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The IIASA-LUC Project Georeferenced Database of Russia. Volumes 1 and 2: Soil and Terrain Digital Database (SOTER).

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Contents

Abstract

The IIASA/LUC georeferenced database for the former U.S.S.R. was created within the framework of the project “Modeling Land Use and Land Cover Changes in Europe and Northern Asia” (LUC). For Russia, essential information on relief, soil, vegetation, land cover and use, etc., for routine environmental analysis was lacking when the LUC project started developing the database. In addition, the environmental data on the former U.S.S.R. which were available occurred in formats (papers, tables, etc.) that in general could not be used with modern information technology, and in particular in model building. In creating the LUC project database, we have established a threefold task:

1) to obtain the relevant information for the LUC project modeling exercises;
2) to develop data which is applicable to modern information technology;
3) to contribute a series of digital databases which could be applied for a number of other specific analyses by the national and international scientific community.

In defining the tasks it was agreed to create a set of digital databases which could be handled by geographic information systems (GIS). The full set of georeferenced digital databases was combined into the LUC project’s GIS, using ARC/INFO. However, each individual item (physiography, soil, vegetation, etc.) was created as a separate digital database, allowing each item to be used independently, according to users’ needs.

The complete series of the unique georeferenced digital databases for the territory of the former U.S.S.R. is described in the IIASA/LUC volumes:

Volume 1: Physiography (landforms, slope conditions, elevations).
Volume 2: Soil.
Volume 3: Soil degradation status (Russia).
Volume 4: Vegetation.
Volume 5: Land categories.
Volume 6: Agricultural regionalization.

The main objective of the research summarized in this report was to compile, fully correlate, and update the FAO Soil Map of the World for the territory of Russia. It originated from several discussions with Drs. W. Sombroek (FAO), R. Brinkman (FAO), R. Oldeman (ISRIC) which took place at the International Soil Reference Information Center (ISRIC) in 1988-89. These discussions were initiated through research being carried out by the project on Global Assessment of Human-Induced Soil Degradation (UNEP/ISRIC, 1990) which urgently required reliable soil information on Russia. It was recognized that several other environment related activities were facing a similar problem.

In response to the discussions, the Food and Agriculture Organization of the United Nations (FAO) launched a project in 1993. According to the Letter of Agreement (CMT

73197) signed by FAO and Dokuchaev Soil Institute, the project was aimed at preparing "a Soil map of Russia at 1:5 million scale using the Revised Legend of the Soil Map of the World (1988) and corresponding database reflecting the information contained in the map and the physiographic map of the same region." The Agreement defined six layers of information to be distinguished for digitizing:

1. Soil mapping unit boundaries.
2. Topographic lines (rivers, contour lines and coastal line).
3. Geographical coordinates (longitude, latitude).
4. Physiographic (landform) units.
5. Graticule of the map.
6. Province boundaries.

In 1994, the requested products were completed and transferred to the FAO for digitizing by scanning. At that time, however, the compilation of a digital database could not be completed at FAO.

In 1995 all materials were passed to the International Institute for Applied Systems Analysis (IIASA) with the objective to complete the digital database. Considerable efforts by the GIS group of the project "Modeling Land Use and Land Cover Changes in Europe and Northern Asia" at IIASA were put into checking, correcting, and linking the digital data, and making them mutually consistent.

Completion of the digital database at IIASA, the first product of this kind to be published on the territory of Russia, has provided a more comprehensive understanding of the territory and its environment. Using modern GIS techniques, this knowledge is now readily available to any scientific or applied analyses of the land resources and environment of Russia.

Acknowledgments

This work could not have been achieved without the publication of the Soil Map of the Russian Soviet Federative Socialist Republic at scale 1:2.5 M. We would like to express our gratitude to the memory of Prof. V.M. Fridland (scientific editor-in chief) and to Dr. E.N. Rudneva, who supervised the technical tasks of map compilation, and to all institutions and co-authors of the soil map for their practical contributions.

Many thanks should be extended to Drs. W. Sombroek, R. Brinkman, F. Nachtergaele (FAO), and R. Oldeman (ISRIC) for providing support and consultation to the study.

We also like to acknowledge the financial support provided by the Food and Agriculture Organization of the United Nations which enabled Dokuchaev Soil Institute to initiate compilation of the *Soil Map of Russia* at 1:5 million scale.

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About FAO

FAO has been collaborating with IIASA, ISRIC, UNEP and other international organizations and national institutes with the objective of updating the *Soil Map of the World* according to the principles developed by the Soil and Terrain database (SOTER). These regional soil and terrain datasets will provide up-to-date information on physical and environmental conditions worldwide.

The Soil and Terrain database for North-East Africa was published this year, and the SOTER for South America and the Caribbean is due for release shortly. The present documentation of the *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 with national soil institutes in Eastern Europe, as well as with efforts of the European Soils Bureau in the same region.

FAO's AGLS Website Address:

http://www.fao.org/waicent/FaoInfo/Agricult/AGL/AGLS/AGLSHOME.HTM

DISCLAIMER

The IIASA-LUC Project Georeferenced Database of Russia. Volumes 1 and 2: Soil and Terrain Digital Database (SOTER).

Vladimir Stolbovoi, Günther Fischer, Boris Sheremet and Igor Savin.

Introduction

The research and data products presented in this report fit within the framework of a worldwide initiative to inventory the soil and terrain data following the SOTER (SOil and TERrain) methodology (ISRIC, 1995; van Engelen & Wen, 1993). The aim of the SOTER is "to utilize current and emerging information technology to establish a World Soils and Terrain Database, containing digitized map units and their attribute data. The main function of this database is to provide the necessary data for improved mapping and monitoring of changes of world soil and terrain resources" (van Engelen & Wen, 1993, p.1). Conceptually, SOTER is based on the *landscape idea* which conceives the land (where soils and terrain occur) as incorporating processes and systems of inter-relationships between physical, biological and social phenomena evolving through time.

The compilation of SOTER databases is aimed at being based on international agreements and the latest mapped data. The Revised Legend of the FAO Soil Map of the World (FAO, 1990) is recommended as a reference manual for the compilation of the soils database. Regarding the physiography database, an international consensus on technical specifications for the delineation of physiography units is lacking. Recent publications (van Engelen & Wen, 1993; ISRIC, 1995) have provided experience in elaborating physiographic (terrain) units in different parts of the World. These techniques have been incorporated into this study.

The critical task in the SOTER approach is a fitting of usually separately mapped soils and terrain data. The practical difficulties related to this key aspect are not considered in much detail in the SOTER manual. The original manual recommends to apply a step-by-step delineation procedure, starting with a drawing of physiography units, and to finish with creating of soil boundaries within physiographic polygons. Hence, this approach may lead to the deformation of the soil polygon geometry and changes of the spatial distribution of soils.

Another problem derives from the fact that many countries have already created their own soil digital databases. For these countries any alteration of the soil information will cause unacceptable discrepancies with other assessments. So the problem of consistency of existing databases with SOTER requirements arises. LUC's research has contributed practical experience in the application of SOTER which may be valuable to the future development of the SOTER methodology.

SOTER, as a digital georeferenced database, comprises of two closely linked types of information: geometry and attributes. Currently, the attribute part seems well defined. However, the geometry part was not considered as a matter of investigation. We have attempted to fill this gap proposing some measures characterizing polygon geometry.

The objective of this report is to introduce a set of digital georeferenced databases on the territory of Russia. The following coverages are included:

1) soil;

2) terrain;

3) soil and terrain (SOTER).

The report provides an explanatory text for the databases, the methodology used in its compilation, and includes technical specifications for users.

I. Data sources

Four major sources were used for the SOTER database compilation:

- The Soil Map of the Russian Soviet Federative Socialist Republic at scale 1:2.5M;
- The State Soil Map of U.S.S.R. at scale 1:1M;
- The Programme of the Soil Map of the U.S.S.R. at scale 1:2.5M;
- Hypsometric (topographic) Map of the U.S.S.R. at scale 1:2.5M.

I.1 The Soil Map of the Russian Soviet Federative Socialist Republic at scale 1:2.5M

The *Soil Map of the Russian Soviet Federative Socialist Republic (SMR)* at scale 1:2.5M was chosen as the main source for the soil database compilation. The last 15 years of the development of Russian pedology, since the publication of the FAO-Unesco Soil Map of the World (SMW), (FAO-Unesco, 1977-81), were characterized by intensive collection of empirical data for soil-mapping, and the development of fundamental topics such as classification and geographical concepts. A great amount of new soil information was obtained which significantly changed the understanding of soil diversity and soil geography of the country. Especially for the territory of North Eurasia, Siberia and the Far East, new soil data were collected massively. For the forested territories soil maps were compiled at scale 1:100 000. For the agricultural regions soil maps were produced at scale 1:10 000 and 1:25 000. These detailed materials were used for compilation of district maps at scale 1:300 000.

