation, humus content, base saturation, absent or weak differentiation of texture, and total chemical composition throughout the profile, etc.). They differ from calcareous peaty Muck by a clearly expressed humus horizon, greater soil thickness caused by more intensive processes of soil formation, and, related to that, a deeper transformation of the mineral part of the soil.

These soils are formed on calcareous rocks in taiga (middle and southern taiga) and forest-steppe zones.

6.4.3 Leptosols Mollic (LPm)

This soil unit occupies 3.77 million ha, which corresponds to 0.2% of the land area of the country, or 2.6% of the major soil grouping area. The soils have a mollic A horizon that does not contain or immediately overlie calcareous material with a calcium carbonate equivalent of more than 40%; they do not have hard rock or a continuous cemented layer within 10 cm nor permafrost within 200 cm of the surface.

This soil unit corresponds to Chernozems shallow, Mountain forest chernozemics, Mountain meadow-steppe, and Mountain meadow-chernozem-like soil.

Chernozems shallow have the soil profile A1-A1B-BC(ca). The soil has a black, granular A1 horizon. The topsoil is slightly stony, and stoniness increases rapidly downward. The reaction is close to neutral in the upper part of the profile, and neutral in the lower part of the profile. The exchange capacity is 45–80 cmol(+) kg–1. These soils are formed from calcareous rocks in semihumid regions in the eastern Caucasus.

Mountain forest chernozemic soils have the soil profile O-A1-A1B-B(ca)-BCca,p. The humic horizon is up to 30 cm thick. It is dark-grey, crumby-granular with humus content of 9–16%. The humus is mainly humic acids. The B(ca) horizon is slightly compact and weakly structured. Carbonates are leached to different depths and form pseudomycelia, loose aggregates, and films on the undersurfaces of rock fragments. The texture becomes coarser with depth, and the lower part of the profile contains rock fragments. These soils differ from Chernozems by their higher humus content and higher percentage of fulvic acids. They are formed on the middle slopes of the Altai Mountains under broad-leaved open forests and grasslands.

Mountain meadow-steppe soils have the profile A1v-A1B-BC-C. They have a rather thin (5–15 cm), loose, sod horizon of a greyish-brown color, and are succeeded by a transitional weakly structured horizon, which is lighter in color and 20–40 cm thick. The soils contain a high proportion of rock fragments and, although the transition to parent rock is gradual, they have been included with the Leptosols. The loss on ignition in the upper horizons is 20–25%. They have slightly acid to neutral soil reaction (pH 5.5–7.5) and high base saturation (up to 70–80%). Such soils are formed on calcareous rocks in relatively dry regions of the mountain meadow zone, transitional to mountain steppes, in the eastern Caucasus, and the mountains of southern Siberia.

Mountain meadow-chernozem-like soils have the profile A1-A1B-BC(ca)-C(ca). The soil has a black granular sod horizon, is succeeded by a distinctive grey transitional horizon, and has a yellowish parent material. The topsoil is slightly stony, and stoniness increases rapidly downward. The soil reaction is slightly acid (pH 6.0–6.5) in the upper part of the profile, and neutral or alkaline (pH 7.5–8.2) in the lower part of the profile. The exchange capacity is 45–80 cmol (+) kg–1.

These soils are formed on eluvium and eluvio-deluvium of limestone and other calcareous rocks in humid regions, and sometimes on basic and ultrabasic rocks in dryer regions. They occur in the eastern Caucasus.

6.4.4 Leptosols Umbric (LPu)

This soil unit occupies 5.62 million ha, which corresponds to 0.3% of the land area of the country, or 3.9% of the major soil grouping. These soils have an umbric A horizon, and they do not have hard rock or a continuous cemented layer within 10 cm or permafrost within 200 cm of the surface. The soil unit correlates with mountain Forest-meadow soils and mountain-meadow Sod soils.

Mountain forest-meadows soils have a profile O-A1-A1B- (Bp)-Cp. A thin layer of litter O covers a grey or dark-grey colored, crumby-granular structured, humus-accumulative A1 horizon, which gradually passes into eluvium or eluvio-deluvium and hard rock. The color of transitional horizons is brownish-grey or brown, depending on the color of the parent rock. The profile is usually very stony. An illuvial Bp horizon is sometimes identified in deep varieties of these soils. The upper part of the soil profile has a slightly acid or neutral soil reaction, while the lower parts are slightly acid or acid. The humus content in the uppermost horizon varies from 7–12%. The exchange complex is highly saturated and total exchangeable bases comprise 20–25 cmol(+) kg–1 of soil. The organic matter is usually humic acids. These soils are formed in the lower parts of subalpine sparse forests of various types in the Caucasus, southern and middle Urals, and Altai Mountains.

Mountain-meadow soddy soils have profiles similar to the mountain-meadow peaty Sod soils, but differ in the character of sod (loss on ignition is 20–30%) and in being less acid (pH 4.6–5.5). They are formed on noncalcareous rocks under subalpine meadows in the Caucasus.

6.4.5 Leptosols Lithic (LPq)

This soil unit occupies 34.42 million ha, which corresponds to 2.1% of the land area of the country, or 23.8% of the major soil grouping area. The soils are limited in depth within 10 cm of the surface by continuous hard rock or a continuously cemented layer. This soil unit corresponds to mountain primitive soils.

Mountain primitive soils have a weakly developed profile O-Bh,p-Cp with total depth up to 30 cm. A peaty litter (2–5 cm) covers a dark-brown, 6–10-cm-thick B horizon colored by illuvial humus. This horizon gradually passes into stony eluvium and eluvio-deluvium of hard rocks. The content of humus in the fine earth of the Bh,p horizon is 8–10%. The soil reaction is very acid (pHKCl = 3.6–3.8); hydrolytic acidity is 20–50 cmol(+) kg–1.

Such soils are found in southern East Siberia.

6.4.6 Leptosols Gelic (LPi)

This soil unit occupies 6.41 million ha, which corresponds to 0.4% of the land surface, or 4.4% of the major soil grouping area. Permafrost occurs within 200 cm of the surface. This soil unit correlates with Spot soils (saline, arctic, and tundra).

Spot soils (saline, arctic and tundra) have the profile Cd-⊥BC. They are formed on unvegetated spots in all natural subzones of tundra. They do not have an organic horizon and present an undifferentiated, nongleyed mass with the permafrost within 50 cm of the surface.

6.5 Arenosols

This major grouping occupies 5.91 million ha, or 0.4% of the land area of Russia (*Table 5.1*). It is scattered particularly over the south of the European part of Russia and in the southern part of the West Siberian plain (*Figure 6.1*).

In general, Arenosols refer to weakly developed coarse-textured soils. The texture is coarser than sandy loam, or is sandy loam with less than 8% clay to a depth of at least 100 cm from the surface; materials that show fluvic or andic properties are excluded, and there are no diagnostic horizons other than an ochric A horizon or an albic E horizon.

This major soil grouping is not distinguished in the soil classification of Russia. It corresponds to the assemblage of weakly developed soils formed from sands. Two FAO soil units are recognized, and the correlated classes from *SMR* are described.

- Arenosols Haplic (ARh)
  – Sierosands
- Arenosols Cambic (ARb)
  – Pine forest sands

6.5.1 Arenosols Haplic (ARh)

This soil unit occupies 0.33 million ha, which corresponds to less than 0.1% of the soil cover of the country. These soils show weakly developed A horizon; they are not calcaric and do not have lamellae of clay accumulation, ferralic properties, an albic E horizon within 50 cm of the surface, or gleyic properties within 100 cm of the surface.

This soil unit corresponds to Sierosands.

Sierosands have the profile A1-A1B-C. The humic horizon is characterized by lack of structure and a gray color gradually becoming paler downward. The humus content is rather low (2–4%). The cation exchange capacity varies from 10–15 cmol(+) kg–1 of soil. Carbonates are absent and the soil reaction is neutral throughout the profile. They occur in the Chernozem zone on sandy deposits.

6.5.2 Arenosols Cambic (ARb)

This soil unit occupies 5.58 million ha, which corresponds to 0.3% of the soil cover of the country. These soils show coloring or alteration characteristics of a cambic B horizon immediately below the A horizon; they are not calcaric and do not have lamellae of clay accumulation, ferralic properties, an albic E horizon within 50 cm of the surface, or gleyic properties within 100 cm of the surface.

Pine forest sands (sometimes slightly podzolized) have a weakly developed, shallow profile O-AO-AB-C. The organic O horizon (about 1 cm thick) consists of pine needle debris. The AO horizon is 1–3 cm thick and is slightly colored by humus. The horizon AB forms a gradual transition to the sandy parent material.

Slightly podzolized soils, with iron movement, commonly form associations with pine forest sands. They have small bleached mottles or quartz grains leached of iron coatings. Both soils are formed in well-drained relief from thick, sorted, windblown quartz sand deposits. They occur in the southern part of the taiga and forest-steppe zones under pine forests with sparse ground vegetation, consisting of dwarf bushes, mosses, and lichens.

6.6 Andosols

This major grouping occupies 16.28 million ha, or 1.0% of the land area of Russia (*Table 5.1*). It is common in the Kamchatka peninsula (*Figure 6.1*).

Andosols are formed from materials rich in volcanic glass and commonly have a dark surface horizon. They show andic properties to a depth of 35 cm or more from the surface and have a mollic or umbric A horizon that possibly overlies a cambic B horizon, or an ochric A horizon and a cambic B horizon. They have no other diagnostic horizons and they lack gleyic properties within 50 cm of the surface, all characteristics diagnostic for Vertisols, and salic properties.

The soils are subdivided into zones according to the frequency and intensity of deposition of the ash. Intensely active zones have frequent deposition and the soil consists of thin layers of fresh ash with some organic material. Moderately active zones have somewhat developed profiles with a thick humus horizon and weathering features. Slightly active means that ash falls are rare, the minerals are well-weathered, and horizons are well-developed.

The term ochre and ochric, used in the description of these soils, has the specific meaning of having an f(Bf) horizon or well-weathered properties with clay formation and abundant SiO_2 and R_2O_3.

The following FAO soil units are recognized with their corresponding soil groups in *SMR*.

- Andosols Haplic (ANh)
  - Volcanics ochre-banded
  - Volcanics dry-peaty
  - Volcanics light-ochre (including podzolized)
  - Volcanics ochre (including podzolized)
  - Volcanics podzolized-ochre
- Andosols Vitric (ANz)
  - Volcanics banded-ash
- Andosols Gelic (ANi)
  - Volcanics illuvial-humic tundra

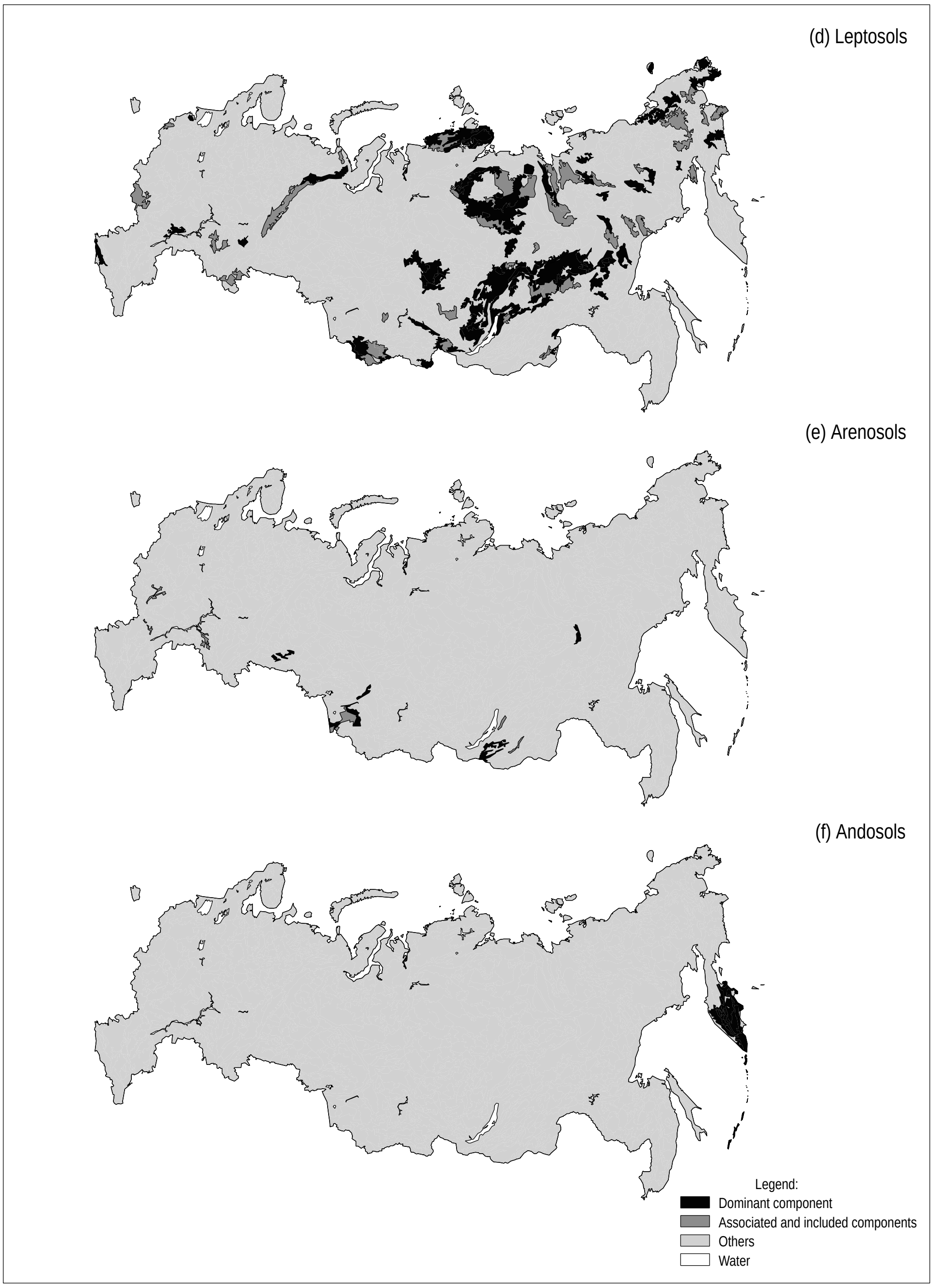

Figure 6.1. Major soil groupings of Russia: (d) Leptosols, (e) Arenosols, and (f) Andosols.

6.6.1 Andosols Haplic (ANh)

This soil unit occupies 11.18 million ha, which corresponds to 0.7% of the land area, or 68.7% of the Andosols major soil grouping.

These soils have an ochric A horizon and a cambic B horizon, with a smeary consistency and a texture that is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; they do not have gleyic properties within 100 cm of the surface or permafrost within 200 cm of the surface.

This soil unit correlates with Volcanics ochre-banded, Volcanics dry-peaty, Volcanics light-ochre (including podzolized), Volcanics ochre (including podzolized), and Volcanics podzolized-ochre.

Volcanics ochre-banded soils have a composite poligenetic soil profile, consisting of between four and 10 simple subprofiles (120–180-cm-thick altogether) developed on volcanic ash. All of them have organic and illuvial-weathered horizons. The organic horizons become weaker downward while the illuvial-weathered features become stronger. The lowest horizons have an ochre color and properties of ochre horizons in the subsoil. These soils develop in volcanic ash deposits under forest vegetation on the Kamchatka peninsula.

Volcanics dry-peaty soils have composite poligenetic soil profiles, consisting of several young, undeveloped profiles. Peaty organic and brown illuvial-humus horizons exist in every profile. The most recent organic horizon is dry peaty (15–25 cm). Such soils are acid and base-unsaturated. They occur under dwarf pine vegetation of the Kamchatka peninsula on moderately active volcanic ash deposited as volcanic sands and ashes falling from the air.

Volcanics light-ochre (including podzolized) soils have the profile O-AO-A2-Bf,h (Bh)-C. They are characterized by a buried humus horizon with amorphous SiO_2 and R_2O_3 in transitional horizons. These soils are formed in the central Kamchatka depression under grassy birch forests.

Volcanics ochre (including podzolized) soils differ from typical ochre Volcanic ones by the presence of a 3–6-cm-thick, loose A2 horizon, which is composed of a light grey-colored (in some places bleached), loamy sand or sandy loam, and formed under forest litter or a raw humus horizon. They are composed of organic debris and volcanic ash particles bleached from the surface down. These soils occur in a moderately active volcanic ash deposition zone under grassy stone-birch forests on the Kamchatka peninsula.

Volcanics podzolized-ochre soils have a soil profile close to that of illuvial-humus podzols. They have a very bright colored B horizon and a buried humus horizon (or its fragments) with a very high humus and amorphous SiO_2 and R_2O_3 content in the lower horizons. The soil profile is developed on aeolian volcanic material. Secondary minerals are represented by allophane and amorphous organo-mineral compounds.

These soils are formed in the slightly active, shallow volcanic ash deposition zone under grassy birch forests on the Kamchatka peninsula.

6.6.2 Andosols Vitric (ANz)

This soil unit occupies 2.73 million ha, which corresponds to 0.2% of the land area of the country, or 16.8% of the Andosols major soil grouping area. They are characterized by lacking a smeary consistency or by having a texture that is coarser than silt loam on the weighted average for all horizons within 100 cm of the surface, or both; they do not have gleyic properties within 100 cm of the surface or permafrost within 200 cm of the surface.

This soil unit correlates to Volcanic banded-ash soils.

Volcanics banded-ash soils have profiles that consist of many superimposed profiles (usually 10–15). Each original profile has a raw humus organic horizon and a layer of volcanic ash only slightly changed by pedogenesis or weathering. The soil reaction is acid or slightly acid. Humus content, cation exchange capacity, and other properties depend very much on the properties of the individual layers.

These soils occur in an intensely volcanic ash deposition zone under coniferous and birch forests on the Kamchatka peninsula.

6.6.3 Andosols Gelic (ANi)

This soil unit occupies 1.73 million ha, which corresponds to 0.1% of the land area of the country, or 10.6% of the Andosols major soil grouping area. Permafrost exists within 200 cm of the surface; this corresponds to Volcanic illuvial-humus tundra soils.

Volcanics illuvial-humic tundra soils have a three-dimensional, anisotropic profile. They are formed in conditions of frost mound relief. No horizons are recognized other than recent peaty-mud and buried peaty horizons (usually two). The latter are folded and torn by cryogenic processes. These soils are acid and characterized by the high content of eluviated humus and amorphous sesquoxides. They are formed in areas of volcanic deposits in a moderately active volcanic ash deposition zone under tundra vegetation, on the Kamchatka peninsula.

6.7 Vertisols

This major grouping occupies 0.21 million ha, or $<$0.1% of the soil cover of Russia (*Table 5.1*). It is confined to the northern Caucasus (*Figure 6.1*).

Vertisols have pronounced features related to churning of the surface layer. They have, after the upper 18 cm have been mixed, 30% or more clay in all horizons to a depth of at least 50 cm; cracks that develop from the soil surface downward that at some period in most years, are at least 1 cm wide to a depth of 50 cm (unless the soil is irrigated); and intersecting slickensides, or wedge-shaped or parallelepiped structural aggregates, which form 25–100 cm below the surface and may have gilgai at the surface.

Only one soil unit is identified (Vertisols Eutric), and corresponding to it in *SMR* are Chernozems compact, Meadow-chernozemic compact, Meadow compact, and Alluvials compact.

6.7.1 Vertisols Eutric (VRe)

This soil unit occupies 0.21 million ha, which corresponds to $<$0.1% of the land area of the country. The base saturation (by NH_4O_{Ac}) is 50% or more at a depth of 20–50 cm from the surface; there is no calcic or gypsic horizon.

Chernozems Compact have the profile A1-A1B(ve)-B(ve)-Bca-Cca. They are identified by the presence of a compact horizon (not deeper than 100 cm) with extremely high bulk density when dry, and highly plastic when moist. They are characterized by slow percolation. The humus horizon has tonguing along the wavy lower boundary. The B horizons have a friable, coarse, subangular to prismatic structure and abundant dark mottles on ped surfaces. These soils are identified by a very high content of clay (up to 80%), a significant amount of unaggregated clay, and a high cation exchange capacity (up to 65 cmol[+] kg–1). The proportion of humic acids that is linked to sesquoxides is high, forming a humus-sesquioxide compound. The soils have no features of solonetzic processes.

Chernozems Compact develop from clayey deposits in depressed sites in the southern region of the European part of the country.

The group of soils Meadow-chernozemic compact, Meadow compact, and Alluvials compact are not described as they occupy a negligibly small area.

6.8 Cambisols

This major grouping occupies 212.03 million ha, or 12.7% of the land area of Russia (*Table 5.1*). It is widespread particularly in the northern Caucasus, East Siberia, and Far East (*Figure 6.1*).

These soils have a cambic B horizon and no other diagnostic horizons other than an ochric or an umbric A horizon, or a mollic A horizon overlying a cambic B horizon with a base saturation (by NH_4O_{Ac}) of less than 50%; they do not have salic properties, characteristics diagnostic for Vertisols or Andosols, nor gleyic properties within 50 cm of the surface.

The soil units and corresponding soil groups in *SMR* are described below.

- Cambisols Eutric (CMe)

- Brownzems residual-calcareous
- Brownzems weakly unsaturated
- Brownzems weakly unsaturated podzolized
- Sod-brownzems weakly unsaturated and saturated

- Cambisols Dystric (CMd)
  - Brownzems acid
  - Brownzems acid podzolized
  - Brownzems raw-humic
  - Brownzems raw-humic illuvial-humic
  - Granuzems
  - Sod-brownzems acid
  - Sod-brownzems ferruginous
- Cambisols humic (CMu)
  - Brownzems muck-humus-accumulative
- Cambisols Calcaric (CMc)
  - Cinnamonics calcareous
- Cambisols chromic (CMx)
  - Cinnamonics typic
- Cambisols gleyic (CMg)
  - Brownzems gleyic and gley
  - Brownzems raw-humic gley
  - Granuzems gley
- Cambisols gelic (CMi)
  - Pales mucky soils
  - Pales typical soils
  - Pales podzolized
  - Pales solodic
  - Grey-pales
  - Pales calcareous
  - Taiga peaty-muck high-humic nongleyic
  - Sod-brownzems gleyic and gley

6.8.1 Cambisols Eutric (CMe)

This soil unit occupies 25.45 million ha, which corresponds to 1.5% of the land area of the country, or 12.0% of the Cambisol major soil grouping area.