The SMR was compiled by the Dokuchaev Soil Institute with participation of representatives from numerous other soil research organizations collaborating in editorial panels. This core group was established to develop the scientific background of the SMR, its legend, technical design as well as the contents of each of the 16 map sheets.

The basic motivation behind the SMR compilation was the synthesis of the current development in soil genesis and geography in one uniform system combining all cartographic materials existing at different scales over the country. It was the first time that such an overview was prepared at the scale 1:2.5M. Considerable innovations were made by including in the legend of the SMR information on soil cover patterns and more detailed data, as compared with previous soil maps of the country, on soil forming factors, like relief, parent materials, and climate.

Unfortunately, due to various constraints, the SMR is not widely known or accessible neither abroad nor in Russia. Language problems and the incompatibility of classifications and data formats, including differences in analytical methods, have prevented a wide international acceptance. Also, the publication of the SMR coincided with the collapse of the Former U.S.S.R. when the order and dissemination of science developments was interrupted by major changes in economic, social and political systems. Until now, the adaptation of the SMR to a wider range of applications has not been undertaken. Thus, most of the global and national programs dealing with the Russian territory have been facing major difficulties due to a lack of adequate soil information.

I.2 The State Soil Map of the U.S.S.R. at scale 1:1M

The sheets of the *State Soil Map (SSM) of the U.S.S.R.* were used to identify FAO texture classes and phases. The complete set of the SSM sheets, including both published and manuscript formats, are available exclusively at Dokuchaev Soil Institute.

The compilation of the SSM started at the end of the 1930s. It was planned to use the map as a basis for inventorization of land resources in the country. However, compilation and publication of the huge amount of sheets took more than 40 years. Due to the long development period, these sheets are conceptually not fully consistent. A considerable number of sheets, mainly on central and northern Siberia and the Far East, were not published and exist only in manuscript form.

I.3 The Programme of the Soil Map of the U.S.S.R. at scale 1:2.5M

The *Programme of the SMR* (Fridland, 1972) was used as the main information source for correlation of the FAO SMW legend and the SMR legend. The Programme is an extensive document compiled on the basis of a preliminary proposal delivered to the national soil community in 1971, and based on notes prepared during the discussion of these materials. The Programme contains descriptions of basic elements of the SMR legend. A significant part of the program is devoted to diagnostics of soil horizons and profiles. The latter were distinguished on the basis of the classification and diagnostics of the soils of the U.S.S.R. (Kolos, 1977). Also, it should be mentioned that during the long period of compiling the SMR several technical details in the program were changed. All these unpublished additions were used in the present soil database compilation.

I.4 Hypsometric Map of the U.S.S.R. at scale 1:2.5M

The *Hypsometric (topographic) map of the U.S.S.R.* (GUGK, 1976) was used in several ways: 1) to delineate physiographic units; 2) to establish sloping characteristics for the SMR meeting the FAO SMW requirements; 3) to define projection parameters essential to georeference the physiography and soil map polygons.

The map uses a normal equidistant projection of sphere. This projection is known as "*the projection of the Map of the U.S.S.R. at 1:2.5M scale*" or "*the GUGK*[1] *projection*". According to E.A. Nefedova (Nefedova, 1995) the GUGK projection is characterized by the standard parallels:

φ_n=67°48' and φ_s=49°24'

[1] Abbreviation of the Central Administration for Geodesy and Cartography, the organisation responsible for any cartographic issues in the former U.S.S.R.

II. Compilation of the soil and terrain information for creating SOTER

Due to the differences in scales between the original SMR, the hypsometric map (scale 1:2.5M) and the FAO SOTER requirements (scale 1:5M) both of the original input maps had to be generalized to a less detailed map at a smaller scale.

II.1 The generalization procedure and the soil coverage

Usually generalization deals with two types of aggregation: 1) a generalization of the thematic content or attributes, and 2) a generalization of the mapping units or polygon geometry.

The first aspect of generalization is rather complicated. Frequently, the process of scaling up soil information is based on vaguely defined arguments, like the notion of their representativeness, the purpose the aggregated product will serve, the professional skills and experience of the author, etc.

The second aspect, a generalization of mapping units, is due to the fact that polygons occurring at a larger scale cannot always be shown on a smaller scale. In this study, the soil mapping units were generalized in accordance with traditional rules of observational cartography stating that the minimal size of a mapped polygon should not be less than 1 cm^2.

In the present study, generalization was achieved in two steps (Stolbovoi & Sheremet, 1995). In the first step, the soil groups of the SMR were correlated with the FAO SMW soil units[2]. Further, all soil polygons of the original SMR were described by attributes according to the FAO Revised Legend (FAO, 1990). Through some additional manipulations, as described below, the characteristics of soil texture and sloping conditions were created.

Secondly, to fit the 1:5M scale, neighboring soil mapping units were combined, when containing genetically, morphologically and analytically related soils. This procedure eliminated soils where their extent was less than 4% of the area of newly created soil polygons. When appropriate, other relevant information was shown as soil phases[3].

Two main difficulties had to be addressed in creating soil texture attributes. The first dealt with differences in information on the soil texture which is shown on the SMR and that required by the FAO SMW legend. Practically new data on the soil texture was collected for numerous soil polygons. The sheets of the SSM of the U.S.S.R. were used for this purpose. The second difficulty relates to the differences in the definition of textural fractions in Russia (Kolos, 1977) and the FAO SMW. The discrepancies between the two systems can be found in Table 1. The number of texture classes defined in the FAO SMW are less than those proposed in Russia. This is because the FAO legend is used at the global scale. However, the differences are not too big and the general textural classes could roughly be correlated for practical tasks at this scale. For a more precise analysis at a more detailed scale this correlation needs to be done more accurately on the basis of laboratory measurements.

The sloping conditions which are shown on the SMR do not meet the requirements formulated in the FAO SMW. Therefore, it was necessary to create a new set of these characteristics, as was done for texture. The practical problem was that the topographic maps at scales 1:2.5M and 1:5M are very rough for creating slope classes. For example, the hypsometric map at scale 1:2.5M (GUGK, 1976) used for the compilation of the SMR, has contour intervals of 50 m up to an altitude of 300 m above sea level (a.s.l.), of 100 m between 300 m to 800 m (a.s.l.). Above 1000 m (a.s.l.), the contour intervals are 250 m.

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[2] A full list of correlated soils is given in Appendix 1.

[3] A full list of phases for the Russia territory is given in Appendix 2.

To fulfill the task a representative number of plots for slope calibration have been established at different relief positions around the country. Topographic maps at scale 1:100 000 were analyzed to define slope classes for these sites. This procedure allowed to establish a correlation between the more reliable sloping conditions determined for the pilot plots and the density of contour lines on the hypsometric map at the scale 1:2.5M. This correlation was applied to create the attribute of prevailing sloping conditions in the soil mapping units.

II.2 Compilation of the terrain coverage

According to FAO requirements, four layers of information have been distinguished: physiography, topographic lines (rivers, contour lines and coastal line), administrative boundaries, and the grid of geographical coordinates (longitude, latitude) of the 16 sheets of the hypsometric map.

The delineation of the physiographic units, composed of landforms, sloping conditions and hypsometry (elevation) and complex landform, was carried out according to the principles of the SOTER manual (van Engelen & Wen, 1993; ISRIC, 1995) and drawn in ink pen directly on the hypsometric map.

Based on topography criteria, the first hierarchic tier composed of three major landforms was distinguished: level land, sloping land and steep land. For this step the criterion of "*characteristic slope*", referring to the dominant slope gradient within a terrain unit, was applied. The plots for slope calibration mentioned above were used at this step. A further breakdown of the three main landform classes was achieved through differentiation by relief intensity, and the position of a unit in relation to surrounding land, and by hypsometry. The criteria for delineation vary with major landform class:

- for level lands (slopes <8%) the relief intensity is always less than 100m/km while the absolute height above sea level is taken as hypsometric criterion;
- for sloping lands (slopes 8-30%) the same hypsometric criteria are valid as for steep land (see below), but relief intensity must be less than 600m/2 km, while always more than 50m/slope unit;
- for steep land (slopes >30%) relief intensity is more than 600m/2 km and the relative height above the local base level defines the hypsometric class.