These soils have an ochric A horizon and a base saturation (by NH_4O_{Ac}) of 50% or more at 20–50 cm from the surface, but are not calcareous within this depth; they have a cambic B horizon that is brown to red (the rubbed soil having a hue of 7.5YR and a chroma of more than 4, or a hue redder than 7.5YR); they do not have vertic properties, ferralic properties in the cambic B horizon, gleyic properties within 100 cm of the surface, or permafrost within 200 cm of the surface.

The Cambisols Eutric soil unit correlates with Brownzems residual-calcareous, Brownzems weakly unsaturated, Brownzems weakly unsaturated podzolized, Pales mucky, Pales typical, and Sod-brownzems weakly unsaturated and saturated.

Brownzems residual-calcareous have the profile O-AO-Bm-BmCpca-Ccap. The humus horizon A1 has a black or brownish-black color with a subangular or angular blocky (beech nut-like) structure. The altered Bm horizon is of reddish-brown color, compact, and shows clay movement and neoformation. The transitional Bm-Cpca horizon contains calcareous fragments and gradually merges with increasing stoniness into calcareous parent rock. There is a well developed clay profile with uniform distribution of clay, sesquoxides, and SiO_2; a neutral or near-neutral reaction in the A1 and Bm horizons; high cation exchange capacity and slight base unsaturation (20- 30%) in the topsoil; a high humus content (12–16%) in the A1 horizon with a gradual decrease downward; and a significant content of humic acids and dominant calcium-humates.

These soils are formed on eluvio-deluvium from calcareous parent rocks in the broad-leaved forest zone.

Brownzems weakly unsaturated have a profile similar to acid brown forest soils. They differ from them in that they are slightly acid (pH KCl 4.5–6.0), and have significantly higher base saturation (40–60%) and cation exchange capacity (12–20 cmol[+] kg–1, and the organic matter composition has significant quantities of a humus fraction linked with Ca_2+ as humin). Such soils are widespread in the southern Far East.

Brownzems weakly unsaturated podzolized have the profile O1-AO-A1-A1A2-Bm,t-BmC-C, which is similar to that of acid brown forest podzolized soils. They are similar to slightly unsaturated brown forest soils in some chemical properties (acidity, low base saturation, cation exchange capacity, humus composition). They differ from them in color and texture differentiation of the profile, and also by the weakly developed profile differentiation of the total chemical composition and amorphous Fe_2O_3. These soils occur in the southern Far East.

Sod-brownzems weakly unsaturated and saturated have a profile similar to acid sod-brown forest soils. They are identified by their neutral or slightly acid reaction and high base saturation. They are found in the same regions as Brownzems.

6.8.2 Cambisols Dystric (CMd)

This soil unit occupies 68.98 million ha, which corresponds to 4.1% of the land area of the country, or 32.5% of the Cambisols major soil grouping area.

These soils have an ochric A horizon and a base saturation (by NH_4O_{Ac}) of less than 50% at 20–50 cm from the surface; they lack vertic properties, ferralic properties in the cambic B horizon, gleyic properties within 100 cm of the surface, and permafrost within 200 cm of the surface.

The Cambisols Dystric soil unit correlates with the following soil groups in *SMR*: Brownzems acid, Brownzems acid podzolized, Brownzems raw-humic, Brownzems raw-humic illuvial-humic, Granuzems, Pales podzolized, Pales solodic, Sod-brownzems acid, and Sod-brownzems ferruginous.

Brownzems acid have the profile O1-AO-Bm-BmC-C. The O1 horizon is thin (1–3 cm), and formed by forest litter from trees and grasses. The AO organo-mineral horizon (1–3 cm thick) is grey and loose and contains from 30–70% (by bulk) organic matter in different stages of decomposition; the AO horizon is predominantly mixed with the mineral part of the soil and easily separated from it. The A1 horizon has a greyish-brown color, granular-subangular structure, and contains from 3–8% humus. The Bm altered horizon is pale-brown, is more clayey and compact, and sometimes has weakly expressed illuviation. It gradually merges into parent rock. These soils are identified by the weak differentiation in the profile; very weakly expressed (or nonexistent) redistribution of finely dispersed silicate material; a strongly acid reaction and low base saturation (70- 90%) of the topsoil; fulvate humus tightly linked with the mineral fraction, and predominantly humic acids linked to sesquioxides; a narrow C:N ratio (8–10); and a high content of amorphous and crystallized iron and aluminium compounds in the humus horizon (A1).

These soils are developed on stony silicate substrates in flat or mountainous terrain under broad-leaved and mixed coniferous/broad-leaved forests in a humid and moderately warm climate. Accordingly, there is significant nutrient recycling and a relatively high rate of weathering, leading to alteration of the clay throughout the profile, and a release of iron from primary minerals. Such processes play an important role in humification and aggregation.

These soils are found in the mountainous regions of southern Russia and the Far East.

Brownzems acid podzolized have the profile O1-AO-A1-A1A2-Bm,t-BmC-C. They are similar to acid Brownzems in acidity, low base saturation, cation exchange capacity, humus content, and composition and distribution in the profile. Podzolization is shown by color and texture, and by weak differentiation of both amorphous and crystallized sesquioxides without noticeable illuviation in the Bm horizon. Gleying features (vague pale blue-grey and brownish mottles and small friable manganese-iron nodules) may occur in the lower part of the soil profile.

These soils are formed in the same regions as acid Brownzems from relatively less stony and more weathered loamy eluvium and eluvio-deluvium of silicate rocks.

Brownzems raw-humic have the profile O1-AO-A1(A1A2)-Bm-BmC-C. The O1 horizon is weakly decomposed forest litter. The AO horizon (3–5 cm) has greyish-brown color and consists of partly decayed litter with additions of mineral particles. In the lower part of the horizon, this material is humified. The A1 horizon (5–10 cm) has a dark grey or brownish-grey color, loamy texture, fine subangular structure, and contains from 7–15% humus.

Podzolized variants of these soils have a shallow (2-3 cm) A1A2 horizon below the A1 horizon, with features of eluviation. The Bm horizon has a brown color, loamy and clay loamy texture, and compact consistency. It shows signs of alteration and clay neoformation and movement. The horizon gradually merges into parent rock. The typical properties are: weak differentiation into soil horizons, and the absence or weak redistribution of total R_2O_3 without noticeable illuviation in the Bm horizon. The humus is always humate-fulvate (Cha:Cfa equal to or less than 1). The fraction of humic acids linked to Ca is predominant. The cation exchange capacity of the mineral part is low. Oxalate-soluble Fe (extracted by the Tamm method) is usually evenly distributed in the soil profile or, more rarely, increases downward by accumulation.

Brownzems raw-humic are developed in well-drained, stony, loamy eluvio-deluvium from hard silicate rocks and ancient alluvial deposits, under larch forests with bushes and grass ground vegetation, which provides conditions of high organic matter input with a relatively slow rate of humification. These conditions result in the formation of mobile humus compounds. The soil is seasonally frozen until the first half of the vegetation growth period. These soils are found in mountainous and plain regions in the southern Far East.

Brownzems raw-humic/illuvial-humic have the profile O(AO)-A1-A1A2-Bm,f,h(Bh,m)-C. The shallow (3–5 cm), weakly decomposed forest litter (O horizon) sometimes overlies a brownish-black, structureless, raw humus AO horizon (2–3 cm). The A1 horizon has a dark greyish-brown color, stony-loamy texture, and granular-subangular structure. Sometimes an A1A2 horizon is present and represented by a lighter brown color. The humus horizon is underlain by the Bm,f,h horizon, which has rusty-ochre or reddish-brown colors, stony-loamy texture, and a blocky (beech nut-like) structure with signs of humus illuviation.

These soils are characterized by three factors:

- weak differentiation of soil horizons (strongly acid in the upper part and acid in the lower part), a high humus content in the AO (15–28%) and A1 horizon (8–10%), and deep humus illuviation that gradually decreases downward into the mineral soil;
- organic matter having a fulvate humus character and prevalent humin acids of the first fraction;
- low content of bases (3–8 cmol[+] kg–1), high base saturation (60–90%), and relatively weak differentiation of total iron, aluminium, and silica dioxide.

The humus horizon is sometimes enriched in quartz and is relatively poor in iron and aluminium because of podzolization. The highest iron and aluminium content (extracted by the Tamm method) is mainly in the humus horizon.

These soils are formed from stony-loamy eluvium of sedimentary and igneous rocks under coniferous forests with dead pine needles, lichen, and moss groundcover.

Granuzems have the profile O1-AO-B-BC -BCg-Cg. The surface horizon consists of forest litter and is up to 10 cm thick, with its lower part characteristically peaty-humus material. The topsoil is brown, loose, well aggregated with a fine subangular and rounded (granular) structure, and is approximately 20–30 cm thick. It gradually merges into a platy horizon with a dirty brown color up to 50 cm thick. Below it (80–100 cm), features of gleying are marked. The topsoil is acid or slightly acid and the subsoil is close to neutral. There is no differentiation of texture or total chemical composition. Amorphous R_2O_3 compounds are accumulated in the topsoil.

These soils are formed from rich, loose, loamy deposits developed by weathering and redeposition from basic rocks in the northern or, more rarely, the taiga regions of middle Siberia.

Sod-brownzems acid have the profile O-A1-Bm-C. The forest litter O horizon is 1-3 cm thick. The A1 horizon is 5–10 cm thick and has a grey color and subangular blocky structure. It gradually merges into a brown, altered horizon Bm. These soils are acid and unsaturated. The profile is undifferentiated by texture and total chemical composition. The organic matter (4–8%) in the A1 horizon is humate. The maximum amorphous R_2O_3 content is in the humus horizon. Such soils are formed from fine-textured or stony deposits in southern (partly middle) taiga subzones with a severe continental climate.

The Sod-brownzems ferruginous soil profile is similar to acid Sod-brownzems soils, but has good aggregation and a greater iron content in the silt and clay material. These soils are formed in the same regions as acid Sod-brownzems soils, but are derived from the weathering products of basic rocks.

6.8.3 Cambisols Humic (CMu)

This soil unit occupies 0.6 million ha, which corresponds to less than 0.1% of the land area of the country, or 0.3% of the major soil grouping area.

The soils have an umbric A horizon or a mollic A horizon overlying a cambic B horizon with a base saturation (by NH_4O_{Ac}) of less than 50%; they do not have vertic properties, ferralic properties in the cambic B horizon, gleyic properties within 100 cm of the surface, or permafrost within 200 cm of the surface.

The Cambisols Humic soil unit correlates with the following soil groups in *SMR*: humus-accumulative muck Brownzems, grey pale-yellows, taiga nongleyic high-humic peaty-muck.

Brownzems humus-accumulative muck have the profile O-AOA1-A1-A1h-A1Bh-BhC-C. The O horizon is formed by weakly decomposed forest litter from bamboo and stone birch leaves and pine needles. The OAA1 horizon (4–5 cm) has a dark brown color and consists of raw organic materials with additions of mineral clay particles. The A1 horizon (10–15 cm) is dark brown and consists of accumulative-muck loam with some stones and debris of quartzite rocks. It has a friable, fine porous structure and contains up to 35% well-decayed organic matter, formed in situ due to strong Kuril's bamboo root decomposition. The A1h horizon (30–40 cm) is of dark, almost black, and reddish colors, is loamy with much plant debris, and has subangular to fine granular structure. It has abundant root penetration from Kuril's bamboo, contains up to 43% well-decomposed organic matter, and is of an accumulative-illuvial origin (black, formed in situ, subangular-fine granular organo-mineral peds and rock debris, covered with organo-ferruginous films and streaks of illuvial chemical origin). The ABh horizon (10–20 cm) is transitional to the illuvial-humus one. It is a dark brown, stony loam with abundant rock debris containing up to 20% humus. It differs from the A1h horizon by the decreasing humus accumulation process (in situ) and a significant increase in the humus illuviation process. The illuvial humus horizon Bh (15–20) is a brown, sandy loam with a very fine subangular structure. Loose silt material forms sparse patches among rock debris and contains up to 3% illuviated humus.

These soils are acid (pH KCl is 3.7–4.1). The cation exchange capacity in the A1 and lower mineral horizons is significantly base saturated (77–83%). It becomes much lower in the A1h and A1Bh horizons. The organic matter is fulvate; the Cha:Cfa ratio in the topsoil is 0.7–0.6. A peculiarity of these soils is the presence of two zones of humus accumulation: a zone of residual raw humus accumulation and eluviation of Al-Fe-humus compounds in O and AOA1 horizons, and a zone of black humus accumulation in situ due to the decomposition of bamboo root systems and humus illuviation from forest litter and raw humus horizons. The upper part of the soil profile has significantly increased clay and ferruginous material as compared with parent materials. The distribution of total and mobile oxalate-soluble forms of R_2O_3 in the soil profile increases downward. Their maximum content is in the A1, A1h, and A1Bh horizons.

These soils are formed on well-drained terrain under stone birch and mixed coniferous-stone birch forests with continuous Kuril's bamboo cover. They are widespread in West Sakhalin, Susunay, Tankino-Anivsky ridges, and, more rarely, in the East Sakhalin ridge.

6.8.4 Cambisols Calcaric (CMc)

This soil unit occupies 5.44 million ha, which corresponds to 0.3% of the land area of the country, or 2.6% of the major soil grouping area.

The soils have an ochric A horizon and are calcareous at 20–50 cm from the surface. Additionally, they lack vertic properties, gleyic properties within 100 cm of the surface, and permafrost within 200 cm of the surface.

This soil unit correlates with Cinnamonic calcareous and Pales calcareous soils.

Cinnamonic calcareous soils are similar to Cinnamonics typic and differ only by the presence of carbonates in the topsoil.

6.8.5 Cambisols Chromic (CMx)

This soil unit occupies 1.31 million ha, which corresponds to 0.1% of the land area of the country, or 0.6% of the major soil grouping area.

These soils have an ochric A horizon and a base saturation (by NH_4O_{Ac}) of 50% or more at 20–50 cm from the surface, but they are not calcareous within this same depth. Additionally, these soils have a strong brown to red cambic B horizon, but no ferralic properties, and no gleyic properties within 100 cm of the surface or permafrost.

This soil unit corresponds to Cinnamonics typic soils in *SMR*.

Cinnamonics typic have the soil profile A1-Bm-Bm,ca-Cca. The altered horizon (with a higher clay content) is clearly identified and contains carbonates in its lower part (Bm,ca). The upper horizons contain 5–8% humus under natural vegetation. Humus penetrates deep, and humus content at 1 m is 0.8–1.0%. The middle and lower parts of the profile are marked by a high percentage of clay. The Cation exchange capacity decreases with depth; the exchange complex is completely or almost entirely base-saturated.

These soils are formed under oak and hornbeam xerophytic forests and bush in the Krasnodar Kray and Dagestan.

6.8.6 Cambisols Gleyic (CMg)

This soil unit occupies 6.69 million ha, which corresponds to 0.4% of the land area of the country, or 3.16% of the major soil grouping area.

These soils have gleyic properties within 100 cm of the surface, but no permafrost within 200 cm of the surface.

The Cambisols Gleyic soil unit correlates with Brownzems gleyic and gley, Brownzems raw-humic gley, Granuzems gley, and Sod-brownzems and gleyic and gley.

Brownzems gleyic and gley have the profile O1-AO-A1g-Bm,g,t-BmCg-Cg. They are similar to slightly unsaturated Brownzems, but excessive moistening by surface rainfall leads to gleying of the soil profile and results in peculiarities of its morphological and physico-chemical properties. Neoformation of clay is typical for all horizons, taking place simultaneously with surface gleying. The soil profile has weak color differentiation (vague boundaries between horizons) as well as some desaturation in bases (5–20%); a slightly acid reaction; an absence of leached clay particles, sesquoxides and silica dioxide redistribution; and an accumulative type of amorphous and crystallized iron forms distributed in the soil profile.

They are formed on slowly drained flat landscapes on loam and clay deposits in the southern Far East.

Brownzems raw-humic gley have the profile O-AO-A1g-Bm,g-BmCg-C. The soil profile is characterized by weak differentiation of the soil horizons. The O horizon (5–10 cm) is distinguished by litter. A1g and Bm,g horizons have a brownish blue-grey color with rusty and blue-grey mottles of gleying. The humus content in the A1 horizon is up to 18%. It sharply decreases downward, although it permeates the whole soil profile. The reaction is acid and base saturation of the topsoil is 60% or more. The exchangeable acidity is determined by Al. There is some redistribution of clay and amorphous and crystallized iron compounds, and there is accumulation in the gleyed, altered Bm,g horizon. Gleying is caused by surface waterlogging. Continuous seasonal permafrost is found in the soil.

These soils occur on flat, poorly drained relief under moss-larch forests in regions where brown-Forest soils are common.

Granuzems gley have the soil profile O1-OA-B-BCg-Cg. They differ from Granuzems by the presence of a gley horizon beneath the structured one. Such soils are formed on very steep, depressed sites in the same areas as Granuzems.

6.8.7 Cambisols Gelic (CMi)

This soil unit occupies 103.56 million ha, which corresponds to 6.2% of the land area, or 48.8% of the major soil grouping area.

These soils have permafrost within 200 cm of the surface. They correspond to Taiga peaty-muck high-humic nongleyic soils and Sod-brownzems gleyic and gley.

Taiga peaty-muck high-humic nongleyic soils have the profile O1-Bh-BhC-⊥C. The O horizon (10–20 cm) is gradually transformed into the dirty brown or grey-colored Bh horizon, which is significantly permeated by humus and contains plenty of partly decomposed debris. The profile is always very wet, has an acid reaction, and is base-unsaturated. The iced permafrost is marked at the depth of 40–60 cm.

These soils are formed under taiga vegetation, with bush-moss ground cover, in northern East Siberia.

Sod-brownzems gleyic and gley have the profile O-AOA1-Ag-Bg⊥. Fresh litter in the O horizon (0–5 cm thick) covers a dark brown peaty forest litter AOA1 horizon (5–20 cm). The Ag gleyed horizon (20–40 cm) has a brown color and fine texture. It merges into brown seasonally frozen clay. The soil is identified by an acid reaction, a significantly unsaturated exchange complex, the absence of clay and sesquoxides differentiation down the profile, and gleying of the humic horizon by the seasonal waterlogging above the permafrost. These soils are formed from fine-textured deposits on flat and depressed relief in the southern and middle taiga zones.

Pales mucky have the profile Ov-AB-B-BC-C. Lichen tissue (2–3 cm) covers the dry peaty dark brown or brown Ov horizon (2–3 cm). The AB horizon (8–12 cm) is light brownish loamy sand or loam. The horizon gradually merges into almost undifferentiated brown subsoil (B-BC). There are no morphological features of gleying nor of clay eluviation. The reaction is slightly acid in the AB horizon and close to neutral in the B. Total R_2O_3 and the oxalate-soluble forms are either evenly distributed down the profile or accumulate. The humus has a humate-fulvate composition. These soils develop in cold and semiarid continental permafrost mountainous regions of East Siberia under northern taiga lichen/moss/dwarf bush/larch forests.

Pales typical have the profile Ov-A1-AB-B-BC-C. The presence of an A1 horizon differentiates these soils from pale-yellow muck soils. They occur usually in the middle and southern taiga of semiarid areas of East Siberia.

Pale podzolized soils have the profile O-AOA1-A1A2-B-BC-C. The O horizon consists of forest litter, mainly pine and larch needles. The AOA1 horizon (2–3 cm) is distinguished by raw humus muck material and contains up to 10–20% organic matter. The A1A2 horizon (12 cm thick) has a bleached light-grey color, is structureless, and contains up to 1.8% humus. The illuvial B horizon has a greyish-brown or pale-yellow-brown color. Lower horizons of loamy soils have the platy structure of frozen soil. The topsoil is acid and the subsoil has a neutral pH. Base saturation is 60–80%. The profile is differentiated by texture and total chemical composition. The podzolized A1A2 horizon is low in clay, R_2O_3, and exchangeable cations, with a marked increase of all three in the illuvial B horizon.

These soils are formed from fine loams, loamy sands, and sands under larch and pine forests with dwarf bush ground cover, on moderately dissected, well-drained watersheds and their slopes in the middle taiga zone.

Pales solodic have the profile AO-A1A2-B1-B2ca-BCca-Cca. The AO horizon (2–3 cm) is characterized by weakly decomposed forest litter (needles and leaves of birch and bushes). The A1 horizon (5–6 cm), with sod in the upper part (2–3 cm), contains up to 4% humus and has a loamy texture. The A2 horizon (5–25 cm) is of light-grey color, light- and medium-loamy texture, and has features of solodization (ash color); it is loose and structureless, or thin platy in strongly solodized soils; the humus content is about 3.2%. The B1 horizon (10–20 cm) has a dark brown color, compact consistency, granular-subangular structure, and no carbonates in the illuvial horizon. The humus content is about 1.5%. The B2ca horizon (20–30 cm) has an irregular color, and light brown, less-calcareous tongues are mingled with pale-yellow bleached wedges. This calcareous illuvial horizon is characterized by a loamy texture and a loose, fine granular porous structure. It gradually merges into a light brown loess-like loam with a plate-leafy structure that is succeeded by permafrost. These soils have neutral or slightly alkaline reaction (pH 6.5–6.7 in A1 and A2 horizons and pH 7.6–8.0 in B2ca and Cca horizons). The solodized A2 horizon has a smaller sum of exchangeable cations (about 11 cmol[+] kg–1) than the B1 horizon, and exchangeable sodium is 4–5% of the total cations. The exchange capacity is significantly higher in the B1 horizon (30–40 cmol[+] kg–1), and Na+ content is up to 5–10%.

These soils are formed under larch taiga with dwarf bushes and grasses, and have a lower land productivity rating.

Grey-pales soils have the profile AO-A1-B1-B2ca-C. The AO horizon is shallow (2–3 cm) and characteristically composed of forest litter. The A1 horizon is 16–30 cm thick, of dark grey color in the upper part and grey or greyish brown in the lower part, and has a loose fine subangular structure. It contains 4.5–7% humus. The B1 horizon (10–15 cm) has brown color, is compacted and does not have carbonates. The B2ca horizon (15–25 cm) is light brown and greyish, has carbonates, a fine subangular and platy structure, and is porous. The C horizon is from loess-like parent material with platy-leafy structure. These soils are rich in humus, nitrogen, and phosphorus, and have a neutral reaction in the topsoil and are slightly alkaline in the subsoil. The cation exchange capacity is 25–50 cmol(+) kg–1. The dominant cation is Ca_2+ (up to 55%), and the Na+ content is 4–8%.