A further delineation was achieved according to the relative position of a terrain unit vis-à-vis the surrounding terrain. This for example distinguishes a plain from a plateau.

II.3 Elaboration of combined soil and terrain (SOTER) coverage

The SOTER database for the Russian territory resulted from combining the digital soils and terrain coverages in the GIS by means of applying specific algorithms. First, the geometry for SOTER map units was created. For this, the terrain and soil coverages were intersected. terrain boundaries were used for creating the polygons of SOTER units. Some adaptations in the terrain layer were accepted due to discrepancies which had occurred when drawing inland water bodies independently of the soil and terrain layers. A new common coverage of inland water bodies was established combining information from both.

Polygons resulting from the intersection of terrain, soils, and inland water bodies were deleted when the corresponding area was less than 625 km^2, i.e., less than 1cm^2 on the map at scale 1:2.5M. Such closed area features were dropped by merging with the neighboring polygon that shared the longest border between them. The output coverage obtained by this operation forms the geometry of the SOTER database.

The next step was to elaborate the attribute information of the SOTER database. The attributes from the terrain layer were directly copied to the SOTER units. For soils, the procedure was more complicated. Soil attributes were defined by overlaying the new SOTER coverage with the original soil coverage. In this way all original soil information could be retained even when soil units were dropped in the process of creating SOTER polygons. The characteristics of the soil components in SOTER units were derived from the soil attribute database. In the calculation procedure, the following rules were applied:

a) When the area of a soil unit was less than 4% of the extent of the respective SOTER polygon, the area was attributed to other occurring soil units belonging to the same major FAO soil group. When several such units were found, the area was summed up with the largest of the applicable soil units.

b) If a soil unit area within a SOTER polygon was less than 4% and no other soil unit of the same major soil group was found, the soil unit was deleted. Its area was shared proportionally between other soil units within the SOTER polygon with an extent of more than 4%.

c) Soil texture, which is linked to the dominant soil unit in the original soil coverage, was kept. In the case where a SOTER polygon contains more than one dominant soil unit (coming from the original soil coverage) all texture classes have been retained. However, if the area of an original dominant soil unit was less than 4% of the new SOTER polygon, its texture was not included.

d) Phases are linked to the original soil polygons and thus are directly inherited by the SOTER polygon. If the area of an original soil polygon with an attached soil phase occupied less than 4% within a new SOTER polygon, the phase was not included.

II.4 The digitizing procedure

The digitizing of all maps was carried out by scanning. After entering into the GIS, further processing was done such as changes of projection and scale. The digitized polygons were corrected according to information on coastal lines, water bodies and rivers obtained from the *Digital Chart of the World* at the scale 1:1M (ESRI, 1993). Mapping unit identification codes were entered in the soil database and linked to the corresponding polygon labels in the GIS.

III. Summary of the soil, terrain and SOTER data

In general, digital databases are intended to serve multiple purposes and applications. Depending on a specific task, the relevant attributes and corresponding polygons from a database can be selected and processed. Therefore, there is not much use in characterizing the databases in a very abstract and general way. On the other hand, it seems important to describe some thematic and geographic features of the territory.

Such specification can be achieved in two complementary ways, namely by: (i) the list of attributes and their definitions which are used to characterize different aspects of a mapping unit, and (ii) a characterization of the geometry of the geographic features in a coverage.

As to the first, information on the attributes of the digital SMW (FAO, 1995) and terrain in SOTER (van Engelen & Wen, 1993) can be found in the respective manuals. For a summary of specific regional soils and terrain, we use the concept of the soil and terrain fund (reserves), which refers to the entirety of all combinations of soils and land characteristics occurring in a given region.

As far as the geometric characteristics of a georeferenced database is concerned, we apply a set of simple indicators. These consist of: the number of polygons; their granularity as described by minimum, maximum, and average polygon size; and a measure of polygon boundary complexity.

The latter is represented by the *Nagel* coefficient, Kp, (see Fridland, 1972), calculated according to the following formula:

$$Kp = \frac{P}{3.54\sqrt{S}}$$

where P denotes the polygon perimeter and S the polygon area. A few classes can be used to characterize polygon boundary complexity for ranges of Kp:

< 2 Regular

2-4 Slightly dissected

4-6 Moderately dissected

> 6 Highly dissected.

III.1 Soil fund (reserves) of Russia

The soil fund of a region is important to know because it can be applied to various assessments dealing with soil parameters, for example, to estimate the soil carbon pool, the soil fluxes of gas emissions, the distribution of wetlands, hydrological characteristics, etc.

The total area covered by soils and other solid surface formations in Russia, calculated from the database, is 1680 million ha (see Table 2). The respective official estimate (Lands of Russia, 1995), which was obtained by subtracting the areas of water bodies, from the total area of the country, is 1638 million ha. The discrepancy in total extents of land is mainly due to some differences between the statistics and extents of mapped inland water bodies.

Podzols are the most widespread major soil group on the territory of Russia. These soils are formed under coniferous forests from coarse textured siliceous parent materials. Podzols occupy more than 371 million ha, i.e., about 22% of the total area (Table 2). They are found in the northern part of the East European plain, in the middle part of West Siberia, in the central and southern parts of East Siberia and in the Far East (see Figure 1).

Gleysols are the second largest major soil group occurring in Russia. They are found in conditions of excess wetness. Gleysols have formed on plains or depressions with shallow groundwater. They cover about 275 million ha, i.e., more than 16% of the territory, being widespread in the extreme north of the East European plain, in the West Siberian plain, particularly in the middle and northern parts, in the northern parts of East Siberia and the Far East.

Another important major soil group are Cambisols occupying about 212 million ha, or 13% of the territory. These soils are characterized by a beginning differentiation of soil horizons through changes in color, structure, and/or texture. They are formed from medium and fine-textured parent material in various environments. Cambisols are found in the northern Caucasus, Ural, the central and northern parts of East Siberia and the Far East.

Podzoluvisols cover about 207 million ha, or 12% of the territory. The soils are developed under boreal taiga, coniferous forest or mixed forest from medium fine-textured loess-like and glacial till deposits. The soils are widespread in the central part of the East European plain, in some parts of central West Siberia and the southern part of East Siberia.

Leptosols occupy about 145 million ha, i.e., some 9% of the territory. The soils are developed in strongly dissected topography with high rates of erosion from various kinds of rocks. These soils are found in the mountain areas of East Siberia and the Far East.

More than 118 million ha, about 7% of the Russian territory, is covered by Histosols. These soils are confined to poorly drained basins and depressions, and swamps with shallow groundwater. The biggest extents of these soils are found in the central part of West Siberia.

The major soil group most valuable for agriculture are Chernozems. They occupy about 94 million ha, i.e., less than 6% of the total territory. Chernozems are developed on flat plains with an original vegetation of tall grasses from loess-like deposits. These soils extend in the southern parts of the East European plain and West Siberia, and on the southern slopes of inter-mountain depressions in East Siberia.

Four other major soil groups which are also well-suited for agriculture include Fluvisols (especially in the cold northern regions), Greyzems, Phaeozems, and Kastanozems, together occupying about 160 million ha, approximately 10% of the country. Fluvisols are closely linked with river valleys such as Volga, Ob, Enisey, Lena, Kolyma, etc. Greyzems are widespread under forest in the forest-steppe natural zone in the southern parts of the East European and the West Siberian plains, the East Siberian inter-mountain depressions and the Zabaikalie. Phaeozems are found in the southern parts of West Siberia and the Far East. Kastanozems are developed in the southern part of the East European and the West Siberian plains and the Zabaikalie.

Other major soil groups as well as non-soil formations occupy about 90 million ha, i.e., a little more than 5% of the country.

III.2 Characteristic of the soil coverage geometry

The geometric component of the soil database is represented by 1271 polygons (Table 3). In general, the number of polygons of a soil unit corresponds with its extent in the sense that the most wide-spread soil units contribute the largest number of polygons. For example, the most widespread major soil group of Podzols comprises of 267 polygons, Gleysols account for 203 polygons, etc. From a pedogenetic viewpoint, the extent of a soil and the number of occurring polygons reflect the ecological tolerance of the soil. If a soil has a very limited extent and is found rarely, this indicates that the soil is formed only by a very specific combination of soil-forming factors. There are few such major soil groups for the Russian territory. For instance, Vertisols occupy only one polygon. It is known that this soil develops from specific clay parent material with a high content of smectite (1:2 lattice) clays and an alternation of distinct dry and wet seasonal pedo-climate regime. There is only a rather limited occurrence of Solonchaks and Planosols in the database. Both of them are represented by two polygons. The limited number of polygons of these soils is the result of generalization because usually these soils are represented by small mapping units, which cannot be shown at the scale 1:5M.