These soils occur on specific alas complexes of the central Yakutia region. These complexes are flat depressions of various sizes (10 m^2 to a few km^2) formed in permafrost regions where thermokarst processes take place, and are usually covered by lakes, bogs, or meadows.

Pales calcareous soils have the profile O-A1-A1Bca-Cca. The color of the profile is pale-brown. Effervescence from HCl is marked below humus horizon or in a B horizon.

These soils are found in the Lena-Vilyuy and Lena-Angara interstream area. They are formed under larch taiga from loose calcareous loamy deposits of various grass, moss, and lichen groundcover. Polygonal cracked nano-relief is well-developed.

6.9 Calcisols

This major grouping occupies 4.57 million ha, or 0.3% of the land area of Russia (*Table 5.1*). It is widespread (*Figure 6.1*) particularly in the southern part of the European territory of Russia in the Kalmikya Republic.

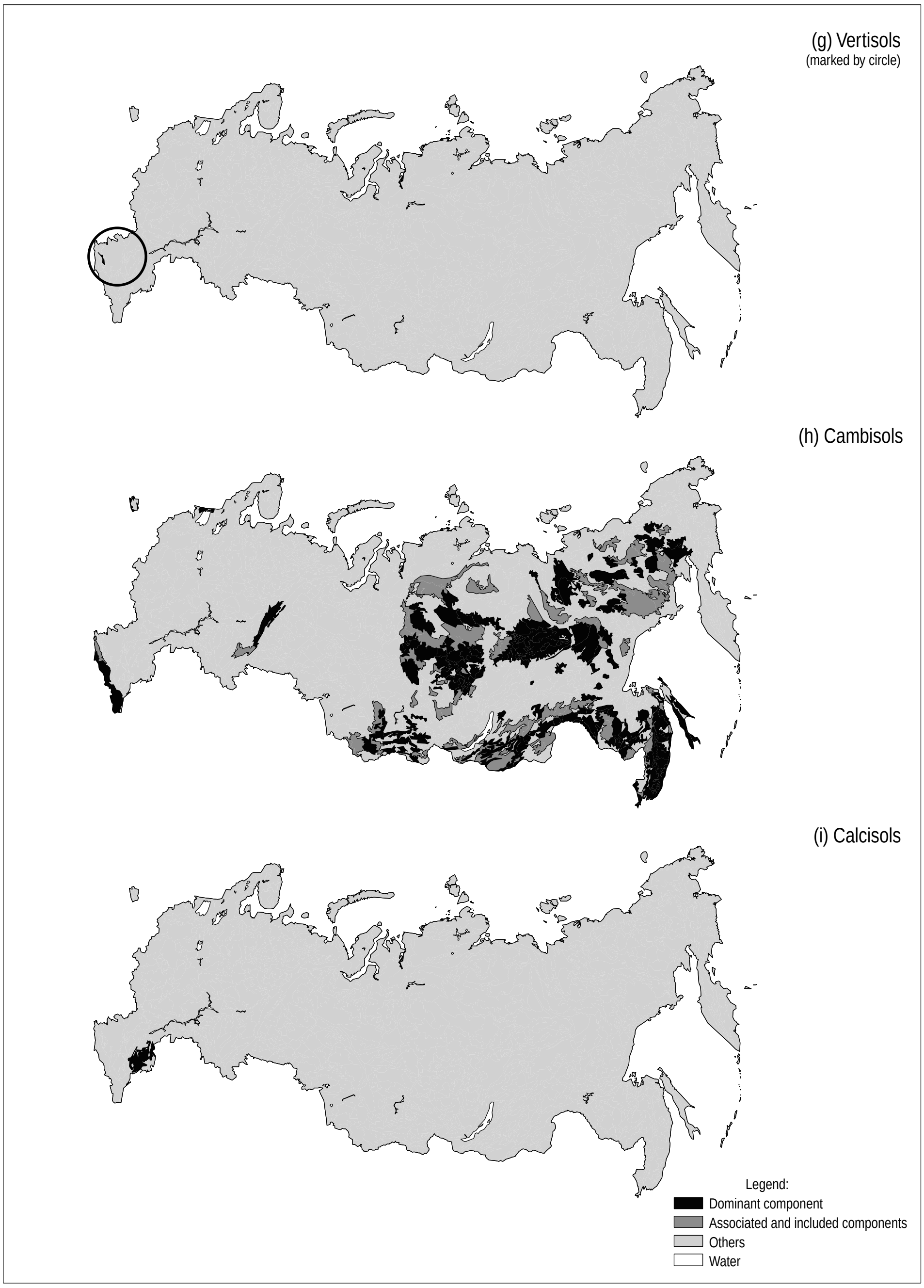

Figure 6.1. Major soil groupings of Russia: (g) Vertisols, (h) Cambisols, and (i) Calcisols.

This major soil grouping has one or more of the following characteristics: a calcic horizon, a petrocalcic horizon, or concentrations of soft powdery lime within 125 cm of the surface; a lack of diagnostic horizons other than an ochric A horizon, a cambic B horizon, or an argic B horizon permeated with calcium carbonate; a lack of characteristics that are diagnostic for Vertisols or Planosols; or salic properties or gleyic properties within 100 cm of the surface.

The following FAO soil units are present, and the corresponding soil groups in *SMR* are described. (Although no Gypsisols are mapped in Russia, they are common in the semidesert zones of central Asia.)

- Calcisols Haplic (CLh)
  – Brown soils
- Calcisols Luvic (CLl)
  – Brown soils solonetzic and solonchakous.

6.9.1 Calcisols Haplic (CLh)

This soil unit occupies 1.75 million ha, which corresponds to 0.1% of the land area of the country, or 38.4% of the area of the Calcisols major soil grouping.

These soils are characterized by having neither an argic B horizon nor a petrocalcic horizon; they correspond to Brown soils in *SMR*.

Brown (semidesert) soils have the soil profile A1-A1B-Bca-Bcs-Cs. They are characterized by weakly expressed humus horizons with a brownish color. The A1 humus horizon, 12–15 cm thick, has a loose platy structure. The transitional A1B horizon extends to the depth of 25–40 cm and has a brownish color, compact consistency, and coarse crumb structure. It is underlain by an illuvial-carbonate horizon, Bca (or Bca,cs), which has a whitish-brown color, dense consistency, and nut-crumby structure. The carbonates appear in the form of irregular soft spots and powder. Effervescence begins at a depth of 15–20 cm, and rarely from the surface. Soluble salts and gypsum appear in considerable quantities (Bcs horizon) at an average depth of 80–100 cm. The Brown (semidesert) soils have a low humus content (0.7–1.4%). The exchangeable cations are almost entirely calcium and magnesium with exchangeable magnesium making up 20–25%. Exchangeable sodium is found in small quantities (1.0–1.5% of CEC). The soil reaction is slightly alkaline (pH 7.4–7.6) in the upper horizons and alkaline (8.2–8.8) in the lower ones.

The Brown soils are widely spread in the semidesert regions in the Kalmikya.

6.9.2 Calcisols Luvic (CLl)

This soil unit occupies 2.82 million ha, which corresponds to 0.2% of the land area of the country, or 61.6% of the area of the Calcisols major soil grouping.

These soils have an argic B horizon but no petrocalcic horizon. They correlate with solonetzic and solonchakous Brown soils.

Brown solonetzic and solonchakous soils have the profile A1-Bsl-Bca-Bca, cs-Bcs-Ccs. The A1 horizon (9-14 cm in thickness) has a pale brown color, weak loose platy structure, and a distinct transition to Bsl horizon. This horizon extends to the depth of 30–40 cm and has clear solonetz features such as coarse blocky structure, compactness, and cracks. The effervescence in such soils usually appears from a depth of up to 50 cm, and sometimes in the topsoil. Carbonates impregnate the soil mass as a whole but can also occur as soft spots at a depth of 35–60 cm. Soluble salts and gypsum are present in considerable quantities (Bcs horizon), usually at a depth of 60–110 cm. The gypsum appears at a depth of 40–70 cm. Alkali and saline Brown soils are poor in humus (0.5–1.3%). The exchangeable magnesium is 20–25% of CEC; exchangeable sodium is present in considerable quantities (7–13% of CEC). The soil reaction is alkaline (pH 7.8–8.5) throughout the soil profile.

These soils occur in the same regions as Brown soils.

6.10 Solonetz

This major grouping occupies 11.16 million ha, or 0.7% of the land of Russia (*Table 5.1*). It occurs in the southern part of the European territory of Russia and in the southern part of West Siberia (*Figure 6.1*).

These soils have a nitric B horizon. The following FAO soil units and corresponding soil groups in *SMR* are distinguished:

- Solonetz Haplic (SNh)
  – Solonetz
- Solonetz Gleyic (SNg)
  – Solonetzes Meadowy
  – Solonetzes Meadow-like

6.10.1 Solonetz Haplic (SNh)

This soil unit occupies 2.56 million ha, which corresponds to 0.2% of the land area of the country, or 23.0% of the Solonetz major soil grouping.

These soils have an ochric A horizon, and do not have stagnic or gleyic properties within 100 cm of the surface. They correlate with solonetzes (automorphic), which have a sharply differentiated soil profile A1A2-Bsl-Bxa,(sl),(s)-(Bcs)-(Bs)-Cs. The humus-solod A1A2 horizon, above the solonetzic horizon, is grey with platy-crumby structure and varies in depth from 10 cm (shallow solonetz) to more than 18 cm (deep solonetz). The illuvial Solonetz Bsl horizon is brownish-grey with columnar, prismatic, or nut structure, and has deep cracks, a very hard consistency, and numerous clay skins. Its thickness varies from 6–8 cm to 10–15 cm. It is succeeded by the second solonetz horizon Bca,(sl),(s), or directly by a saline horizon. It usually contains soluble salts, mostly chlorides, while sulphates appear at greater depths. Gypsum appears at the depth of about 100 cm. The humus content in the humus-solod horizon is 1.5–2.5%, though it is sometimes higher in the solonetz horizon. The CEC and exchangeable Na+ content are highest in the solonetz horizon (sometimes the second solonetz horizon). Carbonates are usually right under the solonetz horizon and comprise 3–8% of the total mass of the soil. Soluble salts appear at a depth of 40–50 cm, beginning with chlorides (0.5%); by a depth of 1 m, the total amount of salts rises to 2.5%, and sulphates start dominating chlorides. The maximum gypsum accumulation is at a depth of 1–2 m. Such soils are found in the steppe and dry steppe zones.

6.10.2 Solonetz Gleyic (SNg)

This soil unit occupies 8.6 million ha, which corresponds to 0.5% of the land area of the country, or 77.1% of the Solonetz major soil grouping

These soils show gleyic properties within 100 cm of the surface. They correlate with meadowy and meadow-like Solonetzes.

Solonetzes meadowy (semihydromorphic) are formed with additional moisture input, while ground water remains at a depth of 3–6 m. They are usually in complexes with other semihydromorphic soils, but may form large individual tracts on river terraces. They differ morphologically from the Solonetz soils described above in the form of the horizons above and below the solonetzic horizon. The horizon above is usually thinner (about 10 cm) and more bleached with fine platy structure. The subsolonetzic horizon is less dense and better aggregated due to higher salinization; the composition of soluble salts determines its color, density, and structure.

These soils are developed in the same territories as Solonetzes (automorphic).

Solonetz meadow-like (hydromorphic) are characterized by relatively weak profile differentiation, and have a faint B horizon with an undeveloped structure that gradually merges into parent material.

These soils are formed under the influence of rather shallow ground waters (not deeper than 3 m) that are mineralized to various degrees, on river and lake terraces, by shores, brackish lagoons, etc., and are mostly shaped as narrow bordering areas or small patches in the steppe and dry steppe zones.

6.11 Solonchaks

This major grouping occupies 0.98 million ha, or 0.1% of the land area of Russia (*Table 5.1*). It occurs in the same regions as Solonetzes – the southern part of the European territory of Russia and the southern part of West Siberia (*Figure 6.1*)

These soils are characterized by salic properties but not fluvic properties nor any diagnostic horizons other than an A horizon, a histic H horizon, a cambic B horizon, a calcic horizon, or a gypsic horizon.

The following FAO soil units and corresponding soil groups in *SMR* are distinguished:

- Solonchaks Haplic (SCh)
  – Solonchaks typic
- Solonchaks geyic (SCg)
  – Solonchaks meadow

6.11.1 Solonchaks Haplic (SCh)

This soil unit occupies 0.64 million ha, which corresponds to less than 0.1% of the land of the country, or 65.1% of the Solonchaks major soil grouping.

These soils have an ochric A horizon, and lack gleyic properties within 100 cm of the surface and permafrost within 200 cm of the surface. They correlate with Solonchaks typic.

Solonchaks typic have a gleyed, weakly differentiated soil profile, and are effervescent at the top. Groundwater is usually at 2–5 m depth. Flooding is unusual. The maximum content of soluble salts (never less than 1%) is typically in the upper 5 cm or on the soil surface (crusts, etc.). Down the profile, the content of salts may decrease or remain constant.

The vegetation is sparse and salt resistant. These soils are formed on unflooded terraces of salt lakes, low river terraces, and in irrigated plains. Such soils are common in deserts, semideserts, and, more rarely, the steppe zone.

6.11.2 Solonchaks Gleyic (SCg)

This soil unit occupies 0.34 million ha, which corresponds to less than 0.1% of the land area of the country, or 34.9% of the Solonchaks major soil grouping.

These soils show gleyic properties within 100 cm of the surface and have no permafrost within 200 cm of the surface. They correlate with meadow Solonchaks.

Solonchaks meadow differ from typical Solonchaks by the presence of a humus-accumulative horizon in the upper part of the soil profile, which is related to richer meadow vegetation. The main peculiarity of meadow Solonchaks is periodic flooding with fresh water, causing the periodic leaching of salts against a general background of evaporative water movement.

Such soils are formed around brackish lagoons and on low river terraces and piedmonts in semidesert, steppe, or, more rarely, desert zones.

6.12 Kastanozems

This major grouping occupies 25.80 million ha, or 1.5% of the land area of Russia (*Table 5.1*). It occurs in the southern parts of Russia (*Figure 6.1*).

These soils have a mollic A horizon with a moist chroma of more than 2 to a depth of at least 15 cm, and one or more of the following characteristics: a calcic or gypsic horizon or concentrations of soft powdery lime within 125 cm of the surface; a lack of a natric B horizon or salic properties; a lack of the characteristics that are diagnostic for Vertisols, Planosols, or Andosols; and no gleyic properties within 50 cm of the surface when no argic B horizon is present (which would meet the definition of the mollic Gleysols).

The following FAO soil units and corresponding soil groups in *SMR* are distinguished:

- Kastanozems Haplic (KSh)
  - – Chestnut dark
  - – Chestnut
  - – Chestnut light
  - – Dark chestnut deep,
  - – Chestnut deep,
  - – Light chestnut deep
  - – Chestnut leached
- Kastanozems Calcic (KSk)
  - – Chestnuts dark calcareous
- Kastanozems Luvic (KSl)
  - – Chestnut solonetzic and solonchakous
  - – Chestnut dark solonetzic and solonchakous
  - – Chestnut light solonetzic and solonchakous

6.12.1 Kastanozems Haplic (KSh)

This soil unit occupies 17.28 million ha, which corresponds to 1.0% of the land area of the country, or 67.0% of the total Kastanozems major soil grouping.

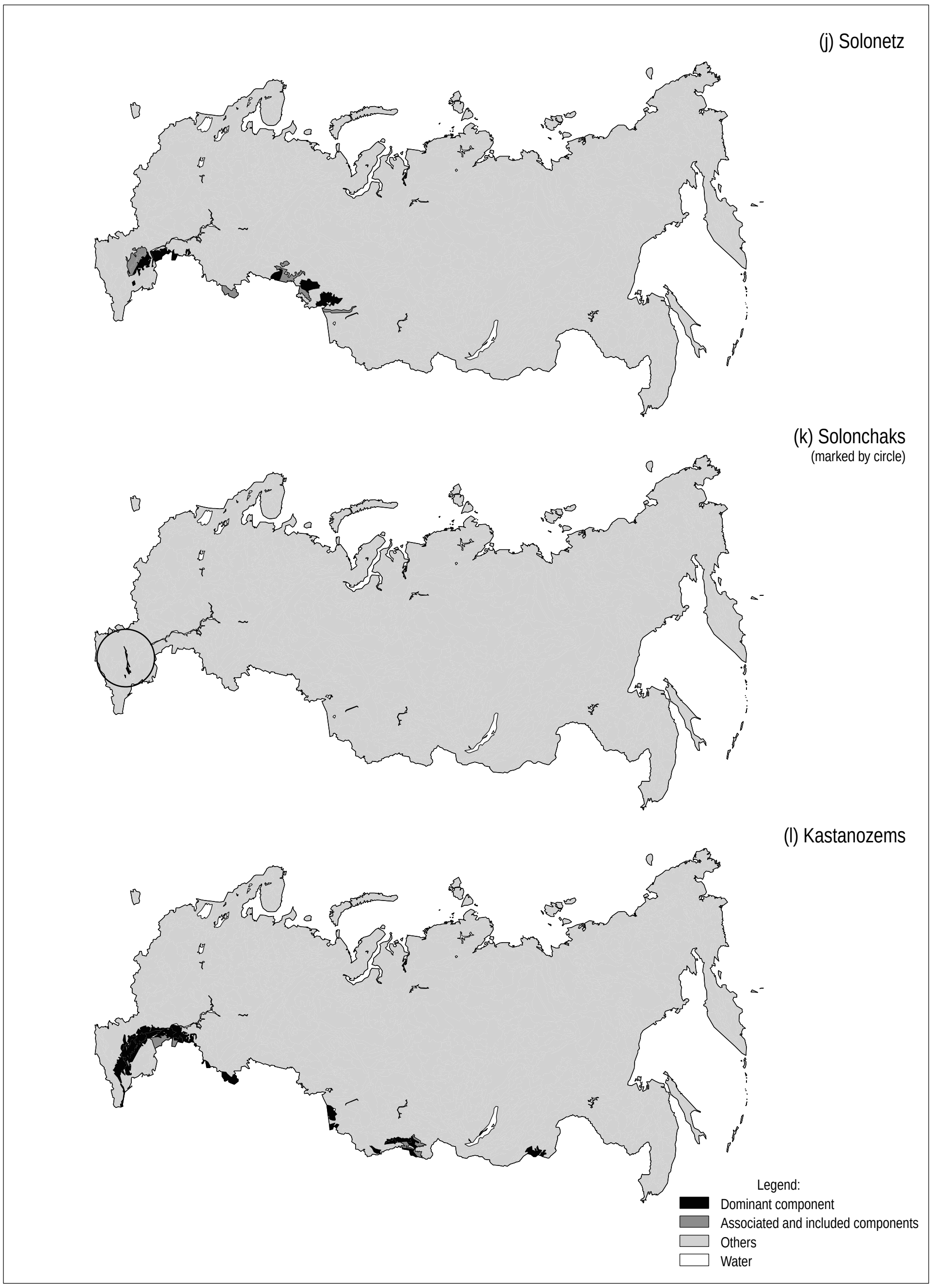

Figure 6.1. Major soil groupings of Russia: (j) Solonetz, (k) Solonchaks, and (l) Kastanozems.

These soils are characterized by not having an argic B horizon, a calcic horizon, or a gypsic horizon. The unit correlates with dark Chestnut, Chestnut, light Chestnut, deep dark Chestnut, deep Chestnut, deep light Chestnut, and leached Chestnut soils.

Chestnut dark soils have the profile A1-A1B-Bca-Bca,cs- Ccs. The A1 horizon has a dark brownish-grey color, and a powdery, fine granular structure. The A1B horizon is brownish and unevenly colored by humus (spots, linguoids). The Bca horizon is more compact, usually with prismatic-crumby structure, and white soft calcium carbonate spots. The Bca,cs is an illuvial carbonate horizon with abundant patches of $CaCO_3$ and some gypsum. The Bcs is the horizon of maximum gypsum accumulation. The Ccs is the parent material with patches of gypsum at a depth of 120–170 cm and increased contents of soluble salts. The humus content of the A1 horizon (upper 15 cm) varies within the limits of 3.0–5.5% in clay loams and 2.0–4.0% in sandy loams and loamy sands. The thickness of the humic layer (A1+A1B) decreases eastwards (the A1 is 25–40 cm and A1+A1B is 40–60 cm in the European part, and respectively 20–25 cm and 35–40 cm in East Siberia). Effervescence starts usually in the lower part of the A1 horizon. The exchangeable cations are mainly represented by Ca_2+ and Mg_2+. The soil reaction changes from neutral (pH 7.0–7.2) in the upper horizons to alkaline (pH 8.3–8.6) in the lower ones.

These soils are formed under dry steppe vegetation in the south of the country.

Chestnut soils have the profile A1-B-Bca,cs-BCcs-Ccs. They differ from the dark Chestnut soils in lower humus content, in compaction, and by the prismatic structure in B and Bca horizons. In virgin and fallow soils, a bleached horizon (up to 3–5 cm thick) with weak fine platy structure is common on the surface above the A1. The content of humus in the A1 horizon (upper 15 cm) varies within the limits of 2.5–4.0% in clay loams and 2.0–3.0% in sandy loams and loamy sands. Such soils develop in the southern part of the dark Chestnut soils zone.

Chestnut light soils have the profile A1-B-Bca-Bcs-Ccs. The A1 horizon (10–18 cm thick) has a brownish-grey color, slightly stratified texture, and poorly expressed crumby structure. The transitional horizon B (30–40 cm thick) has a brownish color, compact consistency, and prismatic-crumby structure. The illuvial-carbonate horizon Bca has yellowish-brown color, very dense consistency and an angular-nut structure. White soft carbonate spots usually appear at the depth of 40–60 cm. The humus content in the upper horizon is 2.0–2.5%. The exchangeable cations are mainly Ca_2+ and Mg_2+. Exchangeable sodium forms 1.5–5.0% of CEC. The soil reaction changes from slightly alkaline (pH 7.2–7.4) in the upper horizons to alkaline (pH 8.2–8.5) in the lower ones.

These soils are developed under sparse, low, artemisia absinthum and grass steppe in the southern dry steppe subzone.

Dark chestnut deep soils have the profile A1-A1B(ca)-Bca-Bcs. They are characterized by deep penetration of humus and pseudomycelia of calcium carbonate, which already appear within the humus-accumulative horizon. White soft carbonates spots begin 30–50 cm below the lower boundary of the humus horizon. The A1 horizon, 20–30 cm thick, is greyish-brown. The thickness of the A1+A1B horizons is 50–65 cm. The humus content in the A1 horizon (or upper 20 cm) varies from 3–4%. The CEC is 25–30 cmol(+) kg–1 per 100g of soil. The white soft carbonate spots start at a depth of 60–70 cm, and gypsum at a depth of 150–200 cm. These soils are found in the southern regions of the European part of Russia.

Chestnut deep (pseudomycelia) soils have the profile A1(ca)-A1Bca-Bca-Ccs. They differ from dark Chestnut (pseudomycelia) soils by the thinner humus-accumulative horizon, lower humus content, and higher position of white soft carbonates spots and gypsum. The Chestnut pseudomycelia soils have a 20-cm-thick A1 horizon and the thickness of A1+A1B horizons is 30–50 cm. The humus content in the A1 (or upper 20 cm) horizon varies from 2.8–3.4%. Effervescence occasionally appears from the surface but usually from 30–50 cm. Gypsum is encountered from a depth of 130 cm and more.

These soils are developed mainly in the eastern Pre-Caucasus.

Light chestnut deep (pseudomycelia) soils have the profile A1ca-A1Bca-Bcs-Ccs. The A1 horizon does not usually exceed 18 cm. The lower boundary of the transitional A1B horizon is at 40–45 cm. White soft carbonates spots start at a depth of 55–65 cm. The pseudomycelia of carbonates are not abundant and appear at a depth of 30–40 cm. Effervescence usually begins from the soil surface and gypsum and soluble salts from a depth of 110–130 cm. The humus content in the A1 horizon is 2.0–2.5%. The exchangeable cations are mainly Ca+ and Mg_2+. Exchangeable sodium is 1.5–5.0% of CEC. The soil reaction changes from slightly alkaline (pH 7.4–7.6) in the upper horizons to alkaline (pH 8.4–8.6) in the lower ones.

These soils are formed from clay loam and clay parent materials in the Pre-Caucasus.

Chestnut leached (powdery-lime) soils have the profile A1(ca)-A1Bca-Cca. They are characterized by the very shallow A1 horizon (8–30 cm) and especially the A1B horizon (5–10 cm), and the shallow depth (15–30 cm from the surface) to carbonates in the form of soft powdery lime in the fine earth and encrustations on the lower surfaces of stones. They lack both gypsum and soluble salts throughout the soil profile. The effervescence starts from a depth of 15–20 cm, sometimes from the surface. The humus content in the A1 horizon is usually 1.2–3.0%. The exchangeable ions are predominantly Ca_2+ and Mg_2+. Exchangeable sodium is 1–3% of total exchangeable bases. The soil reaction is alkaline throughout the profile (pH 7.8–8.5). Such soils occur in the Trans-Baikal and Tuwa regions.

6.12.2 Kastanozems calcic (KSk)

The soil unit occupies 0.15 million ha, which corresponds to less than 0.1% of the land area of the country, or 0.6% of the total Kastanozems major soil grouping area.

These soils have a calcic horizon and no argic B or gypsic horizons.

The Kastanozems calcic soil unit correlates with Chestnut dark calcareous soils.

Chestnut dark calcareous (including residual calcareous) soils have the profile A1-A1Bpca-Bpca-Cpca-Dca or A1ca-A1Bca-Bca-Cca,cs. These soils have carbonates in the upper 20 cm. Residual calcareous soils inherit carbonates from calcareous gravel and stones included in the parent material. The soils are characterized by weak structure. Calcareous soils have cracks on the soil surface and blocky structured B horizons. Morphological features of carbonates are not apparent. These soils contain carbonates and remain calcareous because the fine clay texture decreases the leaching processes.

Both soils are formed in the subzone of Chestnut dark soils on calcareous loose deposits or, more frequently, hard limestone rocks.

6.12.3 Kastanozems Luvic (KSl)

This soil unit occupies 8.37 million ha, which corresponds to 0.5% of the land area of the country, or 32.5% of the Kastanozems major soil grouping.

These soils have an argic B horizon and do not have a gypsic horizon. They correspond to Chestnut dark solonetzic and solonchakous, Chestnut, and Chestnut light soils.

Chestnut dark solonetzic and solonchakous soils have similar soil profiles to Chestnut dark soils. However, some morphological features of solonetz soils can be recognized in these soils (compaction, nut-crumby or prismatic structure of the Bsl horizon, etc.) The content of exchangeable sodium exceeds 5%, and the content of soluble salts at a depth of 50–150 cm is higher than in dark Chestnut soils.

These soils are formed from saline deposits in the subzone of Chestnut dark soils.

Chestnut solonetzic and solonchakous soils differ from the typical Chestnut soils because of the presence of soluble salts within the upper 50 cm of the profile.

These soils are formed from saline deposits in the regions of Chestnut soils.

Chestnut Light solonetzic and solonchakous soils differ from the light Chestnut soils because of a stronger differentiation of horizons. The A1 humus horizon (8–12 cm thick) is of light-brown color, and has a fine-banded structure. It is underlain by the Bsl horizon (30–40 cm thick), which has a brownish-yellow color, compact consistency, and prismatic structure with cracks. The Bca horizon (35–50 cm thick) has a whitish-yellow color, very compact consistency, nut structure, and pronounced white spots of soft carbonates. There are considerable quantities of soluble salts and gypsum at a depth of 60–100 cm. The humus content in the A1 horizon is 1.5–2.0%. The main exchangeable cations are Ca_2+ and Mg_2+. Exchangeable sodium is 5–10% of CEC. In spite of the low sodium content, solonetz properties are clearly identified morphologically.

These soils are formed from saline deposits in the zone of Chestnut light soils.

6.13 Chernozems

This major grouping occupies 92.84 million ha, or 5.6% of the land area of Russia (*Table 5.1*). It occurs in the southern parts of the European territory of Russia, West Siberia, and Zabaikalye (*Figure 6.1*).

These soils have a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm, a calcic horizon or concentrations of soft powdery lime within 125 cm of the surface, or both. These soils do not have a nitric B horizon (the characteristics of which are diagnostic for Vertisols, Planosols, or Andosols), salic properties, gleyic properties within 50 cm of the surface when no argic B horizon is present,[1] or uncoated silt and quartz grains on structural ped surfaces.

The following FAO soil units are recognized, and the corresponding soil groups in *SMR* are indicated.

- Chernozems Haplic (CHh)
  - Chernozems typic
  - Chernozems ordinary
  - Chernozems non-calcareous, deep-effervescing, on coarse parent material
  - Chernozems leached deep
  - Chernozems washed
- Chernozems Calcic (CHk)
  - Chernozems southern
  - Chernozems southern and ordinary mycelial-calcareous
  - Chernozems residual-calcareous
- Chernozems Luvic (CHl)
  - Chernozems leached
  - Chernozems solonetzic
- Chernozems Glossic (CHw)
  - Chernozems leached glossic
  - Chernozems ordinary glossic
  - Chernozems southern glossic

[1]Gleyic properties present within 50 cm of the surface in the absence of an argic B horizon meet the definition of the Mollic Gleysols.

- Chernozems Gleyic (CHg)
  – Meadow-chernozemics

6.13.1 Chernozems Haplic (CHh)

This soil unit occupies 30.41 million ha, which corresponds to 1.8% of the land area of the country, or 32.8% of the Chernozems major soil grouping.

These soils are characterized by not having an argic B horizon, a calcic horizon, or tonguing of the A horizon into a cambic B or C horizon.

The FAO Chernozems Haplic soil unit correlates to Chernozems typic and ordinary, Chernozems non-calcareous deep-effervescing on coarse parent material, and Chernozems leached deep and washed.

Chernozems typic have the profile A1-A1Bca-Bca-BCca-Cca. The humus horizons are subdivided into two parts: The A1 is dark grey or black, and has a granular or subangular-granular structure. Its humus content is 8–12%, and is of mostly a calcium-humate complex. The reaction is 6.5–7.0, increasing downward. The A1Bca is a browner color with larger peds. Bleached mineral particles are usually absent. The Bca horizon is identified by a variable straw-yellow color with grey mottles and tongues. It has a coherent structure and maximum of secondary (accumulated) carbonates. The lower part of the A1 or A1B horizons are effervescent. Calcareous accumulations appear in the form of mold, mycelia, and veins, and, below 200 cm depth, as loess dolls. There are many mole burrows present, and sometimes general soil profile perturbation is found. The cation exchange capacity is 35–60 cmol(+) kg–1. There is no differentiation in distribution of either the clay fraction or the sesquioxides in the soil profile.

These soils occur in meadow steppes and southern forest-steppe zones, mostly under arable cultivation.

Chernozems ordinary have the profile A1-A1Bca-Bca-BCca-Cca-Cs. They are similar to Chernozems typic, but have a lower humus accumulation and higher carbonate content and salts in the deeper part of the soil profile. Effervescence appears in the humus horizon (A1 and A1B), white soft carbonate spots in the B horizon, and soluble salts and gypsum at a depth of 300–500 cm. The humus is calcium-humate. The reaction is neutral and the cation exchange capacity is 35–55 cmol(+) kg–1. The distribution in the profile of clay and sesquioxides is undifferentiated.

These soils are formed under cereals or various grasses, often cultivated steppes.

Chernozems non-calcareous deep-effervescing on coarse parent material have the profile A1-A1B-B-C-(Cca). The humus horizon is thick, grey, with a coherent subangular structure, and without bleached mineral particles. The calcareous horizon is absent or situated below 200 cm. The humus content is low (3–5%), cation exchange capacity is also low (up to 20 cmol[+] kg–1), and the reaction is about neutral in all the profile. (Note that these soils are not FAO Chernozems or Phaeozems, which must have a calcic horizon. They are an inclusion in the Chernozems Haplic and are probably Cambisols Eutric or Luvisols Haplic.)

They are formed on coarse parent material or stony parent rocks in various grasses and cereals steppes.

Chernozems deep leached (synonym: Chernozems leached mycelia carbonate) have the profile A1-A1B-Bt,z-BCca,Z-Cca. The thickness of the humus horizon varies from 80–120 cm. The humus content is 4–7%. These soils are characterized by the distinct clay increase in the B horizon (like the Chernozems Luvic) and the abundant carbonate pseudomycelia. There are numerous deep animal burrows present in the soil. The soil reaction of the topsoil is slightly acid or nearly neutral (pH 6.2–6.8), and the subsoil is slightly alkaline. Effervescence starts from 100–160 cm. The cation exchange capacity is 40–50 cmol(+) kg–1.

These soils occur in the Pre-Caucasian plains and in the southwestern part of the European territory of Russia.

Chernozems washed (synonym: Chernozems carbonate-impregnated, including leached, typical, ordinary and southern) have the profile A1-A1B(ca)-Bca-Cca. The humus horizon is comparatively thin (30–45 cm), and brown-colored with a weakly expressed structure. A calcareous horizon is always present, but its depth varies significantly (from 20–120 cm) over short distances. Carbonates penetrate uniformly in solution to impregnate the whole soil, resulting in a pale color. Soluble salts and gypsum are usually absent. The humus content is 4–7%, with a Cha:Cfa ratio near 1. The reaction of the humus horizon is close to neutral (pH 6.0–7.0), but when the calcareous horizon lies deep, the reaction decreases to a pH of 4.5–5.0 in the middle part of the profile (such soils do not fit the definition of an FAO Chernozem, but are an inclusion).

These soils are formed outside the normal Chernozem zone in intermountain depressions of the steppe zone of East Siberia.

6.13.2 Chernozems Calcic (CHk)

This soil unit occupies 26.48 million ha, which corresponds to 1.6% of the land area of the country, or 28.5% of the total Chernozems major soil grouping.

These soils are characterized by a calcic horizon, no argic B horizon overlying the calcic horizon, and no tonguing of the A horizon into a cambic B or into a C horizon.

The Chernozems Calcic soil unit correlates with Chernozems southern, Chernozems southern ordinary mycelial-calcareous, and Chernozems residual-calcareous.

Chernozems southern have the profile A1ca-A1Bca,sl-BCs-Cs. They have a thinner humus horizon as compared to ordinary Chernozems. The humus content (in the A1) is 3–6%. Effervescence begins in the A1 horizon or on the surface. Carbonate concretions are in the form of white soft spots. Some features of the solonetz process are present, resulting in prismatic blocky subangular structure. Traces of gypsum and easily soluble salts appear at a depth of 150–300 cm. The reaction is nearly neutral or slightly alkaline, and the cation exchange capacity is 35–40 cmol(+) kg–1.

These soils occur in various dry grass-and-cereal steppes, often under arable cultivation.

Chernozems southern ordinary mycelial-calcareous have the profile A1ca,z-A1Bca,z-BCca,z-Cca. The humus horizon is 60–100 cm thick, with a low humus content (3–6%). Some stratification is common in the upper part of the humus horizon. Effervescence starts in the A1 horizon, sometimes from the surface. Abundant carbonate pseudomycelia are usual in the A1ca,z horizon, sometimes with white soft carbonate spots below. Usually neither gypsum nor soluble salts are present. The reaction is neutral or slightly alkaline. The cation exchange capacity is 30–45 cmol(+) kg–1. There are numerous animal burrows present in these soils.

These soils are formed under various grasses or cereals, usually cultivated, on the Pre-Caucasian steppes and also in some southern areas of the European part of Russia.

Chernozems residually calcareous have the profile A1pca-A1Bcap-Bcap-Ccap. They are shallow, and their depth depends on the thickness to which the hard limestone rocks have been weathered. They have a thin humus horizon and effervescence at the surface. The presence of calcareous rock fragments is typical.

They are formed in foothills in some regions of southern Russia.

6.13.3 Chernozems Luvic (CHl)

This soil unit occupies 27.51 million ha, which corresponds to 1.7% of the land area of the country, or 29.6% of the total Chernozems major soil grouping. The soils are characterized by having an argic B horizon. A calcic horizon may underlie the B horizon and there are no gleyic properties within 100 cm of the surface.

The Chernozems luvic soil unit corresponds to Chernozems leached and Chernozems solonetzic.

Chernozems leached have the profile A1-A1B-Bt-Bca-Bcca-Cca (very similar to the Chernozems podzolized, but characterized by a weaker degree of differentiation). The humus horizon is subdivided into two subhorizons: A1, which is dark grey or black with a granular structure (it is coarse subangular when ploughed), and A1B, which is browner and has larger peds. Less lightening of the color, as compared with Chernozems podzolized, is usual in all humus horizons. Especially noticeable in dry soil are the bleached mineral particles covering the peds. The Bt horizon has features of clay and sesquoxides illuviation, a dark brown color, a well-defined blocky subangular structure, and, often, dark films on the ped surfaces. It is compact and does not contain carbonates. These soils do not have a carbonate horizon if formed on non-calcareous parent rocks. The cation exchange capacity is 25–45 cmol(+) kg–1 and almost entirely base-saturated. The reaction is usually higher than that of Chernozems podzolized (5.8–6.8). The mineral components are not stable and there is evidence of sesquoxides migration and distinct clay redistribution in the soil profile, detected by micromorphological analysis.

These soils occur in meadow and northern forest-steppe zones, and are mostly cultivated.

Chernozems solonetzic have the profile A1-A1Bslca-Bsl,ca-Cca. They have solonetzic features in the humus horizon A1 (the content of exchangeable Na+ is more than 5% of cation exchange capacity) and distinct compaction (and sometimes stratification) in the upper part or, more often, in A1Bsl or Bsl horizons. The solonetzic process also appears as a prismatic-blocky subangular structure, and is especially evident when dry. A weak clay and sesquioxides soil profile differentiation can be detected analytically. In some places, the solonetzic horizon lies above the gypsum horizon (Chernozems deep-solonetzic). Sometimes morphological, physical features of solonetzic processes are due to increased exchangeable Mg+ (more than 25% of the cation exchange capacity) when the exchangeable Na+ content is low (less that 5%). So-called Chernozems residually solonetzic are usually combined with Chernozems solonetzic . These soils have features of solonetzic processes but a low content of exchangeable Mg+ and Na+. They occur in the southern part of West and East Siberia.

6.13.4 Chernozems Glossic (CHw)

This soil unit occupies 8.44 million ha, which corresponds to 0.5% of the land area of the country, or 9.1% of the total Chernozems major soil grouping area.

These soils are characterized by tonguing of the A horizon into a cambic B horizon or C horizon, and by lacking an argic B horizon.

The Chernozem Glossic soil unit corresponds to Chernozems leached glossic, ordinary glossic, and southern glossic.

Chernozems leached glossic have the profile A1-A1B-A1B/B-BCca-Ccs. The humus horizon (A+AB1) is 35–60 cm thick with a pocket-like or tongued lower boundary. The lower part of the humus horizon (30–60 cm) is effervescent. Calcareous accumulations are in the form of veins and occur at a depth of 70–90 cm or, more rarely, deeper. A horizon of white soft carbonate spots occurs in Chernozems of the foothills at a depth of 125 cm or more. Gypsum occurs sporadically at a depth of 200–250 cm. The humus content in the A1 horizon is 7–9%, and sharply decreases downward. The amount of humin is very high (up to 50%). The reaction is neutral and becomes slightly alkaline downward. The cation exchange capacity is about 50 cmol(+) kg–1.

These soils are formed on commonly cultivated land under various grasses and cereals on the steppes of West Siberia and central Siberia.

Chernozems ordinary glossic have the profile A1-A1Bca-A1Bca(Bca)-BCca-Cca. Humus horizons (A+AB1) are 36–60 cm thick, with the lower boundary pocket-like or tongued, and effervescent in the lower part. (30–60 cm). Calcareous accumulations in the shape of veins or penetrations start at a depth of 70–90 cm. Chernozems tongued of foothills have a horizon of white soft carbonate spots at a depth of 125 cm or more. Gypsum appears at a depth of 200–250 cm. The humus content of the A1 horizon is 7–9% and decreases downward. The humus composition is identified by a high content of humin (up to 50%). The soil reaction in the upper part of the humus horizon is neutral and becomes slightly alkaline downward. The cation exchange capacity is about 50 cmol(+) kg–1.

These soils are formed under various grasses and cereals, on the mainly arable land of the steppes of West Siberia and central Siberia.

Chernozems southern glossic have the profile A1-A1Bca,sl-A1Bca,sl/Bca,-sl-BCca,sl-C. The humus horizon is shallow (25–45 cm) with a tongued and pocket-like lower boundary. Tongues and pockets reach a depth of 100 cm. The macrostructure is weakly expressed, typically with high microaggregation simultaneously present. Effervescence starts from a depth of 20–40 cm, but can be much deeper in tongues and pockets. Calcareous accumulations in the form of infiltrated patches, veins, and sometimes white soft carbonate spots occur at 35–40 cm or deeper. A gypsum horizon lies at a depth of 150–200 cm. Weak solonetzic features are present in the lower part of the humus and AB horizons, and include compaction, a subangular- and angular-blocky structure, a slight increase of clay content, and some exchangeable Na+ (1–2% of the exchangeable cations). The humus content in the A1 horizon is 4–6% and decreases downward, decreasing gradually in tongues and pockets. The humus composition is identified by a low Cha:Cfa ratio and a high content of humin. The reaction is neutral and becomes alkaline downward. The cation exchange capacity is 15–45 cmol(+) kg–1.

These soils occur under various sparse grasses and cereals and on cultivated steppes of West Siberia.

6.14 Phaeozems

This major grouping occupies 26.26 million ha, or 1.6% of the land area of Russia (*Table 5.1*). It occurs particularly in the southern part of West Siberia (*Figure 6.1*).

The soils have a mollic A horizon and a base saturation (by NH_4O_{Ac}) that is 50% or more within 125 cm of the surface; they have no calcic horizon, gypsic horizon, concentrations of soft powdery lime, ferralic B horizon, natric B horizon, nor characteristics that are diagnostic for Vertisols, Nitisols, Planosols, or Andosols. They have no salic properties, gleyic properties within 50 cm of the surface when no argic B horizon is present,[2] and no uncoated silt and sand grains on structural ped surfaces when the mollic A horizon has a moist chroma of 2 or less to a depth of at least 15 cm.

This major soil grouping does not have analogues in Russian soil classification. The following FAO soil units have been identified and the corresponding soil groups in *SMR* are described.

- Phaeozems Haplic (PHh)
  - – Meadow-chernozemics leached
  - – Meadow-chestnuts
- Phaeozems Calcaric (PHc)
  - – Meadow-chernozemics calcareous
- Phaeozems Luvic (PHl)
  - – Chernozems podzolized
  - – Meadow-chernozemics solonetzic and solonchakous
  - – Meadow-chestnuts solonetzic
- Phaeozems Gleyic (PHg)
  - – Meadow-chernozem-like "Amur prairie"

6.14.1 Phaeozems Haplic (PHh)

This soil unit occupies 7.81 million ha, which corresponds to 0.1% of the land area of the country, or 29.7% of the total Phaeozems major soil grouping.

These soils are characterized by being noncalcareous from 20–50 cm of the surface, not having an argic B horizon or gleyic properties within 100 cm of the surface, and not having stagnic properties.

The Phaeozem Haplic soil unit corresponds to leached Meadow-chernozemics and Meadow-chestnut soils.

Meadow-chernozemics leached soils have the profile A1-A1B-B-Bca-Cca(Cca,g). They have a noncalcareous B horizon, with neutral reaction, lying between the humus horizon and the upper boundary of the calcareous horizon.

They are formed on fine-textured deposits under an intensive percolating water regime in a Chernozem zone.

[2] Gleyic properties present within 50 cm of the surface in the absence of an argic B horizon meet the definition of the Mollic Gleysols.

Meadow-chestnuts soils have the profile A1-B-Bca-Cca (Cca,g). The A1 horizon (20–25 cm thickness) has sod in the upper part, a dark-grey color, and loose consistency. The B horizon (10–50 cm thick) has a brownish color with humus tongues. The Bca has a whitish-brown color, prismatic structure, and is 50–70 cm thick. The parent material is made up of calcareous, sometimes gleyic, deposits. These soils are characterized by a high humus content (4–6%, sometimes more than 8%) in the A1 horizon that gradually decreases with depth. The soil reaction changes from neutral in the upper horizons to alkaline in the lower ones. The CEC is 25–30 cmol(+) kg–1 per 100 g of soil in the humus horizon. Exchangeable sodium occupies about 2% of the CEC.