Several major soil groups are characterized by a minimum polygon size of less than 10 thousand ha. The largest maximum area of polygons is attained by Leptosols, found on mountains, and by Histosols covering a vast area in West Siberia and other places.

The Nagel coefficient of the polygon boundary complexity reflects the polygon configuration. The boundary complexity should be taken into account when overlaying is applied. For instance, when overlaying several coverages with highly irregular polygon boundaries one can expect to operate with rather coincidental data which may provide highly variable results. The value of the coefficient highly correlates with the soil extent and number of polygons.

III.3 Characteristic of the terrain coverage

The terrain component is described by four items: landform, sloping conditions, hypsometry (elevation), and an additional qualifier used for complex landforms. A complete list of landforms and their characteristics are shown in Table 5 (see Appendix 3). The spatial distribution of landforms is shown in the Figure 2-4. The terrain components comprise of 1229 polygons (Table 4) amounting to 1674 million ha.

Plains are the most widespread landform in Russia (Figure 2). They occupy more than 1179 million ha which corresponds to 70.4% of the country. Geographically it is represented by huge shields: the Russian and the West Siberian shields with their corresponding plains (East European and West Siberian), and in East Siberia the Lensko-Viluyskaya, Sredne-Indigirskaya, Kolymskaya and Anadyrskaya alluvial plains. The relief of these plains is frequently complicated depending on orographic features, composition of loose rock deposits, and past and present denudation-accumulation processes.

With regard to hypsometry, most of the plains are at an altitude of less than 300 m above sea level (Figure 3). The central part of East Siberia and the southern part of the Far East extend between 300-600 m a.s.l. Only a few plains of East Siberia and the Far East occur at an altitude between 600-1500 m, and very rarely they reach 1500-3000 m a.s.l. There is no plain in Russia higher than 3000 m a.s.l.

The sloping conditions of the plains are fairly diverse (Figure 4). Roughly half of the East European plain is characterized by flat (0-2%) and flat wetland (0-2%) relief. The remainder is gently undulating (2-5%) and undulating (5-8%). Most of the West Siberia plain is represented by flat wetland relief and only the southern part is characterized by flat relief. On the other hand, East Siberia has rather few landscapes with flat relief and most of it is mapped as gently undulating and undulating sloping territories. The vast region of the northern part of the Far East is characterized by flat wetland. Other territories of the Far East have gently undulating and undulating sloping conditions. Undulating slopes prevail also in the southern part of the Far East.

Plains account for 637 (of 1229) polygons (Table 3). Their granularity varies over a very wide range. The minimum size of the polygons is less then 0.01 million ha, the maximum exceeds 142 million ha, and 1.56 million ha being the average. The boundary complexity of plains is estimated as highly irregular.

Mountains are the landform ranking second in Russia (Figure 2). They were formed at different orogenetic time by a variety of parent rocks. Differing in historical development, mountains were affected by numerous external processes, like glacial and other denudations. Thus they exhibit a variety of relief peculiarities. Physiographically the mountain areas comprise of the Alpine-Gimalay belt, the Tyan-Shyan up-lifting belt, the Middle and East Siberian mountain highlands and the Pacific Ocean mountain belt.

In terms of terrain, mountainous areas are represented by various landforms: mountainous highland - 311.3 million ha (more than 18% of the country area); mountains - 61.6 million ha (3.7%); ridges 13.7 million ha (0.8%); uniform mountain slope - 14.2 million ha (0.8%); isolated mountains - 0.7 million ha (0.04%); escarpment zones - 1.8 million ha (0.1%); composite landforms with inselberg cover - 0.4 million ha (0.02%).

Most of the mountains are of low altitude, below 1000 million a.s.l (Figure 3). Only a few mountain systems in the southern part of Siberia and the Far East reach an altitude of more than 1500 and 3000 m a.s.l. There are no high mountains above 5000 m a.s.l. in Russia.

The relief of mountain physiographic units is characterized by steep (30-60%) and very steep (>60%), very rarely by moderately steep (15-30%) slopes (Figure 4).

The total amount of polygons with mountainous landforms is 375 (Table 4). The polygons vary widely in granularity. The coefficient of polygon boundary complexity ranges from slight dissected (K_p = 2-4) to highly irregular (K_p = 27.6) (Table 4).

Depressions distinguished in the terrain database of Russia have mainly been formed under the influence of tectonic processes; thus they can be defined as tectonic valleys. This explains why depressions are widespread in tectonically active zones of East Siberia and the Far East (Figure 2). The extent of depressions caused by karst, suffusion and other origin is too small to be shown at 1:5M scale. The total area of depressions in SOTER is 39 million ha covering about 2.3% of the country (Table 4).

Depressions occur in a wide range of hypsometry situations varying from less than 300 m a.s.l. to more than 3000 m a.s.l. sloping conditions are mainly flat (0-2) and flat, wetland (0-2). There is a total of 118 polygons for depressions (Table 4). The granularity of the polygons varies from less than 0.01 million ha to a maximum of 2.9 million ha, averaging some 0.4 million ha. The coefficient of polygon boundary complexity indicates medium dissected (K_p = 5) conditions.

The valley floor landform polygons which are included in the database refer to the biggest rivers of Russia: Volga, Ural, Ob, Enisey, Lena, and others (Figure 2).

These landforms have developed at various altitude levels varying from less than 300m a.s.l. to 1500-3000 m a.s.l. Practically all of them are characterized by flat (0-2) and flat, wetland (0-2) sloping conditions. Valley floor landforms occupy a total area of 26 million ha, i.e., about 1.6% of the country. They are represented by 35 polygons with a granularity ranging from less than 0.01 million ha, to a maximum area of 3.8 million ha. The average polygon size is 0.7 million ha. The coefficient of the polygons boundary complexity is estimated as 6.3, i.e., highly irregular.

Plateau landforms have widely developed in East Siberia and the Far East (Figure 2). They represent the surfaces resulting from relief leveling (denudation) during epochs of tectonic stagnation. Plateaus occur at different altitude levels ranging from less than 200 m a.s.l. to 1500-3000 m a.s.l. Sloping conditions are gently undulating (2-5%) and undulating (5-8%). The total area of plateau landforms is 26.1 million ha, or 1.6% of the country (Table 4). Plateau landforms include 73 polygons in a range of sizes: a minimum polygon area of less than 0.01 million ha, maximum of 2.6 million ha, and 0.4 million ha on average. The Nagel coefficient of polygon boundary complexity is medium dissected (4.1).

Finally, hills are distinguished as a separate landform in the terrain database of Russia. They spread in the north-east of the European part of Russia and in East Siberia (Figure 2). This landform is characterized by an altitude range from less than 200 m a.s.l., to 600 m a.s.l., with rolling (8-15%) sloping conditions. 6 polygons represent hills. Polygons sizes range from less than 0.01 million ha to a maximum of 0.6 million ha, the average being 0.26 million ha. The coefficient of the polygons boundary complexity is estimated as slightly dissected (K_p = 2.6).

III.4 Characteristic of the SOTER coverage

As explained in Section II.3, the SOTER database was created by overlaying and processing the original soil and terrain coverages.

The total number of resulting SOTER units for the territory of Russia is 3907. Because of this large number, it is not possible in this report to describe their regularities and distribution over the country. Table 6 provides a very general overview of the SOTER polygon geometry.

Compared with the original soil and terrain coverages, the complexity of the combined soil and terrain database has approximately tripled. Consequently, both the maximum and average polygon sizes decreased, respectively to 10.1 million ha and 0.43 million ha. The larger number of (smaller) polygons resulted also in relatively less complex polygon boundaries, i.e., Nagel coefficient of 2.0.

Because of the method of overlaying the two soil and terrain coverages, the elimination of polygons with size less than $1cm^2$, and the recalculation of the soil distribution within polygons, it is necessary to compare the contents of the SOTER database with the attribute information of the original layers. Since the terrain information was essentially not changed no important differences resulted. When creating SOTER units, any changes affected only the soil distribution. A comparison by soil unit of the extents derived from the original soil map with those from SOTER is shown in Figure 5. The histogram indicates that more than 37% of the soil unit areas remained unchanged. For an additional 26% of the area, the assessed differences are less than 1%. Roughly 30% of the soil units differ by 1-3% compared with the original coverage. Thus, in total about 90% of the entire area, when compared by soil unit, matches the original figures to within 3%.