These soils are dispersed among Chestnut and Chestnut light soils. They are formed in depressions (flat ditches, gullies, etc.) under the influence of excessive surface wetting, and sometimes have a rather high ground water table (2.5–7.0 m).

6.14.2 Phaeozems Calcaric (PHc)

This soil unit occupies 0.09 million ha, which corresponds to less than 0.1% of the land area of the country, or 0.3% of the total Phaeozems major soil grouping.

These soils are characterized by being noncalcareous from 20–50 cm of the surface, not having an argic B horizon or gleyic properties within 100 cm of the surface, and not having stagnic properties.

The Phaeozem Calcaric soil unit corresponds to Meadow-chernozemics calcareous.

Meadow-chernozemics calcareous have the profile A1ca-A1Bca-Bca-Cca-Cca(g). They are identified by effervescence from the surface.

These soils are basically developed from fine-textured (clayey) parent rocks or in outlying parts of depressions in a Chernozem zone.

6.14.3 Phaeozems Luvic (PHl)

This soil unit occupies 17.62 million ha, which corresponds to 1.1% of the land area of the country, or 67.1% of the Phaeozems major soil grouping.

These soils have an argic B horizon and do not have gleyic properties within 100 cm of the surface, nor stagnic properties.

This soil unit correlates with Chernozems podzolized, Meadow-chernozemics solonetzic and solonchakous soils, and Meadow-chestnuts solonetzic soils.

Chernozems podzolized have the profile A1-A1B-Bt-Bca-Bcca-Cca. The humus horizon is subdivided into two subhorizons: A1, which is dark grey or black with a granular structure (or coarse subangular when ploughed), and A1B, which is browner and has larger peds. Abundant bleached mineral particles cover the peds. The Bt horizon has features of clay and sesquoxides illuviation, a dark brown color, well-defined blocky subangular structure, and often has dark films on the ped surfaces. It is compact and does not contain carbonates. The thickness of the noncalcareous and humusless layer is not less then 40–50 cm. The calcareous Bca horizon beneath has carbonate accumulations modifiers in the form of veins. The BCca horizon often has patches of carbonates and concretions. The calcareous horizon may be absent in soils developed on noncalcareous parent rocks, which are therefore inclusions of other soil groupings. The humus content in the A1 horizon varies significantly (5–12%) and has calcium-humate composition, which varies down the profile. The reaction is slightly acid (pH 5.5–6.5) in the topsoil, but it is usually neutral or slightly alkaline in the subsoil. The lowest pH value is found below the humus horizon. The cation exchange capacity is almost entirely base saturated, but, nevertheless, some exchangeable H may be present in the B horizon. The sum of exchangeable bases is 20–40 cmol(+) kg–1, and hydrolytic acidity usually is not more than 5–7 cmol(+) kg–1. There is a consistent but weak eluvio-illuvial differentiation of the soil profile.

These soils occur in meadow steppes, mostly cultivated, in the northern forest-steppe zone.

Meadow-chernozemics solonetzic and solonchakous soils have the profile A1-A1Bsl,ca-Bsl,ca-Cca(g). They are identified by the presence of either a solonetz horizon with more than 5% exchangeable Na+, or soluble salts, or both, at a depth of 30–80 cm.

These soils are found in southern West and East Siberia.

Meadow-chestnuts solonetzic soils have the soil profile A1-A1Bsl-Bca-BCca(cs)-Ccs(g). They differ from the Meadow-chestnut soils by the presence of a prismatic A1Bsl horizon, where the content of exchangeable sodium exceeds 5%. Soluble salts are frequent at a depth of 50 cm; salinization may or may not be accompanied by the formation of a solonetz horizon. These soils also have a lower humus content than the Meadow-chestnut soils.

These soils are formed with less influence of surface wetting and with rather shallow saline ground waters (3–5 m deep). Solonetzic Meadow-chestnut soils are usually in depressions among Chestnut soils.

6.14.4 Phaeozems Gleyic (PHg)

This soil unit occupies 0.74 million ha, which corresponds to 0.1% of the land area of the country, or 2.8% of the total Phaeozems major soil grouping.

These soils show gleyic properties within 100 cm of the surface.

The gleyic Phaeozems soil unit correlates with Meadow-chernozemics soils and Meadow-chernozem-like “Amur prairie” soils.

Meadow-chernozemics have the profile A1-A1B-Bca-Cca(Cca,g), which is similar to that of Chernozems. The humus horizon (A1) is dark-grey colored, loose, and of granular (or subangular-granular) structure. It merges into the AB horizon, which has a dark-grey brownish color and a coarse granular or subangular blocky structure. Effervescence starts in the lower part of the humus horizon. The combined thickness of humus horizons is 35–70 cm, with a high humus content in upper horizons (up to 17%), which sharply decreases downward. A weakly developed illuvial-carbonate Bca horizon lies below. It is underlain by calcareous parent rock, sometimes with gleying features. These soils differ from automorphic Chernozems by their increased humus content and deep gleying, which relates to excessive surface water or surface and ground water, generally at a depth of up to 7 m. The deep gleying may be poorly developed.

These soils are developed on undrained plains of terraces above floodplains, on the lower part of slopes and in closed depressions, under meadow-steppe vegetation in the Chernozem zone, or under deciduous forests in the northern forest-steppe zone.

Meadow-chernozem-like “Amur prairie” soils have the profile AO-A1n-A1Bt,n-Bt,g,n-BCg,n,t-Cg. The AO horizon is 7–12 cm thick. Below it is the A1 horizon (10–50 cm), which is black, with a granular or fine subangular-granular structure, and contains iron concretions. The humus color becomes lighter downward, disappearing at a depth of 60–80 cm, the structure becomes curdled, and, in the lower part, caviar-like, with distinctive features of gleying (blue-grey and rusty mottles). The amount of concretions decreases downward. Carbonates and easily-soluble salts are absent from the soil profile. Bleached quartz particles are maximal in the middle part of the soil profile, which is characterized by the highest content of clay. The SiO_2: Al_2O_3 ratio and SiO_2: Fe_2O_3 ratio are almost uniform throughout. The content of humus in the A1n horizon varies from 5% to 8–10%, and gradually decreases downwards. The Cha:Cfa ratio in this horizon is 1.9–2.3; the fulvic acids increase relatively with depth. The soil reaction is slightly acid (pH 5.9–6.3). Base saturation is 98–99%, and the sum of exchangeable cations in the humus accumulative horizons is 27–46 cmol(+) kg–1, while in the Bt,g,n horizon, it goes down to 23–26 cmol(+) kg–1. These soils are characterized by deep seasonal freezing to a depth of 2–3 m, and complete thawing happens only in mid-August. The profile frequently contains surface waters.

These soils are formed in monsoon continental climates under meadow-steppe vegetation with brush, in poorly drained plains, and on heavy-textured deposits with deep ground water (more than 10 m). They occur in the southern plains of the Amur River basin, especially in the Zea-Boorea plain.

6.15 Greyzems

This major grouping occupies 44.96 million ha, or 2.7% of the land area of Russia (*Table 5.1*). It occurs particularly in the southern part of West and East Siberia (*Figure 6.1*).

These soils have a mollic A horizon with a moist chroma of 2 or less to a depth of at least 15 cm, uncoated silt and sand grains on structural ped surfaces, and an argic B horizon; they do not have characteristics that are diagnostic for Planosols.

The following FAO soil units are mapped and the corresponding soil groups in *SMR* are described.

- Greyzems Haplic (GRh)
  - Brownish-dark-grey Forest
  - Dark-grey Forest
  - Grey Forest residual-calcareous
  - Grey Forest
  - Grey Forest nonpodzolized
  - Grey Forest with a second humic horizon
  - Grey Forest solodic
- Greyzems Gleyic (GRg)
  - Grey Forest gleyic and gley

6.15.1 Greyzems Haplic (GRh)

This soil unit occupies 44.96 million ha, which corresponds to 2.7% of the land area of the country, or 99.1% of the total Greyzems major soil grouping.

These soils are identified by their lack of gleyic properties within 100 cm of the surface.

The Greyzems Haplic soil unit correlates with brownish-dark-grey Forest, Dark-grey Forest, Grey Forest residual-calcareous, Grey Forest, Grey Forest non-podzolized, Grey Forest with a second humic horizon, and Grey Forest solodic soils.

Brownish-dark-grey Forest soils have the profile A1-AB(A1A2)-Bt-BtC-Cca(C). The sequence of the soil horizon is similar to Dark-grey Forest soils. They differ from them by the pronounced brown hue of the soil profile and greater clay accumulation in the Bt horizon.

These soils are found in the northern Caucasus.

Dark-grey Forest soils have the profile A1-AB(A1A2)-Bt-BtC-Cca(C). They are identified by a dark (dark-grey) humus horizon (25–30 cm thick) with a granular structure. The soil profile differentiation is weak. Podzolization appears as

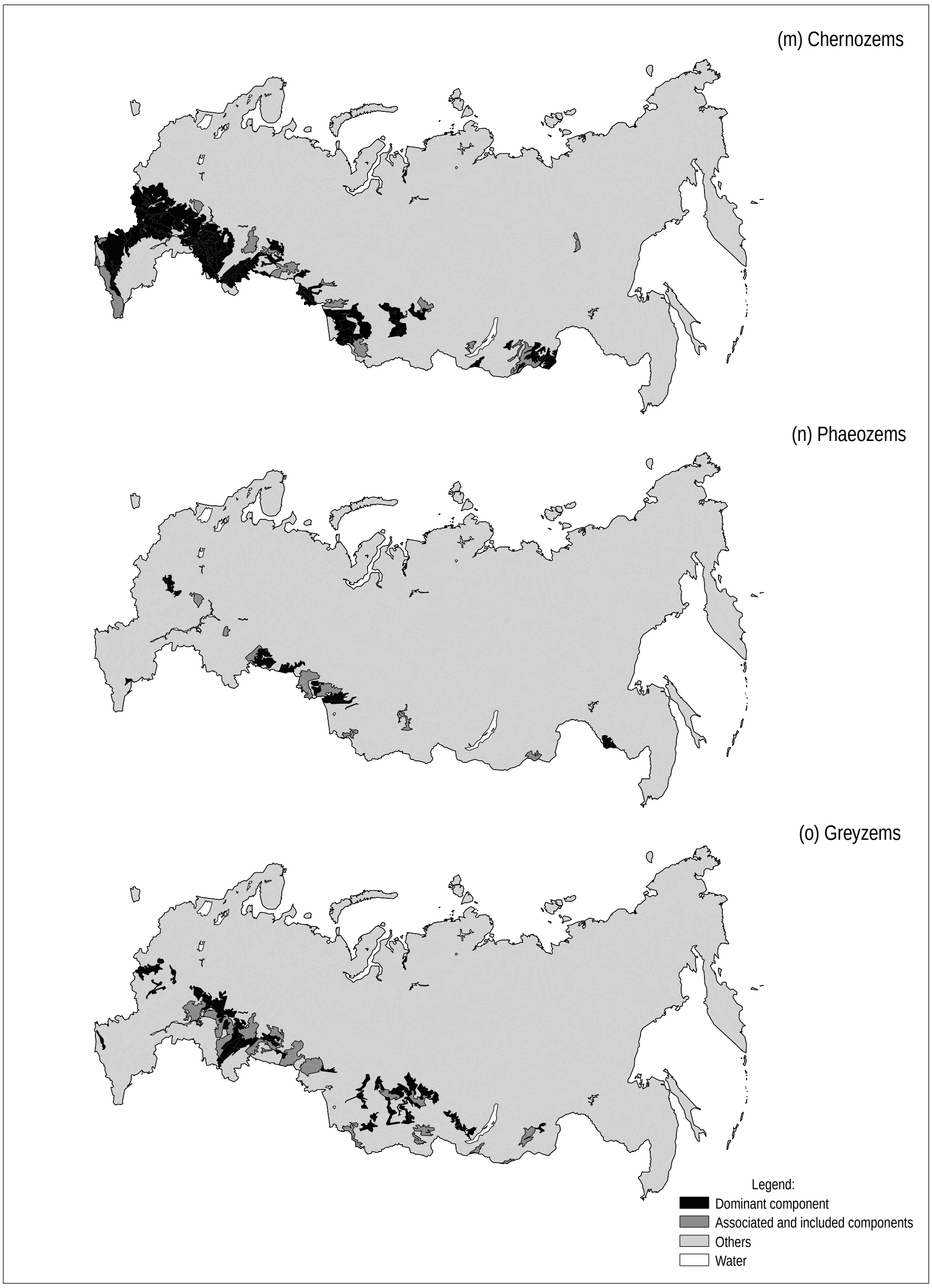

Figure 6.1. Major soil groupings of Russia: (m) Chernozems, (n) Phaeozems, and (o) Greyzems.

bleached fine material in the lower part of the humus horizon. An A1A2 horizon is usually absent, whereas the AB horizon is present. The illuvial horizon has a fine blocky subangular friable structure and sometimes has films of humus on peds. The soil reaction is slightly acid or sometimes neutral in the topsoil, and neutral or alkaline in the subsoil. The humus content is 5–12%, with calcium-humate composition. The amount of humic acid fractions linked to Ca_2+ often increases downward. Textural and total chemical composition differentiation is weak.

Such soils are formed in the southern part of the forest and forest-steppe zones.

Grey Forest residual-calcareous soils have the profile A1-A1/A2-Bt(Bt,ca)-BCca-Cca(Ccap). Effervescence is marked in the Bt horizon.

These soils are found southward and eastward from Kazan City in the south-eastern part of the Russian plain. They are formed from calcareous parent rocks (often solid rock).

Grey Forest soils have the profile A1- A1A2(A2B)-Bt-BtC(BtCca)-C, which is less differentiated than the light-grey Forest soils, from which they differ by the darkness and thickness (15–25 cm) of the humus horizon. The A1 horizon is grey with granular structure. The podzolized A1A2 or A2B horizons are less well expressed in color and structure than those of the light-grey Forest soils. These horizons have a fine subangular structure with bleached fine material and humic bright films on ped surfaces (these films are usually absent in the forest-steppe "islands" of central Siberia). Carbonates appear deeper than 1 m in various forms of accumulation. The reaction of the topsoil is slightly acid or acid, and becomes mostly acid in the illuvial horizon. The humus content in the A1 horizon is 4–8%. The humus has humic acids of the second fraction linked with Ca_2+. Accumulation of exchangeable base cations is evident in the humus horizon. The eluvio-illuvial differentiation of texture and total chemical composition is less marked compared with light-grey Forest soils.

These soils are formed under broad-leaved and narrow-leaved forests and in the forest-steppe zone.

Grey Forest nonpodzolized soils have the profile O-A1-AB-B-BC-C(ca). They do not have morphological or analytical features of podzolization. The O horizon is 4–6 cm thick and consists of forest litter. The A1 horizon (10–25 cm) is dark grey and contains about 5–14% organic matter, with a prevalence of humic acids. The AB horizon has greyish brown or dark brown color, and a fine subangular/blocky angular structure with no evidence of podzolization. The B horizon is recognized by its compaction and friable blocky subangular structure. The reaction is slightly acid to acid in the topsoil and neutral or slightly alkaline in the subsoil.

These soils are formed from loamy, often enriched, parent materials and rocks under birch, larch-birch, and larch forests with grasses on the border between forest-steppe and southern taiga. They also occupy relief depressions in the intermountain steppe of central Siberia and the Trans-Baikal region.

Grey Forest soils with a second humic horizon have the profile A1-A1A2(A2Bh)-Bt-BtCca(BtC)-Cca. The profile differentiation is less distinct, but horizon A2Bh is clearly expressed. Features of gleying (diffusive ochre and blue-grey mottles) occur in the lower part of deep-gleyed variants of these soils.

These soils occur in the same territories as grey Forest soils.

Grey Forest solodic soils have a profile similar to the grey Forest soils: A1-A1A2(A2B)-Bt-BtCca(BtC)-Cca. One morphological feature that differs from grey Forest soils is the presence of a carbonate horizon close to the surface, usually less than 1 m deep. Solodized grey Forest soils with a second humus horizon have a dark grey humus horizon in the lower part of the A1 or beneath the A1A2 horizon. The distinctive features of solodized grey Forest soils are the accumulation of amorphous quartz (silica dioxide soluble in 5% alkaline extraction) in the topsoil and the presence of exchangeable Na+ up to 2% of the cation exchange capacity.

These soils are developed under birch and pine forests of the southern taiga and forest-steppe zones. They are common on elevated positions of the relief, such as the tops of small ridges, and also occur around the periphery of depressions.

6.15.2 Greyzems Gleyic (GRg)

This soil unit occupies 0.42 million ha, which corresponds to less than 0.1% of the land area of the country, or 0.9% of the Greyzems major soil grouping.

These soils have gleyic properties within 100 cm of the surface. They correlate with gleyic and Grey Forest gley soils.

Grey Forest gleyic and gley soils have the profile A1-A1A2-(A2Bh)-Bt,g-BtCg-Cg. They differ from Grey Forest soils by the greater thickness and humus content of their A1 horizon, the weak podzolization processes (even including unpodzolized variants), and the usually weakly developed gley features in the B, BC, and C horizons. The gley grey Forest soils, formed under the influence of ground water, have a pronounced gley horizon. Both soils occur among grey forest soils in depressions of the relief and on lower parts of slopes.

6.16 Planosols

This major groupings occupies 2.26 million ha, or 0.1% of the land area of Russia (*Table 5.1*). It occurs in the southern part of the Far East (*Figure 6.1*).

These soils have an E horizon with stagnic properties in at least part of the horizon, abruptly overlying a slowly permeable horizon within 125 cm of the surface, and without a natric or spodic B horizon.

This major soil grouping does not have an analogue in the soil classification of Russia. The following FAO soil units are recognized, and corresponding soil groups of *SMR* are described.

- Planosols Eutric (PLe)
  - Solods
- Planosols Mollic (PLm)
  - Chernozems solodic
  - Meadow-chernozemics solodic
  - Meadows differentiated (and solodic) soils

6.16.1 Planosols Eutric (PLe)

This soil unit occupies less than 0.01 million ha, which corresponds to less than 0.1% of the land area of the country, or less than 0.1% of the total Planosols major soil grouping.

These soils have an ochric A horizon and a base saturation (by NH_4O_{Ac}) of 50% or more throughout the slowly permeable horizon within 125 cm of the surface; they do not have permafrost within 200 cm of the surface. They correlate with Solods.

Solods have both chemically and morphologically well-differentiated soil profiles: O-AO-A1-A2-A2Bn-Bt, n-Bca, t-Cca(s). The O or AO horizons overlie a dark-grey nut-granular A1 horizon, which gradually passes into a bleached whitish A2 horizon (sometimes with iron oxide nodules) with fine platy structure. In the lower part, this horizon becomes more compact and the amount of ferruginous concretions increases. The thickness of the solodic A2 horizon varies from 2 cm to 25 cm. It is formed of primary minerals completely denuded of clay material, partially cemented by iron hydroxides.

The grey-brownish A2Bn horizon is mottled and displays alternations of microzones enriched and poor in clay and iron. The horizon contains a large quantity of ferruginous nodules and thick-layered clay skins. The Bt,n horizon is brownish, dense, and enriched with iron and manganese. Clay skins are common in the pores and on aggregate facets. The maximum amount of clay skins is present in the middle of this horizon. Here they have a complex layered composition: silt-clay, ferruginous-clay, clay-humus. Density and clay content are higher in the lower part of the Bt,n horizon, while the iron and manganese accumulations are succeeded by calcareous concretions (Bca,t horizon). The B horizon gradually passes into parent material C. The lower part of the soil profile is under the constant influence of mineralized ground water solutions. The humus and solod horizons have slightly acid or neutral pH. The lower horizons have a neutral or alkaline reaction (when the ground waters are alkaline, the pH of the lower horizons may increase up to 9). The eluvial horizons are marked by their decrease in clay content, humus, and exchangeable bases in comparison with the humus-accumulative and illuvial horizons. The upper horizons contain 3–10% humus. The humus content sharply drops in the eluvial, and slightly increases in the illuvial horizons. The CEC of humus-accumulative horizons is 40–50 cmol(+) kg–1 per 100 g of soil. It drops to 5–6 cmol(+) kg–1 in the eluvial horizons, and increases again to 15–25 cmol(+) kg–1 or more in illuvial parts of the profile. Calcium dominates the exchangeable bases throughout the soil profile. Besides Ca_2+ and Mg_2+, the upper horizons also contain exchangeable H+ and Al_3+. The illuvial horizons show a decrease in the proportion of exchangeable Ca_2+ in comparison to Mg_2+ and sometimes the appearance of Na+ (up to 10% of exchangeable bases). Solods usually do not contain soluble salts within 1 m of the surface, while the lower strata vary greatly in salinity. Typically, the content of soluble salts does not exceed 2% within the first 2–3 m.

Solods are formed from calcareous, sometimes saline, deposits on stable surfaces in the moist conditions of depressions in the relief, which support birch and aspen wet forests, or wet meadows, because of a shallow ground water table, in the steppe and dry steppe zones.

6.16.2 Planosols Mollic (PLm)

This soil unit occupies 2.26 million ha, which corresponds to 0.1% of the land area of the country, or to practically 100% of the total Planosols major soil grouping.

These soils have a mollic A horizon or a eutric histic H horizon; they do not have permafrost within 200 cm of the surface. They correlate with Chernozems solodic, Meadow-chernozemics solodic, and, Meadows differentiated (and solodic) soils.

Chernozems solodic have the following soil profile A1-A1B-Bt-Bca-BCca-Cca. They are recognized by bleached mineral particles in the humus horizon and the compaction of the B horizon with blocky subangular structure. The soil profile looks like that of Chernozems leached or podzolized, but the soils differ by having strong penetrating humus features. The soil reaction is slightly alkaline in the whole soil profile. There is clear clay and sesquoxides differentiation. They may have an increased amount of exchangeable Na+ and Mg+.

These soils occur in southern West and East Siberia.

Meadow-chernozemics solodic have the profile A1-A1A2-Bt(g)-Btca(g)-Cca(g). They differ from Meadow-chernozemics typic soils by having bleached mineral particles in the humus horizon, a significant penetration of humus color, effervescence to a great depth, and clay and sesquioxides differentiation down the profile. They occur in southern West and East Siberia.

Meadows differentiated (and solodic) soils have a profile A1-A2(A1A2)-Bt, (g)-Bca, (g)-Cg. They differ from typical Meadow soils by having a bleached platy A2 horizon or bleached material. They usually contain exchangeable sodium. They are intermingled with calcareous Meadow soils.

6.17 Podzoluvisols

This major grouping occupies 207.37 million ha, or 12.4% of the soil cover of Russia (*Table 5.1*). It is widespread particularly in the European part of the country, West Siberia, and the southern part of East Siberia. (*Figure 6.1*).

Podzoluvisols show some features of Podzols (a strongly bleached horizon) and of Luvisols (an accumulation of clay). They have an argic B horizon with an irregular or broken upper boundary resulting from deep tonguing of the E into the B horizon, or from the formation of discrete nodules larger than 2 cm; the exteriors of these nodules are enriched and weakly cemented or indurated with iron and have redder hues and stronger chromas than the interiors. The Podzoluvisols do not have a mollic A horizon.

The following FAO soil units and their corresponding soil groups in *SMR* have been recognized and are described briefly.

- Podzoluvisols Eutric (PDe)
  - – Brownzemish-light-grey Forest
  - – Light-grey Forest
  - – Podzolics residual-calcareous
  - – Sod-podzolics with a second bleached horizon
  - – Sod-pale-podzolics (and podzolized-Brownzems)
  - – Sod-podzolics
  - – Sod-podzolics illuvial-ferruginous
  - – Sod-podzolics residual-calcareous
  - – Sod-podzolics with the second humic horizon
  - – Sod-podzolics with a second humic horizon and deep-gley
- Podzoluvisols Dystric (PDd)
  - – Podzolics
  - – Podzolics with a second bleached horizon
- Podzoluvisols Stagnic (PDj)
- Podzolics surface-gleyed
  - – Sod-podzolics surface-gleyed
- Podzoluvisols Gleyic (PDg)
  - – Gley-podzolics
  - – Gley-podzolics with a second bleached horizon
  - – Podzolic-gleys peat and peaty
  - – Podzolics deep-gleyic and gley
  - – Gleyic and gley Sod-pale-podzolics
  - – Sod-podzolic-gleys
  - – Sod-podzolic-gleys with a second humic horizon

– Sod-podzolics deep-gley and gleyic

- Podzoluvisols Gelic (PDi)

  – Podzolics over permafrost gleyic

6.17.1 Podzoluvisols Eutric (PDe)

This soil unit occupies 119.41 million ha, which corresponds to 7.2% of the land area of the country, or 57.6% of the area of the Podzoluvisols major soil grouping.

These soils have a base saturation (by NH_4O_{Ac}) of 50% or more throughout the argic B horizon within 125 cm of the surface, lack gleyic and stagnic properties within 100 cm of the surface, and lack permafrost within 200 cm of the surface.

The Podzoluvisols Eutric soil unit correlates with brownzemish-light-grey Forest, light-grey Forest, Podzolics residual-calcareous, Sod-podzolics with a second bleached horizon, Sod-pale-podzolics (and brownzems podzolized), Sod-podzolics, illuvial-ferruginous Sod-podzolics, Sod-podzolics residual-calcareous, Sod-podzolics with a second humic horizon, and Sod-podzolics deep-gleyic with a second humic horizon.

Brownzemish-light-grey Forest soils have a soil profile similar to the light grey forest soils described below. They differ from them by their brighter brown color and greater clay accumulation in the Bt horizon. These soils occur in the Pre-Caucausian region.

Light-grey Forest soils have a well-differentiated soil profile A1-A1A2-A2B-Bt-BtC-C(Cca). The humus horizon (7–15 cm in thickness) has a light-grey color and granular-fine subangular structure. It is underlain by a podzolized, greyish-bleached A1A2 horizon with a platy or subangular-platy structure and abundant bleached fine material. The A2B horizon has blocky angular (beech nut-like) leafy structure and a brownish bleached color. The illuvial Bt horizon has a brown color and clear blocky angular structure, and sometimes has blackish-brown bright films on the ped surfaces. This structure becomes prismatic downward. Carbonates are absent or appear only at a depth of more than 1.0–1.5 m. The soil is acid with the most acid reaction in the illuvial horizon. Texture and total chemical composition are usually differentiated down the profile. The humus content is 3–7% (increasing from the west to the eastern part of the country). The humus has a humate-fulvate and humin acids composition with a dominant first fraction.

These soils are formed from unconsolidated clay and loam parent material under broad-leaved forest (in the European part of Russia) and narrow-leaved forest with some coniferous species (in the Asian part).

Podzolics residual-calcareous soils have the profile O1-(A1A2)-A2-A2/Bt-Bt,pca-BCcap-Ccap. The soils are characterized by effervescence in the illuvial horizon (Bt,pca), which has reddish color, noticeable compaction, and a neutral or slightly alkaline reaction.

These soils are formed from carbonate rocks and found in taiga-forest zones in autonomous relief positions.

Sod podzolics with a second bleached horizon have the profile O-AO-A1-A2-A2g-IIA2/Bt,g-IIBt,g-IIBtC-IIC. The A2 horizon is pale-yellow. The second bleached A2g horizon has blue-grey-bleached color and occurs on the boundary between coarse and fine-textured layers. These soils are formed on bisequential deposits. They occur in the southern taiga zone.

Sod-pale-podzolics (and Brownzems podzolized) soils have the profile O-AO-A1f-A2g,n(A2)-A2/Bt,g(A2Bt)-Bt-BtC-C. The organic horizon O (2–3 cm) is underlain by the shallow (2–5 cm) AO horizon. The humus horizon A1f (5–10 cm) has a greyish-light brown color and subangular weakly compacted structure. The podzolic horizon A2g,n(A2) has a subangular or flake-platy structure, and, compared with the parent rock, is somewhat poorer in iron oxides and enriched in amorphous and crystallized sesquoxides. It contains a great amount of segregated organo-ferrous nodules. Sometimes the gleying cannot be recognized morphologically. The A2/Bt,g horizon has a bleached blue-greyish color, compact consistency, and varies very much in thickness. It forms deep bleached tongues and pockets, penetrating to the Bt horizon. In comparison with the horizon underneath, the A2/Bt,g is somewhat enriched in total iron and poorer in oxalate soluble iron compounds and aluminium. Sometimes gleying cannot be recognized morphologically. The Bt horizon has a compact consistency, clayey or clayey-loam texture, angular blocky (beech nut-like) or prismatic structure; it has dark manganese films, and is somewhat enriched in sesquoxides and clay. It gradually merges into parent rock through the BtC. The soil reaction is acid, the biotic accumulation is weak, the organic matter content is low (2–4%), and the humus is fulvic and unsaturated, with insufficient amounts of free fulvic acids. The C:N ratio is narrow. The general pattern of sesquoxides and silica distribution is eluvio-illuvial but the distribution of amorphous (oxalate-soluble) iron and aluminium compounds is accumulative.

These soils are formed from homogenous loam and bisequential parent materials, coarse loams, loamy sands, and sands, and are interstratified with fine noncalcareous loams and clays under coniferous-broad-leaved forests and broad-leaved forests with no groundcover grasses. They occur in the Pskov, Novgorod, and Smolensk regions in the Far East.

Sod-podzolics soils have a clearly differentiated profile O-AO-A1-A2/Bt-Bt-BtC-C. The forest litter horizon O is 3–5 cm thick and consists of organic matter with different degrees of decomposition. A shallow (2–3 cm) organo-mineral horizon AO is often present in the lower part of the O horizon. It contains a significant amount (30% and more) of mineral particles, mechanically mixed with organic debris. The humus A1 horizon (5–12 cm) is a grey color and contains well-decomposed organic matter, formed in situ and closely bound with the mineral part of the soil. The “podzolic” A2 horizon has a bleached or greyish bleached color and is loose with platy-leafy structure. This changes through the A2/Bt horizon to the illuvial Bt horizon, which is the most compact and the brightest in the soil profile (brown or reddish-brown). It has the distinctive feature of fine dispersed silicate material illuviated through cracks, pores, and along ped surfaces. The Bt horizon gradually merges into parent material at a depth of 250–300 cm.

These soils are well-differentiated by texture and total composition. The reaction is acid, with the pH increasing downward. The most compact horizons are A2 and A2/Bt. The humus horizon compared with the podzolic one is less acid and more base saturated. The humus content varies from 3–7% (undisturbed) and from 1.2–2.5% (cultivated soils). Fulvic acids are somewhat more prevalent than humic acids in the humus composition.

Sod-podzolic soils are subdivided into several classes according to the depth of the lower boundary of the podzolic A2 horizon from the mineral surface:

- shallow podzolic, less then 10 cm;
- moderately deep podzolic, 10–20 cm;
- deep podzolic, 20–35 cm;
- very deep podzolic, more than 35 cm.

Such soils are formed under coniferous-deciduous forests in flat and mountainous areas in the southern taiga

Sod-podzolics illuvial-ferruginous soils have the profile O-(AO)-A1-A2-Bf-C. The O horizon is shallow (1–3 cm) and contains significant amounts of mineral particles in its lower part. The A1 horizon has a light grey color. The A2 horizon is poorly expressed. The illuvial Bf horizon is a light brown or yellow color and has features of illuvial accumulation from amorphous or crystallized ferrous and aluminium hydroxides and their organo-mineral compounds. These soils are formed from sandy parent rocks under forest vegetation in the southern taiga and forest-steppe zones.

Sod-podzolics residual-calcareous (including those with a second humic horizon) have the profile O-AO-A1-A2-A2h-A2/Bt,h-Bf-Bt,pca-BtCcap-Ccap. They are similar to residually calcareous Sod-podzolic soils. The only difference is the presence of the relict dark humus horizon (Bt,h), inherited from previous phases of soil formation. Such soils are found in the southern taiga subpoena.

Sod-podzolic soils with a second humic horizon have the profile O-AO-A1-A2-A2h-A2/Bt,h-Bt-BtC-C. They are a relict, inheriting horizons A2h and A2h/Bt,h from previous phases of pedogenesis, which are expressed by humus mottles or continuous stripes. These soils occur in the southern taiga of the European part of Russia and West Siberia.

Sod-podzolics deep-gleyic soils with a second humic horizon have the profile O-AO-A1-A2(h)-A2Bt,h-Bt,g-BtCg-C. Most of their physico-chemical properties are similar to Sod-podzolic soils with a second humus horizon. They are characterized by the presence of gleying features in the B and C horizons. They are formed from clays and loams with slow, deep drainage in permafrost regions in West Siberia and central Siberia.

6.17.2 Podzoluvisols Dystric (PDd)

This soil unit occupies 24.07 million ha, which corresponds to 1.4% of the land area of the country, or 11.6% of the area of the Podzoluvisols major soil grouping.

These soils have a base saturation (by NH_4O_{Ac}) of less than 50% in at least a part of the argic B horizon within 125 cm of the surface, lack gleyic and stagnic properties within 100 cm of the surface, and lack permafrost within 200 cm of the surface.

The Podzoluvisols Dystric soil unit corresponds to Podzolics soils, Podzolics deep-gleyic and gley, and Podzolics with a second bleached horizon.

Podzolics soils have the clearly differentiated profile O-(A1A2)-A2-A2/Bt-Bt-BtC-C. They are characterized by a thin layer (5–15 cm) of the weakly decomposed litter O horizon, and an eluvial bleached A2 horizon with a plate-leafy structure and significantly varying thickness (5–50 cm). The A2 horizon is succeeded by the eluvio-illuvial bleached-brown A2/Bt horizon and by the dark brown or brown illuvial Bt horizon, which is 35–55 cm thick. The Bt horizon has a finer texture than the A2 or the transitional A2/Bt horizons, and also has the distinctive features of fine dispersed silicate material deposited in the form of skins along cracks, through pores, and on the edges of peds. It changes gradually through the BtC horizon to the weakly weathered parent rock C at a depth of 300–350 cm.

These soils have an acid reaction and low base saturation. The clay and sesquoxide distributions clearly distinguish the eluvial and illuvial horizons. Fulvic acid dominates the organic matter composition.

According to the depth of the lower boundary of the A2 horizon, podzolic soils are subdivided into four classes:

- shallow podzolic, less 10 cm;
- moderately deep podzolic, 10–20 cm;
- deep podzolic, 20–35 cm;
- very deep podzolic, more than 35 cm.

These soils are formed under coniferous-bush-moss forests in well drained conditions on plains and mountainous regions of the taiga-forest zone.

Podzolics deep-gleyic and gley (sometimes with surface gleying) have the profile O-A2-A2/Bt-Btg-BCg-C. They have distinct, specific gleying features in the

Btg horizon and deeper (waterlogging). They can also have slight surface gleyization, or slight gleying in the A2 horizon, and simultaneously distinctive gleying in the Bt horizon. Such soils are formed in the taiga-forest zone from fine textured parent rocks with some excessive wetting.

Podzolics soils with a second bleached horizon have the profile O-(A1A2)-A2-B(h,f)-A2gh-IIA2/Bt-IIBt-IIC. These soils are formed on double-layered deposits. The upper layer with fine texture is underlain by a heavier-textured one. This results in the formation of a second bleached horizon at the contact of the two layers. The (A2g) is sometimes absent, and then, the A2 and B(h,t) horizons directly change to mottled, irregularly colored, blue-grey bleached wedges and the darker brown wedge-like IIA2/Btg gleyed horizon, which is transitional to the second illuvial IIBt horizon. If the upper, finer-textured layer has a sandy (or sometimes loamy sandy) texture, then a thin (5–20 cm) pale-brownish illuvial humus and iron Bhf horizon is present between the eluvial A2 and the gley-contact A2gh horizons, and has an increased content of mobile iron and humus

These soils are formed from bisequential deposits and found in the taiga-forest zone.

6.17.3 Podzoluvisols Stagnic (PDj)

This soil unit occupies 8.04 million ha, which corresponds to 0.5% of the land area of the country, or 3.9% of the area of the Podzoluvisols major soil grouping.

These soils show stagnic properties within 50 cm of the surface, lack gleyic properties within 100 cm of the surface, and lack permafrost within 200 cm of the surface.

The Podzoluvisols Stagnic soil unit correlates with surface-gleyed Podzolics and Sod-podzolic surface gleyic soils.

Podzolics surface-gleyed have a well-differentiated soil profile O-A2gh-Bt-BtC-C. They differ from Gley-Podzolics because of the lower humus content (up to 1%) in the A2gh horizon, better developed podzolization, and more noticeable clay eluviation from topsoil. These soils are found in the middle (and rarely in the south) taiga subzones and occur in poorly drained relief positions with timely excessive atmospheric moistening. They are formed from fine-textured loams and clays of various origin.

Surface-gleyic Sod-podzolic soils have the profile O-AO-A1g-A2g-Bt-BtC-C. They have features of slight gleying in the topsoil (the A1g and A2g), which are caused by seasonal surface waterlogging by rainfall. They are formed from fine-textured parent rocks (loam and clay) and occur in the southern taiga subpoena among areas of Sod-podzolic soils. They occupy poorly drained flat parts of watersheds, micro-depressions, and gentle slopes.

6.17.4 Podzoluvisols Gleyic (PDg)

This soil unit occupies 55.71 million ha, which corresponds to 3.3% of the land area of the country, or 26.9% of the area of the Podzoluvisols major soil grouping.

These soils show gleyic properties within 100 cm of the surface and no permafrost within 200 cm of the surface. They correlate with Gley-podzolics, Gley-podzolics with a second bleached horizon, peat and peaty Podzolic-gleys, Sod-pale-podzolics gleyic and gley, Sod-podzolic-gleys, Sod-podzolic-gleys with a second humic horizon, and Sod-podzolics deep-gley and gleyic soils.

Gley-podzolics soils have the profile O-A2gh-A2Bg-Bt-BtC-C. The O horizon consists of weakly decomposed peaty forest litter (5–8 cm). The bleached, very shallow (5–10 cm) A2gh horizon has dirty grey and blue-grey colors and is characterized by a high content of light-colored humus (2–4%) and maximal concentration of amorphous and crystallized iron compounds. A lower A2Bg horizon (transitional to illuvial) is also gleyed and characterized by increased iron, as extracted by Tamm and Jackson methods. The amount of amorphous and crystallized iron compound is often higher in the A2Bg than in A2gh horizon. The Bt horizon has a finer texture than the upper horizon, with clear features of allochtonous input of fine dispersed silicate material. It gradually (through the BC horizon) merges to nongleyed parent rock, which is weakly transformed by soil processes.

The soils occur in the northern taiga and are developed on narrowly drained watersheds and the well-drained slopes of river valleys.

Gley-podzolics with a second bleached horizon have the profile O-A2gh-A2Bg-BtA2g-IIBG-IIC. These soils are formed on double-layered deposits. The upper layer has a relatively coarse texture that is underlain by a heavier-textured one. They have morphological and chemical properties similar to Gley-podzolic soils. They are distinguished from them by the formation of a second bleached BtA2g gley-contact horizon on the boundary of a parent rock texture change. The formation of the BtA2g horizon is caused by seasonal waterlogging at the top of the clay loamy layer. Such soils are formed from bisequential deposits (fine loam and coarse loamy sand, underlain by clay loam at the bottom of the soil profile) in the northern and very northern taiga zones.

Podzolic-gleys peat and peaty soils have the profile O1-A2g,n-Bt,g,n-G2. The O1 horizon (10–30 cm) consists of peaty or muck-peaty material. The podzolic A2g+,n horizon has a white-bleached color, and is structureless, with gleying features and a significant amount of nodules (shot-like and bean-like). The illuvial Bt,g,n horizon has a dirty-brown or marble-like color and contains ortsteins. The G2 horizon is of motley color (bluish, greyish, and rusty spots). The typical properties are as follows: acid reaction (pH of KCl extraction is 2.5–4.5), and high base unsaturation of the topsoil (60–90%), with noticeable decreasing of it downwards (30–40%). The A2g horizon is characterized by a small content (1–2%) of illuviated dirty grey humus. There is no humus illuviation in the Bt,g,n horizon.

These soils are formed from loams and clays in a taiga-forest zone, on slow-draining terrain (flat plains, shallow depressions) characterized by seasonal surface waterlogging, or in relief depressions with relatively high levels of ground water.

Sod-pale-podzolics gleyic and gley soils have the profile O-AO-A1-A2g,n-A2/Bt,g,n-Bt,g-BtCg-Cg. They are similar to Sod-pale-yellow-podzolic and podzolic Brown soils. The specific gleyic features caused by combined surface and ground water wetting, are clearly developed in the lower part of the soil profile. The distinct color and textural differentiation are specific features. The humus horizon A1 has a brownish-grey color with abundant spreading bright-ochre mottles, and small-nut structure. The eluvial horizon A2g,n has a bleached-grey or pale-yellow color, compact composition, and plate-nut structure with abundant ochre mottles and iron-manganese stains. The eluvio-gleyed, light-colored contact A2/Bt,g,n horizon has a blue-grey-bleached color, compact consistency with fine pores, and a blocky (beech nut-like) and prismatic structure with ochre mottles and iron-manganese nodules. The Bt,g horizon has a mottled color (blue-grey mottles and dark films on structural ped faces). The transition to parent rock horizon BtCg and lower Cg are gleyed: Bright-ochre mottles are intermixed with bluish-grey streaks.

Sod-podzolic-gleys soils have a clearly differentiated profile A1v-A1-A2g,n-Bt,g-G2. The upper horizon A1v is sod (5–6 cm); the humus horizon A1 (10–20 cm) has grey color; the gleyed podzolic horizon A2g,n has a greyish-bleached color with rusty patches and a great amount of ortstein; the illuvial Bt,g horizon is gleyed, sometimes waterlogged, and gradually merges into gleyed parent rock Cg or G2. The soil reaction is acid, the topsoil is base unsaturated, and the humus is streaked.

These soils are formed on poorly drained plains and in hollows under boggy southern taiga forests with grass cover.

Sod-podzolic-gleys with a second humic horizon have the profile A1v-A1-A2g,n,h-A2Bg,h-Bt,g-G2. The soils are similar to Sod-podzolic-gley, the only difference is the presence of a relict second humus horizon, inherited from previous phases of soil formation, in a lower part of the podzolic horizon or beneath it.

These soils are developed in the same regions as Sod-podzolic-gley soils.

Sod-podzolics deep-gley and gleyic soils have the profile O-AO-A1-A2-(A2g)-(A2/Bt,g)-Btg-BtCg-Cg. Morphologically and physico-chemically, these soils are similar to Sod-podzolics. The differences are indicated by gleying processes in the BtCg and Cg horizons. Sometimes there may be slight gleying in the A2g and A2Bt,g horizons, and the humus content may also be higher.

These soils are formed from loamy and clayey parent materials, among Sod-podzolic soils in the depressions of the relief.

6.17.5 Podzoluvisols Gelic (PDi)

This soil unit occupies 0.13 million ha, which corresponds to less than 0.1% of the land area of the country, or 0.1% of the area of the Podzoluvisols major soil grouping. These soils have permafrost within 200 cm of the surface. They are correlated with Podzolic over permafrost-gleyic soils.

Podzolics over permafrost-gleyic soils have the profile O-A2-A2/Bt-Btg-GC. They have a gleyed horizon, formed above an iced permafrost layer, at a depth of 1.0–1.5 m, which forms an impermeable layer.

These soils are found in permafrost plains and mountainous regions of central Siberia and East Siberia in the northern and middle taiga zones.

6.18 Podzols

This major grouping occupies 371.13 million ha, or 22.2% of the land area of Russia (*Table 5.1*). It is widespread particularly in the north of the European part of the country, central and southern parts of West Siberia, central Yakutia, and the Far East (*Figure 6.1*).

Podzols have a spodic B horizon, generally with a strongly bleached eluvial horizon above it. This major soil grouping also includes Podburs, for which the albic E horizon is lacking. Evidently, such a combination illustrates that the FAO central concept is rather different from the original Russian one, which emphasized the bleached layer rather than the layer of iron and organic matter accumulation.

The following FAO soil units are identified and their corresponding soil groups in *SMR* are described.