The analysis of the SOTER database for Russia led us to conclude that the proposed logic for automatically matching soil and physiographic coverages gives satisfactory results.

IV. Technical specification

This chapter documents the data structures used for storing attributes of the three coverages: soils, terrain, and SOTER. It addresses technical users of the databases, providing the names, the contents, and the list of Arc/Info table items associated with each coverage.

IV.1 Soil coverage

Following the FAO digital SMW (FAO, 1995), each polygon comprises of a dominant soil unit, and one or more of associated soil units and inclusions. Polygons are also described in terms of texture class, slope class, and, where relevant, soil phase.

Each soil polygon on the coverage has a thematic number defined in the polygon attribute table. This item, named CONTOUR, is used to link attribute information to the geometric part. CONTOUR number 9999 is applied to refer to inland water bodies.

All INFO file names (except RSOIL coverage files) have the prefix *"RSOIL"*.

LIST OF FILES

RSOIL.PAT	Polygon attribute table. This file includes for each closed area feature a unique polygon number (item SOIL-ID) and corresponding thematic numbers (item CONTOUR).
FAOLEG	INFO file. Includes a list of dominant, associated and included soils, describing their distribution for each thematic contour.
FAO_TEXTURE	INFO file. Specifies texture classes for each thematic contour.
FAO_SLOPE	INFO file. Includes slope classes for each contour.
FAO_PHASES	INFO file. Specifies soil phases by thematic contour. Description of database files.

File: **RSOIL.PAT**

List of items:

AREA	Standard attribute provided by Arc/INFO, measuring the area of a polygon
PERIMETER	Standard attribute provided by Arc/INFO, measuring the circumference of a polygon
RSOIL#	Polygon number assigned by Arc/Info
RSOIL-ID	Unique polygon identification number
CONTOUR	Thematic soil number used to link attribute information

File:	**FAOLEG**
	This data structure represents a one-to-many relationship, i.e., for any thematic number there can be several records of soil units in file FAOLEG.
List of items:	
CONTOUR	Thematic number
TIP	An integer field describing the occurrence of soils, as follows:
	TIP = 1 - dominant soil
	TIP = 2 - associated soil unit (i.e., > 20 % of polygon area)
	TIP = 3 - inclusions (i.e., < 20 % of polygon area)
FAO_PERCENT	Percentage of polygon area occupied by soil unit
FAO_CODE	Soil unit code in terms of FAO Revised Legend (for codes see Table SOILFAO)

File:	**FAO_TEXTURE** (one to many relation)
List of items:	
CONTOUR	Thematic number
TIP	TIP = 1,2,3 for dominant texture and others
TEXTURE	Texture class
NAME_TEXTR	Texture class name (list of codes and names see Table CTEXTURE)

File:	**FAO_SLOPE** (one to many relation)
List of items:	
CONTOUR	Thematic number
SLOPE	Slope class (a list of codes, names, description, see CSLOPE)
NAME_SLOPE	Slope class name
DESC_SLOPE	Slope class description

File:	**FAO_PHASES** (one to many relation)
List of items:	
CONTOUR	Thematic number
PHASES	Soil phase index (a list of indexes, names, see CPHASES)
NAME_PHASE	Soil phase name

LIST OF LOOK-UP TABLES (INFO Tables):

File:	**SOILFAO (**list of codes and names of major soil groups)
List of items:	
FAO_TYPE	Major soil group code
FAO_TNAME	Major soil group name
FAO_TIND	Major soil group index

File:	**SOILFAO1** (list of codes and soil unit names)
List of items:	
FAO_TYPE	Major soil group code
FAO_CODE	Soil unit code - FAO Revised Legend
FAO_NAME	Soil unit name - FAO Revised Legend
FAO_IND	Soil unit index

File:	**CPHASES** (list of codes and soil phase names)
List of items:	
PHASES	Soil phase code
NAME_PHASE	Soil phase name

File:	**CTEXTURE** (list of codes and names for texture classes)
List of items:	
TEXTURE	Texture class
NAME_TEXTR	Texture class name

File:	**CSLOPE** (one to many relation) - a list of codes, names and description of slope classes
List of items:	
SLOPE	Slope class
NAME_SLOPE	Slope class name
DESC_SLOPE	Slope class description

IV.2 Terrain coverage

All INFO file names (except RPHYSI coverage files) have the prefix *"RPHYSI"*

LIST OF FILES:

RPHYSI.PAT	Polygon attribute table. This file includes a combined index (formula) for all terrain characteristics and indexes for landform, elevation, slope classes (simple landforms) and suffixes for complex landforms, separately listed for each polygon
LANDFORM	Look-up table. It includes a list of landform indexes and names
ELEVATION	Look-up table. It includes a list of elevation codes and descriptions
SLOPE	Look-up table. It includes a list of slope classes for simple landforms
SUFFIX	Look-up table. It includes a list of additional suffixes for complex landforms

FILE DESCRIPTION:

File: **RPHYSI.PAT** Polygon attribute table.

List of items:

AREA	Standard attribute provided by Arc/Info, measuring the area of a polygon
PERIMETER	Standard attribute provided by Arc/Info, measuring the circumference of a polygon
RPHYSI #	
RPHYSI-ID	
SS	Complex index describing polygon (ss=s1+s2+s3 +s4)
S1	Index (character) for landform (Look-up Table LANDFORM)
S2	Index (numeric) for elevation (Look-up Table ELEVATION)
S3	Slope class (character) for simple landforms (Look-up Table SLOPE)
S4	Additional suffix (character) for complex landforms (Look-up Table SUFFIX)

A complex index value equal to 9999 (item SS) is used for inland water bodies.

LIST OF LOOK-UP TABLES:

File:	**LANDFORM** (list of landform indexes and names)
List of items:	
S1	Index of landform type
landform	Name of landform type

A list of LANDFORM values (first letter is a value of item S1, next information - value of LANDFORM item):

P	plain
H	hills
M	mountains
T	plateau
R	ridge(s)
S	escarpment zone
A	valley floor
I	isolated mountain
D	depression
L	mountainous highland
C	composite landform
G	uniform mountain slope

File:	**ELEVATION** (elevation)
List of items:	
S2	Index (numeric) for elevation
elevation	Values of elevation

Different methods of characterization were used for different groups of landforms.

The list of elevation values is given below: the first number is the value of item S2, the second item represents elevation ranges.

For plain (P), plateau (T), valley floor (A), depression (D), composite landform (C):

1	<300m
2	300-600m
3	600-1500m
4	1500-3000m
5	>3000m

For hills (H), ridge (R), isolated mountain (I), mountainous highland (L), uniform mountain slope (G); elevation is relative to the local base level:

6	<200m
7	200-400m
8	>400m

For mountains (M), escarpment zone (S); elevation is relative to the local base level:

9	600-1500m
10	1500-3000m
11	3000-5000m
12	>5000m

File **SLOPE** (slope classes for simple landforms)

List of items:

s3	Slope class (character) for simple landform
perc	Slope class value (%)
slope	Slope class name

A list of slope values. The first letter is the value of item S3, then the value of item PERC, and last is the slope class name (item SLOPE).

w	0-2%	flat, wetland
f	0-2%	flat
g	2-5%	gently undulating
u	5-8%	undulating
r	8-15%	rolling
s	15-30%	moderately steep
t	30-60%	steep
v	>=60%	very steep

File: **SUFFIX** (additional suffixes for complex landforms)

List of items:

s4	additional suffix (character) for complex landform
suffix	additional suffix description for complex landform

A list of additional suffixes (the first letter is the value of item S4, then the value of item SUFFIX:

cu	cuesta-shaped
do	dome-shaped
ri	ridged
te	terraced
in	inselberg covered
du	dune-shaped
im	with inter-mountain plains
we	with wetlands
ka	strong karst

IV.3 SOTER coverage

All INFO file names (except RSOTER coverage files) have the prefix *"RSOTER"*

LIST OF FILES:

RSOTER.PAT	Polygon attribute table of SOTER coverage
SOTER	It includes description of combined physiographic and soil content for each SOTER polygon
SOTER_TXTR	Soil texture of SOTER unit
SOTER_PHASES	Soil phases of SOTER unit

Look-up tables from physiography coverage description:

LIST OF LOOK-UP TABLES:

LANDFORM	A list of landform indexes and names.
ELEVATION	A list of elevations.
SLOPE	A list of slope classes for simple landforms.
SUFFIX	A list of additional suffixes for complex landform.

Look-up tables from soil coverage description:

SOILFAO	A list of codes and major soil group names.
SOILFAO1	A list of codes and soil unit names.
CPHASES	A list of soil phase codes.
CTEXTURE	A list of codes for texture classes.

FILE DESCRIPTION:

File: **RSOTER.PAT** (PAT attribute table of SOTER coverage)

List of items:

AREA	Standard attribute provided by Arc/Info, measuring the area of a polygon
PERIMETER	Standard attribute provided by Arc/Info, measuring the circumference of a polygon

SOTER#	Unique polygon number assigned by Arc/Info software
SOTER-ID	Unique user-assigned SOTER polygon identification

Each SOTER polygon is described in the SOTER table. The description includes two parts: soil and terrain. Furthermore, soil texture (Table SOTER _TXTR) and soil phases (Table SOTER_PHASES) for SOTER polygons are given.

File:	**SOTER** (Description of SOTER and soil content of each SOTER polygon)
List of items:	
SOTER-ID	Unique SOTER polygon ID (the same as in SOTER.PAT)
	Physiographic description
SS	Complex index describing polygon (ss=s1+s2+s3 +s4)
S1	Landform index (Look-up Table LANDFORM)
S2	Elevation index (Look-up Table ELEVATION)
S3	Slope class for simple landforms (Look-up Table SLOPE)
S4	Additional suffix for complex landforms (Look-up Table SUFFIX)
	Soil content
TIP	Number in accordance with FAO_PERCENT value
	(TIP = 1 for max value of FAO_PERCENT)
FAO_PERCENT	Percentage of soil units in polygon area
FAO_CODE	Soil unit code (the list of names, indexes see Table SOILFAO1)
SOIL_AREA	Soil unit area according to FAO_PERCENT from SOTER polygon area
FAO_TYPE	Major soil group code (Look-up Table SOILFAO)
FAO_TNAME	Major soil group name
FAO_NAME	Soil unit name
FAO_IND	Soil unit index

File:	**SOTER_TXTR** (soil texture)
List of items:	
SOTER-ID	Unique SOTER polygon ID (the same as in SOTER.PAT)
FAO_CODE	Soil unit code (Look-up Table SOILFAO1)
TXTR	Texture (a list of values separated by comma) (Look-up Table CTEXTURE)

File:	**SOTER_PHASES** (soil phases)
List of items:	
SOTER-ID	Unique SOTER polygon ID (the same as in SOTER.PAT)
PHASES	Soil phases (a list of values separated by comma) Look-up Table CPHASES)

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Table 1. Correlation of particle size distribution between FAO and Russian systems.

Name of texture fraction	Particle size (mm), FAO system (1990)	Particle size (mm), Russian system (1967)
Gravel, fine gravel	> 2.000	> 1.000
Sand coarse medium fine	0.063 - 2.000	 0.500 - 1.000 0.250 - 0.500 0.050 - 0.250
Silt coarse medium fine	0.002 - 0.063	 0.010 - 0.050 0.005 - 0.010 0.001 - 0.005
Clay	< 0.002	< 0.001

Table 2. Soil fund of Russia by major soil groupings and soil units of FAO.

Major soil groupings and soil units	Extent, million ha	% of total area	% of major soil groupings
FLUVISOLS	57.37	3.43	100.00
Eutric	3.25	0.19	5.66
Dystric	30.38	1.82	52.95
Umbric	22.33	1.34	38.91
Thionic	1.42	0.08	2.47
GLEYSOLS	275.19	16.47	100.00
Dystric	70.06	4.19	25.46
Mollic	9.25	0.55	3.36
Umbric	46.85	2.80	17.02
Gelic	149.03	8.92	54.16
REGOSOLS	4.35	0.26	100.00
Gelic	4.35	0.26	
LEPTOSOLS	144.54	8.65	100.00
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	100.00
Cambic	5.58	0.33	
ANDOSOLS	15.64	0.94	100.00
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	100.00
Eutric	0.21	0.01	
CAMBISOLS	212.03	12.69	100.00
Eutric	49.33	2.95	23.26
Dystric	91.16	5.46	42.99
Humic	1.84	0.11	0.87
Calcaric	5.44	0.33	2.57
Chromic	1.31	0.08	0.62
Gleyic	6.69	0.4	3.16
Gelic	56.26	3.37	26.53
CALCISOLS	4.57	0.27	100.00
Haplic	1.75	0.11	38.37
Luvic	2.82	0.17	61.63
SOLONETZ	11.16	0.67	100.00
Haplic	2.56	0.15	22.95
Gleyic	8.60	0.51	77.05

SOLONCHAKS	0.98	0.06	100.00
Haplic	0.64	0.04	65.14
Gleyic	0.34	0.02	34.86
KASTANOZEMS	25.80	1.54	100.00
Haplic	17.28	1.03	66.97
Calcic	0.15	0.00	0.58
Luvic	8.37	0.50	32.46
CHERNOZEMS	99.71	5.97	100.00
Haplic	30.41	1.82	30.50
Calcic	26.48	1.59	26.56
Luvic	27.51	1.65	27.59
Glossic	8.44	0.51	8.47
Gleyic	6.85	0.41	6.87
PHAEOZEMS	19.41	1.16	100.00
Haplic	0.96	0.06	4.95
Luvic	17.62	1.05	90.77
Gleyic	0.83	0.05	4.28
GREYZEMS	44.96	2.69	100.00
Haplic	44.54	2.67	99.06
Gleyic	0.42	0.03	0.94
PLANOSOLS	2.26	0.14	100.00
Eutric	0.00	0.00	0.00
Mollic	2.26	0.14	100.00
PODZOLUVISOLS	207.37	12.41	100.00
Eutric	119.41	7.15	57.59
Dystric	24.07	1.44	11.61
Stagnic	8.04	0.48	3.88
Gleyic	55.71	3.34	26.67
Gelic	0.13	0.00	0.06
PODZOLS	371.13	22.22	100.00
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
Gelic	16.42	0.98	4.42
HISTOSOLS	118.74	7.11	100.00
Terric	44.31	2.65	37.31
Fibric	54.94	3.29	46.27
Histosols without subdivision	19.50	1.17	16.42
Sands	3.55	0.21	100.00
Rock outcrops	41.94	2.51	100.00
Glaciers	3.85	0.23	100.00
Total	1670.34	100.00	

Table 3. Characteristics of the soil polygon geometry[4].

Major soil groups	Number of polygons	Area, million ha			Coefficient of boundary complexity
		Minimum	Maximum	Average	
CAMBISOLS	157	<0.01	7.24	1.49	26.84
PODZOLS	267	<0.01	10.02	1.43	37.24
LEPTOSOLS	91	0.01	15.68	1.70	21.85
ANDOSOLS	24	<0.01	3.35	0.71	9.96
GLEYSOLS	203	<0.01	10.86	1.34	30.12
REGOSOLS	19	<0.01	1.46	0.23	5.62
PODZOLUVISOLS	172	<0.01	7.50	1.35	28.59
GREYZEMS	38	0.04	3.74	1.06	13.50
HISTOSOLS	84	0.02	10.04	1.11	19.59
FLUVISOLS	40	<0.01	3.13	0.52	13.32
CHERNOZEMS	77	0.02	8.76	1.52	19.45
ARENOSOLS	8	0.09	2.38	0.91	7.36
KASTANOZEMS	28	0.07	2.65	0.91	11.50
PHAEOZEMS	11	0.17	3.40	1.21	6.85
PLANOSOLS	2	0.37	1.28	0.82	3.45
SOLONETZ	9	0.15	2.88	1.24	5.74
CALCISOLS	3	0.20	4.38	1.67	4.21
SOLONCHAKS	2	0.05	0.48	0.26	3.99
VERTISOLS	1	0.23	0.23	0.23	2.30
Sands	11	<0.01	0.83	0.29	5.75
Rock Outcrops	17	0.34	6.09	1.78	10.07
Glaciers	7	0.04	1.27	0.55	3.43
Total	1271				

[4] Representation is by dominant soils at the level of major soil groups.