- Podzols Haplic (PZh)
  - Podzols dry-peaty
  - Podzols humic-illuvial
  - Podzols illuvial-humic-ferruginous (without subdivision)
  - Podzols ochric
  - Podzols with a second bleached horizon
- Podzols Cambic (PZb)
  - Podburs taiga (without subdivision)
  - Podburs dry-peaty
  - Podburs ochric
- Podzols ferric, PZf
  - Podburs tundra (without subdivision)
  - Podzols illuvial-ferruginous
- Podzols gleyic (PZg)

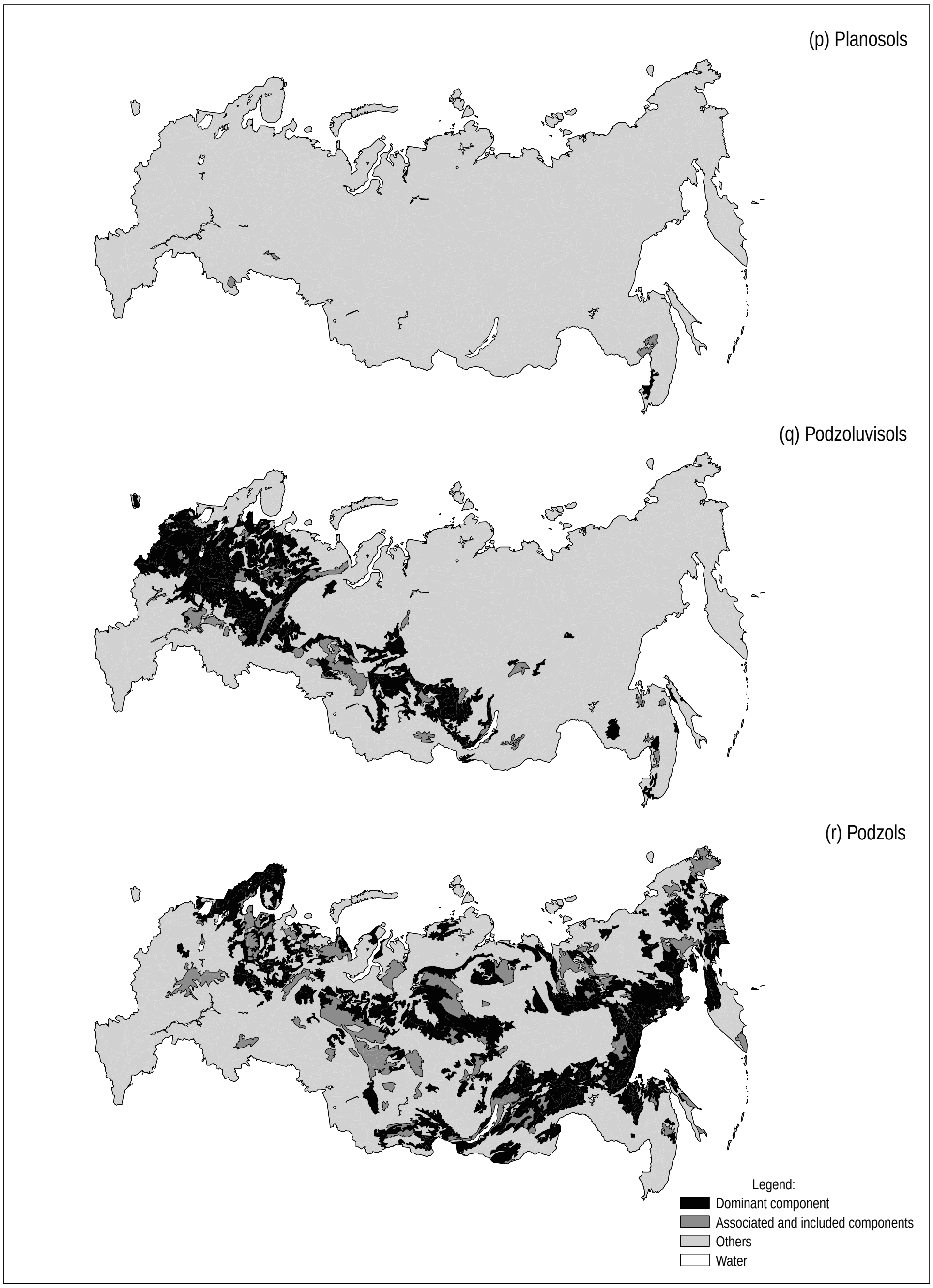

Figure 6.1. Major soil groupings of Russia: (p) Planosols, (q) Plodzoluvisols, and (r) Podzols.

  - Podzols gleyic
- Podzols gelic (PZi)
  - Podburs dark tundra
  - Podburs light tundra

6.18.1 Podzols Haplic (PZh)

This soil unit occupies 147.82 million ha, which corresponds to 8.9% of the land area of the country, or 39.8% of the area of the Podzols major soil grouping.

These soils have a spodic B horizon, which in all subhorizons has a ratio of free iron to organic carbon of less than 6:1, but which contains sufficient free iron to turn redder on ignition; a continuous albic E horizon that is thicker than 2 cm, or a distinct separation within the spodic B horizon of a subhorizon that is visibly more enriched with organic carbon, or both; they do not have gleyic properties within 100 cm of the surface nor permafrost within 200 cm of the surface.

The Podzols Haplic correlate with Podzols dry-peaty, humic-illuvial, and ochric; Podzols illuvial-humic-ferruginous (without subdivision); and Podzols with a second bleached horizon.

Podzols dry-peaty have the profile O-AO-A2-Bf,h(Bh)-C. They are similar to illuvial-humus Podzols (see below), but have a peaty organic horizon O (about 10 cm thick). The Bh horizon is usually dark with a high content of organo-mineral compounds.

These soils usually occur in mountainous areas under dwarf coniferous vegetation.

Podzols humic-illuvial have the profile O-AO-A2-Bf,h (Bh)-C. As compared to illuvial-ferruginous Podzols (see below), they have a higher content of amorphous humus, iron, and aluminium in the illuvial horizon, which is therefore darker (dark brown to reddish brown). The humus content in the Bh horizon is more than 3%.

These soils are formed in the same areas as illuvial-iron Podzols.

Podzols illuvial-humic-ferruginous have the profile O-AO-A2-Bf(Bh,f)-C. The O horizon is shallow (3–8 cm) with slightly peaty litter, which consists of dead tissue from mosses, fallen bushes, and pine needles. The AO horizon is 1–3 cm thick and consists of partly decayed humus, which is peaty in the lower part, with additions of bleached mineral grains with their iron coatings leached away. The A2 horizon is strongly lightened in color, often bleached, and poor in total and mobile (amorphous and crystallized) forms of R_2O_3. The Bt or Bf,h horizons have an ochre-brown or brownish-ochre color, contain 1–3% illuviated fulvate humus, and have a clear accumulation of total and amorphous organo-mineral iron and aluminium hydroxides or other compounds.

These soils are formed from coarse-textured deposits in forest-tundra and taiga-forest zones.

Podzols ochre have a soil profile similar to illuvial-humus Podzols. They are characterized by abundant volcanic glass in the A2 horizon (and more rarely in the Bh,f horizon), the presence of allophane in the B horizon, and a high content of amorphous forms of SiO_2 and R_2O_3 in the whole profile (but especially in illuvial horizons).

These soils are formed in a zone with thin volcanic ash deposits, under birch and larch forests with groundcover grasses, in the regions of the Kamchatka peninsula, and along the coast of the Okhotskoe Sea in the Far East.

Podzols with a second bleached horizon have the profile O-AO-A2-Bh,f-A2(A2g)-IIB(h)t-C. The upper sandy-loam or sandy layer has the same soil profile as illuvial-iron Podzols. The second bleached horizon is developed at the contact between sandy and loamy layers and is underlain by a brown-colored finer-textured horizon. They are formed from bisequential parent materials (sand and loamy sand over loam deposits) in forest-tundra and forest-taiga.

6.18.2 Podzols Cambic (PZb)

This soil unit occupies 117.67 million ha, which corresponds to 7.0% of the land area of the country, or 31.7% of the area of the Podzols major soil grouping.

These soils have a spodic B horizon, which in all subhorizons has a ratio of free iron to organic carbon of less than 6:1, but which contains sufficient iron to turn redder on ignition; lack, or have only a thin (2 cm or less) or discontinuous, albic E horizon; lack a subhorizon within the spodic B horizon that is visibly more enriched with organic carbon; and are without gleyic properties within 100 cm of the surface or permafrost within 200 cm of the surface.

The Podzols Cambic soil unit correlates with Podburs taiga (without subdivision), Podburs dry-peaty, and ochre.

Podburs taiga (without subdivision) have the profile O(AO)-Bh(Bf,h)-C. Peaty, peaty-muck, and muck horizons, and more rarely-forest litter horizons, are evident in the upper part of the soil profile. The humus A1 horizon is absent. The upper organic horizons O and AO are in direct contact with illuvial aluminium-iron-humus and mineral horizons Bh or Bg,h. They have a dark-brown or red-brown color, and become paler downward. The whole profile or most of it has no morphological features of gleying. There are no micromorphological features of podzolization between O(AO) and Bh (Bf,h) horizons. Sometimes micromorphological and chemical features of bleaching (removal of humus-iron films, bleaching, corrosion of mineral grains, iron and aluminium eluviation) are observed in the mineral and organic compounds. The distinctive shallow mottles, lenses and stripes of bleached podzolized mineral material, are formed in the most podzolized Podburs at the contact of O(AO) and the Bh(Bf,h) horizons. Evidence of illuviation of amorphous humus, iron, and aluminium is clear in Bh(Bf,h) horizons when compared with the parent material (films, brown and reddish-brown exudates on stones, coating mineral particles grains in cavities, all enriched in total Fe_2O_3 and Al_2O_3 and in their oxalate-soluble forms). The illuvial humus content in these horizons (2–3%) varies strongly because of the different pedogenetic conditions. The clear differentiation of humus acids is typical for the humus profile, with a dominant accumulation of humic (ulmic) acids in the O(AO) horizons and mobile fulvic acids (groups 1a and 1) in Bh (Bf,h) horizons. The illuvial humus penetration is usually deep. The chemical–physical features of fersiallitization and weak clay formation are often present in the B horizon when it is compared with parent rock.

These soils are formed from internally well-drained, coarse-textured, parent materials in cold humid areas of forest-tundra, and northern and middle taiga zones.

Podburs dry-peaty have the profile O-AO-Bf(Bh)-C. These are dominantly dark-colored soils with a peaty horizon more than 10 cm thick. They are common under mountainous bush coniferous forest in the taiga zone.

Podburs ochre have the profile O-AO-Bfh-C. The soils are characterized by a very high content of SiO_2, Al_2O_3, and Fe_2O_3 (up to 10% of oxalate-soluble SiO_2, 13–20% of Al_2O_3, and up to 8–12% of Fe_2O_3). They take the form of organo-mineral compounds, free hydroxides, and allophonoids. Silicate clay minerals in ochric podburs are absent or present in trace amounts.

These soils are formed under tundra and northern taiga vegetation in young volcanic zones and moderately active volcanic ash deposits beyond the limits of modern intensive agriculture.

6.18.3 Podzols Ferric (PZf)

This soil unit occupies 62.41 million ha, which corresponds to 3.7% of the land area of the country, or 16.8% of the area of the Podzols major soil grouping.

These soils have a spodic B horizon in which all subhorizons have a ratio of free iron to organic carbon of 6:1 or more; they do not have gleyic properties within 100 cm of the surface nor permafrost within 200 cm of the surface.

The Podzols Ferric soil unit correlates with tundra Podburs (without subdivision), and illuvial-ferruginous Podzols.

Podburs tundra (without subdivision) have characteristics that are intermediate between dark tundra Podburs and light tundra Podburs (see below).

Podzols illuvial-ferruginous have the profile O-AO-A2-Bf(Bh,f)-C. The O horizon is shallow (3–8 cm), slightly decomposed litter, consisting of dead tissue from mosses, fallen bushes, and pine needles. The AO horizon is 1–3 cm thick and consists of partly decayed peaty humus in the lower part, with additions of mineral grains. It is bleached and the iron coatings have been washed away. The A2 horizon is much lightened in color, often bleached, and poor in total and mobile (amorphous and crystallized) forms of R_2O_3. The Bt or Bf,h horizons have an ochric-brown or brownish-ochric color, contain 1–3% illuviated fulvate humus, and have a clear accumulation of total and amorphous organo-mineral iron and aluminium compounds or hydroxides.

These soils are formed from coarse-textured deposits in forest-tundra and taiga-forest zones.

6.18.4 Podzols Gleyic (PZg)

This soil unit occupies 26.79 million ha, which corresponds to 1.6% of the land area of the country, or 7.2% of the area of the Podzols major soil grouping.

These soils have gleyic properties within 100 cm of the surface but no permafrost within 200 cm the surface. They correlate with gleyic Podzols.

Podzols Gleyic have the profile O1-A2-Bh-Cg. The O1 horizon (10–30 cm) is peat or peaty-muck. The A2 horizon has a bleached or dirty-white color due to illuviation of organic matter from the O1 horizon with a few gley features. The illuvial Bh horizon has a brownish-black or bright ochre color, is enriched with illuviated humus, and often (not always) contains ortsteins. The C horizon has excess water and is gleyed. The soils are acid (pH of KCl extraction is 2.0–4.0) and base-unsaturated, with a clear eluvio-illuvial humus distribution.

These soils are formed from coarse-textured parent materials (sands and loamy sands) under excessive surface or ground moistening in forest-tundra and taiga-forest zones.

6.18.5 Podzols Gelic (PZi)

This soil unit occupies 16.42 million ha, which corresponds to 1.0% of the land area of the country, or 4.4% of the area of the Podzols major soil grouping.

These soils have permafrost within 200 cm of the surface. They correlate with Podburs dark tundra and Podburs light tundra.

Podburs dark tundra have the profile O(AO)-Bh(Bh,f)-C. Peat, peaty-muck, peaty humus, and sometimes mineral inclusions form the O(AO) topsoil horizon. This horizon is in direct contact with the mineral horizon Bh(Bh,f), containing illuvial aluminium-iron-humus material; the color is dark-brown or red-brown and becomes paler with depth. Such soils are acid, strongly leached, and contain mobile fulvate humus. No morphological features of the gleying process are apparent throughout the whole profile, or most of it. Micromorphological features of the podzolization process are absent from the O(AO) and Bh(Bh,f) horizons. Sometimes the micromorphological and chemical features of bleaching-podzolization (removal of iron-humus films, bleaching, corrosion of mineral grains, loss of iron and aluminium) are evident in the mineral mass of the O or AO horizons. The podzolized podburs have mottles, lenses, and bands of lightened podzolized mineral material, and they may occur at the contact between O(AO) and Bh(Bh,f) horizons. Features typical of illuviation of amorphous compounds of humus, iron, and aluminium are visible in mineral horizons Bh(Bh,f). Brown and red-brown colored films cover stones and mineral particles grains and fill cavities (observed macromorphological cracks in thin layers). They are enriched in total Fe_2O_3 and Al_2O_3 and in their oxalate-soluble forms compared to the parent material. The illuvial humus content is about 2–3% and varies significantly according to specific conditions of pedogenesis. The strong differentiation of humus acids is marked throughout the profile, with dominant accumulation of humic (ulmic) acids in the O(AO) horizons and mobile fulvic acids (group 1 and 1a fractions) in the Bh(Bh,f) horizons. Illuvial humification of the soil profile is usually deep. Chemico-mineralogical features of desilicification, fersiallitization, and weak clay formation are often present in the B horizon as compared to the parent materials.

These soils are formed from coarse-textured deposits in forest-tundra and taiga-forest zones.

Podburs light tundra have the profile AO(O)-Bf(Bh,f)-C. They are distinguished from dark podburs by the thinner AO(O) horizons with more decomposed organic matter, which is mostly peaty humus and raw humus (AO). They also have lighter-colored Bf and Bh,f mineral horizons – pale-reddish-brown, yellow-brown, or strong brown. The features of podzolization are weak and are identified only by micromorphological methods (observing the bleaching of mineral particles grains). The whole profile is not so acid as that of the dark Podburs, in fact, the subsoil is often only slightly acid. As compared with dark podburs, there is less illuvial humus ($\leq$–3%) and amorphous iron and aluminium compounds in light podburs. They also have only weak accumulation of clay, total Fe_2O_3 and Al_2O_3, and their oxalate soluble forms, in the Bf(Bh,f) horizon as compared to the parent material.

They are formed from the same parent materials as dark Podburs, but in colder, more continental and less humid areas, and in local xerophytic, flat, and mountainous regions of tundra.

6.19 Histosols

This major grouping occupies 118.86 million ha, or 7.1% of the soil cover of Russia (*Table 5.1*). It is widespread (*Figure 6.1*), particularly in the central and northern regions of the European part of the country, the central part of West Siberia, and the southern part of the Far East.

Histosols are soils dominated by fresh or partly decomposed organic material. Such soils have 40 cm or more of organic soil materials (60 cm of more if the

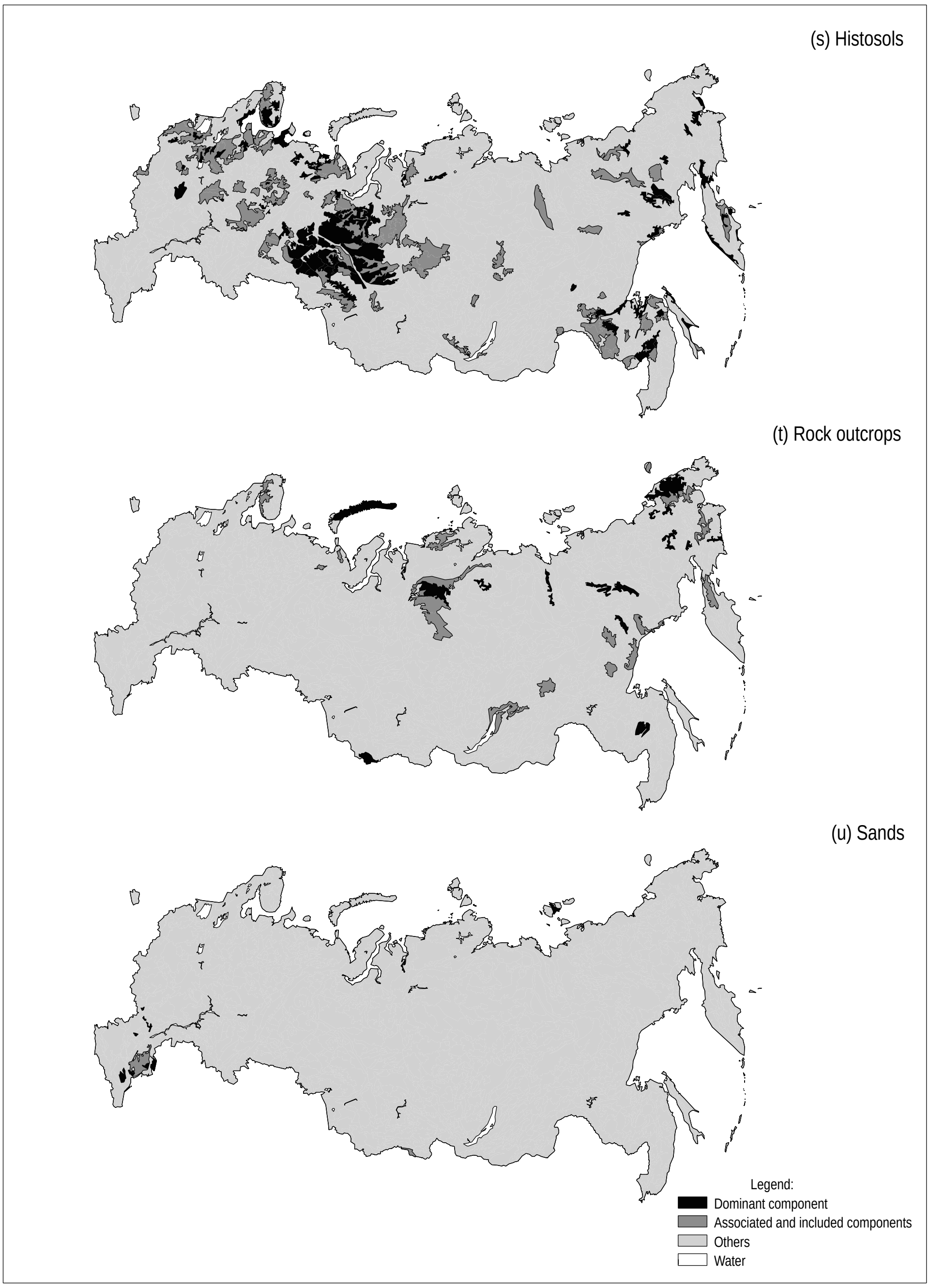

Figure 6.1. Major soil groupings of Russia: (s) Histosols, (t) Rock outcrops, and (u) Sands.

organic material consists mainly of sphagnum or moss or has a bulk density of less than 0.1 g/cm^3) either extending down from the surface or taken cumulatively within the upper 80 cm of the soil; the thickness of the H horizon may be less when it rests on rock or on fragmental material in which the interstices are filled with organic matter.

The following FAO soil units and their corresponding soil groups in *SMR* are distinguished.

- Histosols Terric (HSs)
  – Peat-ashes banded boggy
  – Peats low moor
  – Peats boggy solonchakous
- Histosols Fibric (HSf)
  – Peats transitional moor
  – Peats high moor
- Histosols without subdivision (HS)
  – Peats Boggy
- Histosols Gelic (HSi)
  – Peats boggy degrading (mineralizing)

6.19.1 Histosols Terric (HSs)

This soil unit occupies 8.58 million ha, which corresponds to 0.5% of the land area of the country, or 7.2% of the area of the Histosols major soil grouping.

These soils have highly decomposed organic materials with strongly reduced amounts of visible plant fibers and a very dark grey to black color to a depth of 35 cm or more from the surface, have imperfect to very poor drainage, and lack a sulfuric horizon or sulfidic materials within 125 cm of the surface and permafrost within 200 cm of the surface.

Histosols Terric correlate with Peat-ashes banded boggy, and Peats low moor.

Peat-ashes banded boggy soils are characterized by layers of volcanic sands and ash in the peat horizon.

Peats low moor soils are characterized by the peaty O horizon, which is more than 50 cm thick. They are light-brownish in color and acid in reaction. The mineral ash content is less than 6.5%, and the organic material is not decomposed or only slightly decomposed.

Peats boggy solonchakous soils are characterized by the presence of soluable salts.

6.19.2 Histosols Fibric (HSf)

This soil unit occupies 90.78 million ha, which corresponds to 5.4% of the land area of the country, or 76.4% of the area of the Histosols major soil grouping.

These soils have raw or weakly decomposed organic materials, the fiber content of which is dominant to a depth of 35 cm or more from the surface; they have very poor drainage or are undrained; and they do not have a sulfuric horizon or sulfidic materials within 125 cm of the surface nor permafrost within 200 cm of the surface.