Table 4. Extent and characteristics of the landform mapping units of Russia

Landform	Area		Number of polygons	Polygon size, million ha			Total perimeter, hm	Coeff. of boundary complexity
	million ha	% of the country area		Min	Max	Average		
Plain	1182.68	70.38	720	0.00	139.68	1.64	5820	47.8
Depression	39.00	2.32	119	0.00	2.94	0.33	446	20.2
Hills	1.1	0.07	16	0.00	0.58	0.07	20	5.2
Mountainous highland	308.19	18.34	201	0.00	23.81	1.53	1715	27.6
Plateau	25.67	1.53	47	0.00	2.61	0.55	234	13.0
Isolated mountain	0.72	0.04	25	0.00	0.15	0.03	16	5.2
Mountains	61.55	3.66	72	0.00	7.79	0.85	459	16.5
Ridge(s)	13.69	0.81	47	0.01	3.95	0.29	147	11.2
Valley floor	25.97	1.55	51	0.00	3.81	0.51	293	16.3
Uniform mountain slope	13.19	0.78	26	0.02	3.85	0.51	201	15.6
Escarpment zone	1.82	0.11	4	0.35	0.63	0.45	22	4.5
Composite landform	0.41	0.02	1	0.41	0.41	0.41	8	3.6
Water	6.33	0.38	5	0.14	3.26	1.27	46	5.1
Total	1680		1334					

Table 5. Characteristic of the terrain component of the SOTER database for Russia.

Terrain elements					Number of polygons	Extent, million ha				percentage		Coeff. of boundary complexity
Landform	Elevation* meters	Slope		Complex landform		Min	Max	Average	Total	country area	landform area	
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Plain	<300	0-2	Flat, wetland		64	0.00	142.55	3.40	217.77	13.00	18.46	16.0
			Flat	with wetlands	38	0.00	23.58	2.30	87.25	5.21	7.40	11.9
				dune-shaped	1	0.95	0.95	0.95	0.95	0.06	0.08	1.4
					103	0.00	27.95	1.13	116.64	6.96	9.89	17.9
		2-5	Gently un dulating	with wetlands	10	0.09	10.21	3.22	32.18	1.92	2.73	8.5
					151	0.01	27.49	1.52	229.96	13.72	19.50	22.9
		5-8	Undulating	ridged	1	0.63	0.63	0.63	0.63	0.04	0.05	2.1
					35	0.01	12.68	1.26	44.26	2.64	3.75	9.7
	300-600	0-2	Flat, wetland		1	0.28	0.28	0.28	0.28	0.02	0.02	1.5
			Flat	with wetlands	3	0.72	6.79	3.59	10.76	0.64	0.91	5.3
					23	0.06	9.43	1.59	36.51	2.18	3.10	9.1
		2-5	Gently undulating	with wetlands	1	1.80	1.80	1.80	1.80	0.11	0.15	2.1
					63	0.04	23.90	1.60	100.81	6.02	8.55	14.8
		5-8	Undulating		48	0.04	9.97	1.73	83.08	4.96	7.04	12.5
		8-15	Rolling		2	0.20	1.08	0.64	1.28	0.08	0.11	2.9
	600-1500	0-2	Flat		6	0.23	1.11	0.49	2.92	0.17	0.25	4.3
		2-5	Gently undulating		10	0.26	10.55	1.82	18.23	1.09	1.55	6.9
		5-8	Undulating		57	0.01	19.35	2.84	162.10	9.67	13.74	15.6
	1500-3000	0-2	Flat	dune-shaped	1	0.01	0.01	0.01	0.01	0.00	0.00	1.5
		2-5	Gently undulating		2	0.11	0.21	0.16	0.31	0.02	0.03	2.6
		5-8	Undulating		17	0.09	4.59	1.87	31.77	1.90	2.69	8.1
Total plain					637	0.00	142.55	1.56	1179.50	70.39	100.00	8.5

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Valley floor	<300	0-2	Flat, wetland		16	0.01	2.57	0.64	10.27	0.61	39.66	9.5
			Flat	with wetlands	3	0.73	3.81	1.86	5.57	0.33	21.53	7.1
					14	0.03	2.43	0.68	9.50	0.57	36.71	10.2
		2-5	Gently undulating		1	0.45	0.45	0.45	0.45	0.03	1.74	3.0
	1500-3000	2-5	Gently undulating		1	0.09	0.09	0.09	0.09	0.01	0.36	1.9
Total valley floor					35	0.01	3.81	0.74	25.89	1.54	100.00	6.3
Depression	<300	0-2	Flat, wetland		23	0.03	1.10	0.32	7.31	0.44	18.75	10.2
			Flat	with wetlands	2	0.46	1.39	0.92	1.84	0.11	4.73	3.0
					17	0.04	1.35	0.30	5.11	0.31	13.11	9.0
		2-5	Gently undulating		10	0.06	0.26	0.17	1.74	0.10	4.47	5.1
	300-600	0-2	flat,wetland		3	0.04	0.32	0.16	0.47	0.03	1.19	2.4
			Flat		5	0.02	0.24	0.12	0.61	0.04	1.55	4.3
		2-5	Gently undulating		8	0.10	1.50	0.49	3.96	0.24	10.14	5.4
	600-1500	0-2	Flat, wetland		6	0.05	0.47	0.19	1.12	0.07	2.88	4.4
			Flat		25	0.05	0.55	0.21	5.37	0.32	13.78	9.4
		2-5	Gently undulating		9	0.08	1.66	0.64	5.77	0.34	14.80	5.2
		5-8	Undulating		4	0.21	2.94	0.97	3.87	0.23	9.92	3.0
	1500-3000	0-2	Flat		3	0.05	0.29	0.20	0.60	0.04	1.53	3.8
		2-5	Gently undulating		2	0.47	0.64	0.55	1.11	0.07	2.84	2.9
	>3000	2-5	Gently undulating		1	0.12	0.12	0.12	0.12	0.01	0.30	1.5
Total depression					118	0.02	2.94	0.38	39.00	2.33	100.00	5.0

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Plateau	<300m	5-8	Undulating		1	0.03	0.03	0.03	0.03	0.00	0.11	1.1
	300-600m	0-2	flat		2	0.16	0.32	0.24	0.49	0.03	1.86	3.2
		2-5	Gently undulating		10	0.01	0.74	0.22	2.21	0.13	8.45	4.9
		5-8	Undulating		24	0.01	0.28	0.04	0.92	0.06	3.54	6.4
	600-1500	0-2	Flat		4	0.11	0.69	0.37	1.49	0.09	5.72	4.0
	600-1500	2-5	Gently undulating		16	0.05	2.53	0.62	9.88	0.59	37.82	7.2
		5-8	Undulating		5	0.10	0.51	0.26	1.28	0.08	4.89	3.6
	1500-3000	2-5	Gently undulating		3	0.10	2.61	1.30	3.90	0.23	14.94	3.9
	1500-3000	5-8	Undulating		7	0.14	2.12	0.82	5.72	0.34	21.91	5.0
	<200	5-8	Undulating		1	0.20	0.20	0.20	0.20	0.01	0.75	1.6
Total plateau					73	0.01	2.61	0.41	26.13	1.56	100.00	4.1
Hills	300-600	8-15	Rolling		1	0.58	0.58	0.58	0.58	0.03	52.02	2.6
	<200				2	0.01	0.02	0.02	0.04	0.00	3.26	2.7
	200-400				2	0.05	0.05	0.05	0.10	0.01	9.02	2.5
	>400				1	0.40	0.40	0.40	0.40	0.02	35.70	2.5
Total hills					6	0.01	0.58	0.26	1.12	0.07	100.00	2.6
Uniform mountain slope	<200	0-2	Flat		1	0.44	0.44	0.44	0.44	0.03	3.11	2.1
		2-5	Gently undulating		1	0.19	0.19	0.19	0.19	0.01	1.36	2.5
		8-15	Rolling		2	0.97	1.08	1.02	2.04	0.12	14.44	5.5
	200-400	2-5	Gently undulating		3	0.31	0.35	0.33	0.99	0.06	7.01	3.2
		5-8	Undulating		2	0.15	0.37	0.26	0.52	0.03	3.68	4.2
		8-15	Rolling		2	0.36	0.56	0.46	0.93	0.06	6.54	3.7
		15-30	Moderately steep		1	0.82	0.82	0.82	0.82	0.05	5.78	5.6
	>400	2-5	Gently undulating		5	0.03	0.43	0.16	0.78	0.05	5.51	4.1
		5-8	Undulating		3	0.15	0.41	0.27	0.80	0.05	5.68	3.2
		8-15	Rolling		4	0.24	3.85	1.34	5.36	0.32	37.87	9.9
		30-60	Steep		3	0.02	0.96	0.43	1.28	0.08	9.01	7.1
Total uniform mountain slope					27	0.02	3.85	0.52	14.16	0.84	100.00	4.7