The Histosols Fibric soil unit correlates with Peats transitional moor, Peats high moor, and Peats boggy (without subdivision) soils.

Peats transitional moor soils differ from low moor soils by their darker color, higher rate of decomposition of organic material, and higher ash content (6.5–10.0% of ash).

Peats high moor soils have a dark colored peat horizon that is 50 cm or more thick. The ash content is less than 10%.

6.19.3 Histosols without subdivision (HS)

Peats boggy (without subdivision) soils occupy 19.5 million ha, which corresponds to 1.2% of the land area of the country, or 16.4% of the area of the Histosols.

This group corresponds to generally recognized Histosols with no clearly defined, or not well-known, characteristics. The group can be correlated with combined peat and boggy soils, including soils with hydromorphic organic properties, formed under the influence of excessive stagnating or moving ground water or surface water (fresh or saline) and the associated hydrophilous vegetation.

6.19.4 Histosols Gelic (HSi)

These soils occupy a very small area of about 0.04 million ha, which corresponds to less than 0.1% of land area of the country.

Peats boggy degrading (mineralizing) soils are a component of patterned soils covering the tundra zone. They manifest features of pedoturbation and have permafrost within 100–200 cm from the soil surface.

Appendix 1
Correlation of the Legends: *SMR* (1988), *SMW* (FAO, 1988), and *WRB* (FAO, 1998)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
	Fluvisols (FL)	
Alluvials saturated	Eutric (FLe)	Fluvisols Eutric (FLeu)
Alluvials calcareous	Calcaric (FLc)	Fluvisols Calcaric (FLcc)
Alluvials acid	Dystric (FLd)	FluvisolsDystric (FLdy)
Alluvials meadow	Umbric (FLu)	Fluvisols Umbric (FLum)
Alluvials swamp meadow	Umbric (FLu)	Fluvisols Histic (FLhi)
Marshy saline and solonetzic	Thionic (FLt)	Fluvisols Tionic (FLti)
	Gleysols (GL)	
Gleyzems taiga differentiated	Dystric (GLd)	Gleysols Dystric (GLdy)
Gleyzems taiga differentiated peaty	Dystric (GLd)	Gleysols Histic (GLhi)
Gleyzems taiga	Dystric (GLd)	Gleysols Dystric (GLdy)
Gleyzems peaty and peat boggy	Dystric (GLd)	Gleysols Histic (GLhi)
Sod-gleys podzolized	Dystric (GLd)	Umbrisols Gleyic (Umgl)
Meadows solonetzic and solonchakous	Mollic (GLm)	Gleysols Sodic (GLso)
Meadow-boggy	Mollic (GLm)	Gleysols Histic (GLhi)
Meadow-boggy solonetzic and solonchakous	Mollic (GLm)	Gleysols Sodic (GLso)
Sod-(muck-) gleys	Umbric (GLu)	Umbrisols Gleyic (Umgl)
Sod-(muck-) gley calcareouses	Umbric (GLu)	Umbrisols Gleyic (Umgl)
Meadows	Umbric (GLu)	Umbrisols Gleyic (Umgl)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
Gleyzems arctic	Gelic (GLi)	Cryosols Gleyic (CRgl)
Gleyzems arctotundra muck-gley	Gelic (GLi)	Cryosols Gleyic (CRgl)[a]
Gleyzems and weak-gley humic tundra	Gelic (GLi)	Cryosols Umbric (CRum)[a]
Gleyzems peaty and peat tundra (shallow and deep peat)	Gelic (GLi)	Cryosols Histic (CRhi)
Gleyzems peaty and peat muck tundra	Gelic (GLi)	Cryosols Histic (CRhi)
Gleyzems differentiated peaty-muck and peat tundra	Gelic (GLi)	Cryosols Histic (CRhi)
Gleyzems weak-gley peaty-muck taiga	Gelic (GLi)	Cryosols Histic (CRhi)[a]
Gleyzems peaty-muck taiga	Gelic (GLi)	Cryosols Histic (CRhi)
	Regosols (RG)	
Arctic desert	Gelic (RGi)	Cryosols Yermic (CRye)
Arctic cryozems	Gelic (RGi)	Cryosols Haplic (CRha)[a]
Arctic hydromorphic non-gleyic	Gelic (RGi)	Cryosols Oxyaquic (CRoa)
	Leptosols (LP)	
Podzolics shallow	Dystric (LPd)	Leptosols Dystric (LPdy)
High-Mountain sod-baldy	Dystric (LPd)	Crysosols Turbic (CRtu)
High-Mountain semidesert	Dystric (LPd)	Leptosols Yermic (LPye)
High-Mountain desert	Dystric (LPd)	Leptosols Yermic (LPye)
Mountain-meadow sod-peaty	Dystric (LPd)	Leptosols Umbric (LPum)
Muck-calcareous	Rendzic (LPk)	Leptosols Rendzic (LPrz)
Sod-calcareouses		Leptosols Rendzic (LPrz)
Chernozems shallow	Mollic (LPm)	Leptosols Mollic (LPmo)
Mountain forest chernozemic	Mollic (LPm)	Leptosols Mollic (LPmo)
Mountain-meadow chernozem-like	Mollic (LPm)	Leptosols Mollic (LPmo)
Chestnuts shallow	Mollic (LPm)	Leptosols Mollic (LPmo)
Mountain meadow-steppe	Mollic (LPm)	Leptosols Mollic (LPmo)
Mountain steppe and cold-steppe	Mollic (LPm)	Leptosols Mollic (LPmo)

[a] Cryosol Turbic in patterned cover (cryogenic complexes).

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
High-Mountain steppe	Mollic (LPm)	Leptosols Mollic (LPmo)
Mountain forest-meadows	Umbric (LPu)	Leptosols Umbric (LPum)
Mountain forests humic-accumulative weakly acid	Umbric (LPu)	Leptosols Umbric (LPum)
Mountain-meadow soddy	Umbric (LPu)	Leptosols Umbric (LPum)
Mountain debrital-organogenuos	Lithic (LPq)	Leptosols Lithic (LPli)
Shallow weakly developed	Lithic (LPq)	Leptosols Lithic (LPli)
Mountain primitive	Lithic (LPq)	Leptosols Lithic (LPli)
Muck-calcareous tundra	Gelic (LPi)	Cryosols Calcic (CRcc)
Soils of permafrost cracks	Gelic (LPi)	Cryosols Haplic (CRha)
Soils of spots (saline, arctic and tundra)	Gelic (LPi)	Cryosols Turbic (CRtu)
	Arenosols (AR)	
Sierosands	Haplic (ARh)	Arenosols Haplic (ARha)
Pine forest sands	Cambic (ARb)	Arenosols Protic (ARpr)
	Andosols (AN)	
Volcanics dry-peaty	Haplic (ANh)	Andosols Histic (ANhi)
Volcanics ochric (including podzolized)	Haplic (ANh)	Andosols Acroxic (ANao)
Volcanics light-ochric (including podzolized)	Haplic (ANh)	Andosols Acroxic (ANao)
Volcanics podzolized-ochric	Haplic (ANh)	Andosols Acroxic (ANao)
Volcanics banded-ochric	Haplic (ANh)	Andosols Thaptic (ANth)
Volcanics banded-ashed	Vitric (ANz)	Andosols Thaptic (ANth)
Volcanics illuvial-humic tundra	Gelic (ANi)	Cryosols Andic (CRan)
	Vertisols (VR)	
Chernozems compact	Eutric (VRe)	Vertisols Pellic (VRpe)
Meadow-chernozemics compact	Eutric (VRe)	Vertisols Pellic (VRpe)
Meadow compact	Eutric (VRe)	Vertisols Haplic (VRha)
Alluvials compact	Eutric (VRe)	Vertisols Haplic (VRha)
	Cambisols (CM)	
Brownzems weakly unsaturated podzolized	Eutric (CMe)	Cambisols Eutric (CMeu)
Sod-brownzems weakly unsaturated and saturated	Eutric (CMe)	Cambisols Eutric (CMeu)
Brownzems weakly unsaturated	Eutric (CMe)	Cambisols Eutric (CMeu)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
Brownzems residual-calcareous	Eutric (CMe)	Cambisols Eutric (CMeu)
Pales mucky	Gelic (CMi)	Cambisols Gelic (CMge)
Pales typical	Gelic (CMi)	Cambisols Gelic (CMge)
Brownzems raw-humic	Dystric (CMd)	Cambisols Dystric (CMdy)
Brownzems raw-humic illuvial-humic	Dystric (CMd)	Cambisols Dystric (CMdy)
Brownzems acid	Dystric (CMd)	Cambisols Dystric (CMdy)
Brownzems acid podzolized	Dystric (CMd)	Cambisols Dystric (CMdy)
Sod-brownzems acid	Dystric (CMd)	Umbrisols Humic (CMhu)
Sod-brownzems ferrugenous	Dystric (CMd)	Umbrisols Humic (CMhu)
Pales podzolized	Gelic (CMi)	Cambisols Gelic (CMge)
Pales solodic	Gelic (CMi)	Cambisols Gelic (CMge)
Granuzems	Dystric (CMd)	Cambisols Dystric (CMdy)
Brownzems muck-humus-accumulative	Humic (CMu)	Cambisols Dystric (CMdy)
Grey-pales	Gelic (CMi)	Gambisols Gelic (CMge)
Pales calcareous	Gelic (CMi)	Cambisols Gelic (CMge)
Cinnamonics calcareous	Calcaric (CMc)	Cambisols Calcaric (CMca)
Cinnamonics typical	Chromic (CMx)	Cambisols Chromic (CMcr)
Meadow-cinnamonics	Chromic (CMx)	Cambisols Chromic (CMcr)
Brownzems gleyic and gley	Gleyic (CMg)	Cambisols Gleyic (CMgl)
Brownzems raw-humic gley	Gleyic (CMg)	Cambisols Gleyic (CMgl)
Granuzems gley	Gleyic (CMg)	Cambisols Gleyic (CMgl)
Taiga peaty-muck high-humic non-gleyic	Gelic (Cmi)	Gryosols Histic (CRhi)
Sod-brownzems gleyic and gley	Gelic (Cmi)	Umbrisols Gelic (Umge)
	Calcisols (CL)	
Browns (semidesert)	Haplic (CLh)	Calcisols Haplic (CLha)
Browns solonetzic and solonchakous	Luvic (CLl)	Calcisols Endosalic (CLszn)
	Solonetz (SN)	
Solonetzes	Haplic (SNh)	Solonetz Humic (SNhu)
Solonetzes meadowish	Gleyic (SNg)	Solonetz Geyic (SNgl)
Solonetzes meadowous	Gleyic (SNg)	Solonetz Geyic (SNgl)
	Solonchaks (SC)	
Solonchaks typical	Haplic (SCh)	Solonchaks Haplic (SCha)
Solonchaks meadow	Gleyic (SCg)	Solonchaks Gleyic (SCgl)
Shor Solonchaks	Gleyic (SCg)	Solonchaks Gleyic (SCgl)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
	Kastanozems (KS)	
Chestnuts dark	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts dark deep	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts deep	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts leached	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts light	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts light deep	Haplic (KSh)	Kastanozems Haplic (Ksha)
Chestnuts dark solonetzic and solonchakous	Luvic (KSl)	Kastanozems Luvic (KSlv)
Chestnuts solonetzic and solonchakous	Luvic (KSl)	Kastanozems Luvic (KSlv)
Chestnuts light solonetzic and solonchakous	Luvic (KSl)	Kastanozems Luvic (KSlv)
Chestnuts dark calcareous	Calcic (KSk)	Kastanozems Calcic (KScc)
	Chernozems (CH)	
Chernozems typical	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems ordinary	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems podzolized deep	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems leached deep	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems weakly leached deep	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems washed	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems deeply effervescing and non-calcareous	Haplic (CHh)	Chernozems Chernic (CHch)
Chernozems southern and ordinary mycelial-calcareous	Calcic (CHk)	Chernozems Calcic (CHcc)
Chernozems southern	Calcic (CHk)	Chernozems Calcic (CHcc)
Chernozems residual-calcareous	Calcic (CHk)	Chernozems Calcic (CHcc)
Chernozems leached	Luvic (CHl)	Chernozems Luvic (CHlv)
Chernozems solonetzic		Chernozems Luvic (CHlv)
Chernozems leached glossic	Glossic (CHw)	Chernozems Glossic (CHgs)
Chernozems ordinary glossic	Glossic (CHw)	Chernozems Glossic (CHgs)
Chernozems southern glossic	Glossic (CHw)	Chernozems Glossic (CHgs)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
	Phaeozems (PH)	
Meadow-chernozemics	Haplic (PHh)	Phaeozems Haplic (PHha)
Meadow-chernozemics leached	Haplic (PHh)	Phaeozems Haplic (PHha)
Meadow-chestnuts	Haplic (PHh)	Phaeozems Haplic (PHha)
Meadow-chernozemics calcareous	Calcaric (PHc)	Phaeozems Calcaric (PHca)
Chernozems podzolized	Luvic (PHl)	Phaeozems Luvic (PHlv)
Meadow-chernozemics solonetzic and solonchakous	Luvic (PHl)	Phaeozems Sodic (PHso)
Meadow-chestnuts solonetzic	Luvic (PHl)	Phaeozems Sodic (PHso)
Meadow-chernozem-like “Amur prairie”	Gleyic (PHg)	Phaeozems Gleyic (PHgl)
	Greyzems (GR)	
Grey forest	Haplic (GRh)	Phaeozems Albic (PHab)
Grey forest non-podzolized	Haplic (GRh)	Phaeozems Luvic (PHlv)
Grey forest with the second humic horizon	Haplic (GRh)	Phaeozems Albic (PHab)
Grey forest solodic	Haplic (GRh)	Phaeozems Albic (PHab)
Dark-grey forest	Haplic (GRh)	Phaeozems Albic (PHab)
Dark-grey forest with the second humic horizon	Haplic (GRh)	Phaeozems Albic (PHab)
Brownish-dark-grey forest	Haplic (GRh)	Phaeozems Albic (PHab)
Grey forest residual-calcareous	Haplic (GRh)	Phaeozems Albic (PHab)
Grey forest gleyic and gley	Gleyic (GRg)	Phaeozems Gleyic (PHgl)
	Planosols (PL)	
Solods	Eutric (PLe)	Planosols Albic (PLab)
Solods boggy	Eutric (PLe)	Planosols Gleyic (PLgl)
Chernozems solodic	Mollic (PLm)	Planosols Mollic (PLmo)
Meadow-chernozemics solodic	Mollic (PLm)	Planosols Mollic (PLmo)
Meadows differentiated (and solodic)	Mollic (PLm)	Planosols Luvic (PLlv)
	Podzoluvisols (PD)	
Podzolics residual-calcareous	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics residual-calcareous	Eutric (PDe)	Albeluvisols Umbric (ABum)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
Sod-podzolics illuvial-ferrugenous	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics residual-calcareous with the second humic horizon	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics weakly unsaturated and saturated	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-pale-podzolics (and podzolized-brownzems)	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics with the second humic horizon deep-gleyic	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics with the second bleached horizon	Eutric (PDe)	Albeluvisols Umbric (ABum)
Sod-podzolics with the second humic horizon	Eutric (PDe)	Albeluvisols Umbric (ABum)
Light-grey forest	Eutric (PDe)	Phaeozems Albic (PHab)
Light-grey forest with the second humic horizon	Eutric (PDe)	Phaeozems Albic (PHab)
Brownish-light-grey forest	Eutric (PDe)	Phaeozems Albic (PHab)
Podzolics	Dystric (PDd)	Albeluvisols Haplic (ABha)
Podzolics with the second bleached horizon	Dystric (PDd)	Albeluvisols Haplic (ABha)
Podzolics with the second humic horizon	Dystric (PDd)	Albeluvisols Haplic (ABha)
Podzolics surfacely gleyic	Stagnic (PDj)	Albeluvisols Stagnic (ABst)
Sod-podzolics surfacely gleyic	Stagnic (PDj)	Albeluvisols Stagnic (ABst)
Gley-podzolics	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)
Gley-podzolics with the second bleached horizon	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)
Podzolic-gleys peat and peaty	Gleyic (PDg)	Albeluvisols Histic (ABhi)
Podzolic-gleys peat and peaty with the second humic	Gleyic (PDg)	Albeluvisols Histic (ABhi)
Podzolics deep-gleyic and gley	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)
Sod-pale-podzolics gleyic and gley	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)
Sod-podzolics deep-gley and gleyic	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)

Soil units of SMR	Major soil groupings and soil units (index)	Soil groups and lower-level units of *WRB* (index)
Sod-podzolic-gleys	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)
Sod-podzolic-gleys with the second humic horizon	Gleyic (PDg)	Albeluvisols Gleyic (ABgl)
Podzolics over-permafrost-gleyic	Gelic (PDi)	Albeluvisols Gelic (ABge)
	Podzols (PZ)	
Podzols humic-illuvial	Haplic (PZh)	Podzols Carbic (PZcb)
Podzols illuvial-humic-ferrugenous (without subdivision)	Haplic (PZh)	Podzols Haplic (PZha)
Podzols dry-peaty	Haplic (PZh)	Podzols Histic (PZhi)
Podzols ochric	Haplic (PZh)	Podzols Rustic (PZrs)
Podzols with the second bleached horizon	Haplic (PZh)	Podzols Haplic (PZha)
Podburs taigic (without subdivision)	Cambic (PZb)	Podzols Entic (PZ)et
Podburs dry-peaty	Cambic (PZb)	Podzols Histic (PZhi)
Podburs ochric	Cambic (PZb)	Podzols Rustic (PZrs)
Podzols illuvial-ferrugenous	Ferric (PZf)	Podzols Rustic (PZrs)
Podzols gleyic	Gleyic (PZg)	Podzols Gleyic (PZgl)
Podburs dark tundra	Gelic (PZi)	Cryosols Haplic (CRha)[a]
Podburs light tundra	Gelic (PZi)	Cryosols Haplic (CRha)[a]
Podburs tundra (without subdivision)	Gelic (PZi)	Cryosols Haplic (CRha)[a]
	Histosols (HS)	
Peats boggy degrading (mineralizing)	Gelic (HSi)	Histosols Cryic (HScy)
Peats transitional moor	Fibric (HSf)	Histosols Fibric (HSfi)[b]
Peats low moor	Terric (HSs)	Histosols Sapric (HSsa)[b]
Peats boggy solonchakous	Terric (HSs)	Histosols Salic (HSsz)[b]
Peat-ashes banded boggy	Terric (HSs)	Histosols Sapric (HSsa)[b]
Peats high moor	Fibric (HSf)	Histosols Fibric (HSfi)[b]
Peats boggy (without subdivission)	Histosols (HS), without subdivision	Histosols Fibric (HSfi)[b]
	Nonsoils formations	
Rock outcrops	(R)	
Sands	(S)	

[a] Cryosol Turbic in patterned cover (cryogenic complexes).
[b] Histosol Cryic in permafrost zone.

Appendix 2
Phases Distinguished in the Soil Database for Russia

Gelundic: The gelundic phase marks soils showing formation of polygons on their surface due to frost heaving.

Gilgai: Gilgai is the microrelief typical of clayey soils, mainly Vertisols, that have a high coefficient of expansion with distinct seasonal changes in moisture content. This microrelief consists of either a succession of enclosed microbasins and microknolls in nearly level areas, or of microvalleys and microridges that run up and down the slope. The height of the microridges commonly ranges from a few cm to 100 cm. Rarely does the height attain 200 cm.

Inundic: The inundic phase is used when standing or flowing water is present on the soil surface for more than 10 days during the growing period.

Lithic: The lithic phase is used when continuous hard rock occurs within 50 cm of the surface.

Phreatic: The phreatic phase refers to the occurrence of the groundwater table within 5 m from the surface, the presence of which is not reflected in the morphology of the soil. Therefore the phreatic phase is not shown, for instance, with Fluvisols or Gleysols. Its presence is important especially in arid areas where, with irrigation, special attention should be paid to effective water use and drainage in order to avoid salinization as a result of rising groundwater.

Rudic: The rudic phase marks areas where the presence of gravel, stones, boulders, or rock outcrops in the surface layers or at the surface makes the use of mechanized agricultural equipment impracticable. Hand tools can normally be used and also simple mechanical equipment if other conditions are particularly favorable. Fragments with a diameter up to 7.5 cm are considered as gravel; larger fragments are called stones or boulders. Although it could not be separated on a small-scale map, this difference is obviously important for soil management purposes.

Salic: The salic phase marks soils which, in some horizons within 100 cm of the surface, show electric conductivity values of the saturation extract higher than 4 dSm-1 at 25C. The salic phase is not shown for Solonchaks because their definition implies a high salt content. Salinity in a soil may show seasonal variations or may fluctuate as a result of irrigation practice.

Though the salic phase indicates present or potential salinization, it should be realized that the effect of salinity varies greatly with the type of salts present, the permeability of the soil, climate conditions, and the kind of crops grown. A further subdivision of the degree of salinity would be required for more detailed mapping.

Sodic: The sodic phase marks soils that have more than 6% saturation with exchangeable sodium at least in some horizons within 100 cm of the surface. The sodic phase is not shown for soil units which have a natric B horizon or which have sodic properties, since a high percentage of sodium situation is already implied in their definition.

Takyric: The takyric phase applies to heavy textured soils that crack into polygonal elements when dry and form a platy or massive surface crust.

Yermic: The yermic phase applies to soils that have less than 0.6% organic carbon within 18 cm of the surface when mixed, or less then 0.2% organic carbon if the texture is coarser than sandy loam, and which show one or more of the following features connotative of arid conditions:

1. presence in the surface horizon of gravels or stones shaped by the wind or showing desert varnish (manganese oxide coating at the upper surface) or both. When the soil is not ploughed, these gravels or stones usually form a surface pavement; they may show calcium carbonate or gypsum accumulating immediately under the coarse material.
2. presence in the surface horizon of pitted and rounded quartz grains showing a matte surface, which constitute 10% or more of the sand fraction having a diameter of 0.25 mm or more.
3. presence of two or more palygorskite in the clay fraction in at least some subhorizon within 50 cm of the surface.
4. surface cracks filled with in-blown sand or silt; when the soil is ploughed, this characteristic may be obliterated, however, cracks may extend below the plough layer.
5. a platy surface horizon which frequently shows vesicular pores and which may be indurated but not cemented.
6. accumulation of blown sand on a surface.

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