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Composite landform	>400	8-15	Rolling		1	0.41	0.41	0.41	0.41	0.02	100.00	3.6
Escarpment	1500-3000	>=60	Very steep		3	0.35	0.63	0.46	1.38	0.08	75.83	4.2
zone	3000-5000	>=60	Very steep		1	0.44	0.44	0.44	0.44	0.03	24.17	1.8
Total escarpment zone					4	0.35	0.63	0.45	1.82	0.11	100.00	3.0
Mountainous	<200	8-15	Rolling		10	0.04	14.35	3.03	30.25	1.81	9.72	7.6
highland		15-30	Moderately steep		3	0.55	4.58	2.29	6.88	0.41	2.21	5.3
	200-400	8-15	Rolling		30	0.02	3.91	0.57	17.16	1.02	5.51	9.5
		15-30	Moderately steep		3	0.12	8.59	3.11	9.32	0.56	2.99	4.4
	>400	5-8	Undulating		2	0.38	1.00	0.69	1.38	0.08	0.44	2.3
		8-15	Rolling		74	0.01	23.90	1.91	141.29	8.43	45.38	17.4
		15-30	Moderately steep		65	0.01	18.10	1.62	105.06	6.27	33.74	16.1
Total mountainous highland					187	0.01	23.90	1.89	311.34	18.58	100.00	8.9
Mountains	600-1500	30-60	Steep		23	0.02	3.72	0.83	19.02	1.13	30.90	8.8
		>=60	Very steep		7	0.02	0.44	0.13	0.94	0.06	1.52	4.6
	1500-3000	30-60	Steep		23	0.02	7.79	1.47	33.82	2.02	54.95	11.9
		>=60	Very steep		4	0.30	0.77	0.50	2.01	0.12	3.26	3.1
	3000-5000	30-60	Steep		5	0.07	3.90	1.15	5.76	0.34	9.36	5.2
Total mountains					62	0.02	7.79	0.82	61.55	3.67	100.00	6.7
Isolated mountain	200-400	8-15	Rolling		1	0.02	0.02	0.02	0.02	0.00	3.49	1.0
	>400	8-15	Rolling		6	0.01	0.15	0.04	0.27	0.02	37.63	2.5
		15-30	Moderately steep		16	0.00	0.08	0.02	0.39	0.02	53.82	4.3
		30-60	Steep		2	0.01	0.02	0.02	0.04	0.00	5.06	1.7
Total isolated mountain					25	0.00	0.15	0.03	0.72	0.04	100.00	2.4

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Ridge(s)	<200	2-5	Gently undulating		1	0.12	0.12	0.12	0.12	0.01	0.89	1.9
		5-8	Undulating		6	0.02	0.18	0.07	0.41	0.02	2.96	4.4
		8-15	Rolling		5	0.18	0.34	0.26	1.31	0.08	9.39	4.0
	200-400	5-8	Undulating		1	1.50	1.50	1.50	1.50	0.09	10.69	2.4
		8-15	Rolling		15	0.01	0.74	0.18	2.76	0.16	19.74	6.4
		15-30	Moderately steep		1	0.14	0.14	0.14	0.14	0.01	0.98	1.8
	>400	5-8	Undulating		1	1.03	1.03	1.03	1.03	0.06	7.33	3.0
		8-15	Rolling		16	0.02	3.95	0.35	5.65	0.34	40.43	5.5
		15-30	Moderately steep		8	0.03	0.30	0.13	1.06	0.06	7.59	4.9
Total ridge(s)					54	0.01	3.95	0.42	13.98	0.83	100.00	3.8
Total over the country					1229	0.00	142.55	1.63	1675.60	100.00	100.00	10.2

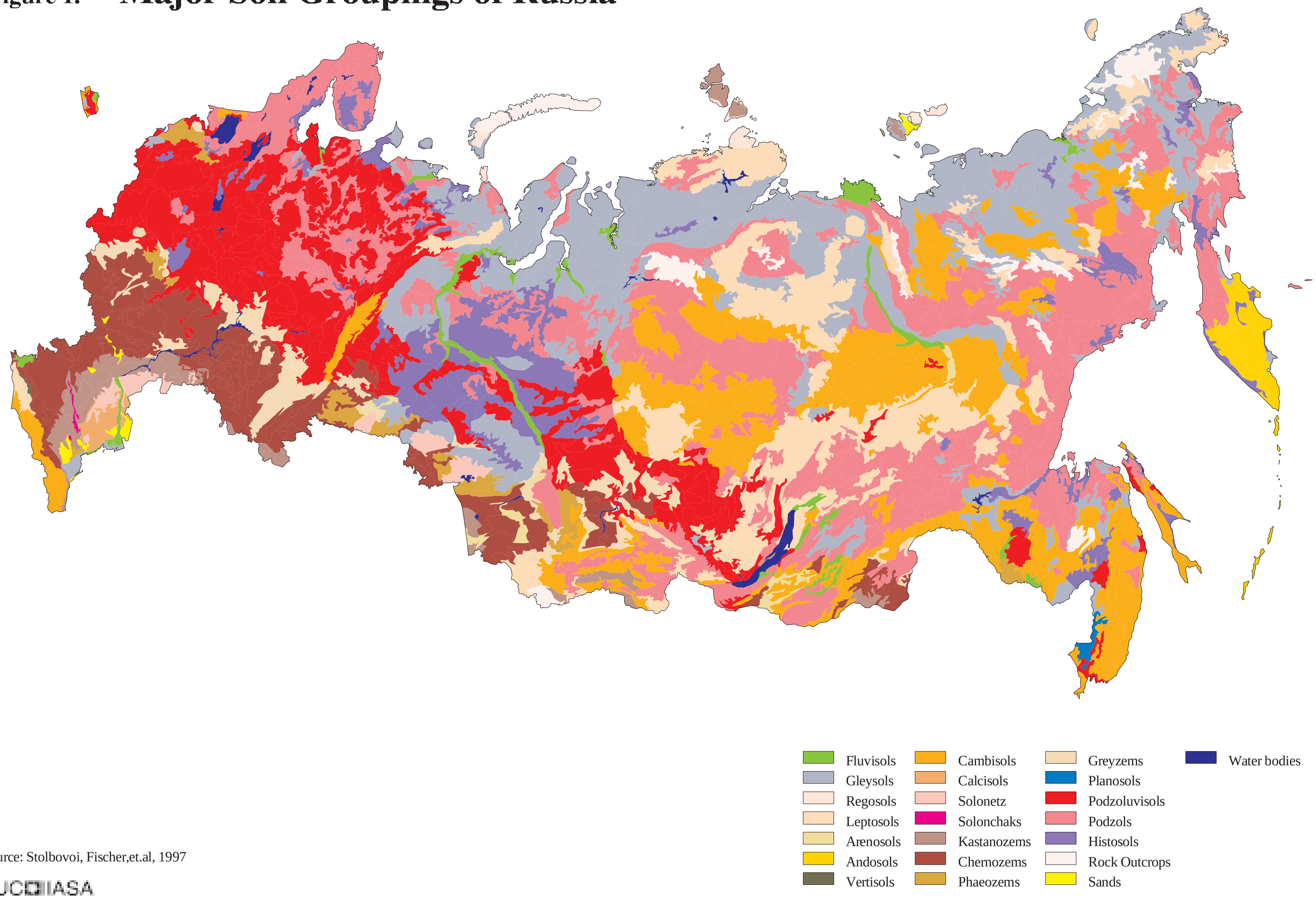
* The hypsometric level for plain, valley floor, depression, plateau landforms is indicated as the height above see level.

Other landforms are characterised as the height above local base level.

Table 6. Geometric characteristics of SOTER coverage

Number of SOTER units	Polygon Extents million ha				Nagel coefficient of boundary complexity
	Minimum	Maximum	Average	Total	
3907	<0.01	10.1	0.43	1682.1	2.0

Figure 1. Major Soil Groupings of Russia



Source: Stolbovoi, Fischer,et.al, 1997

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Figure 2. Land forms of Russia

Source: Stolbovoi, Fischer,et.al, 1997

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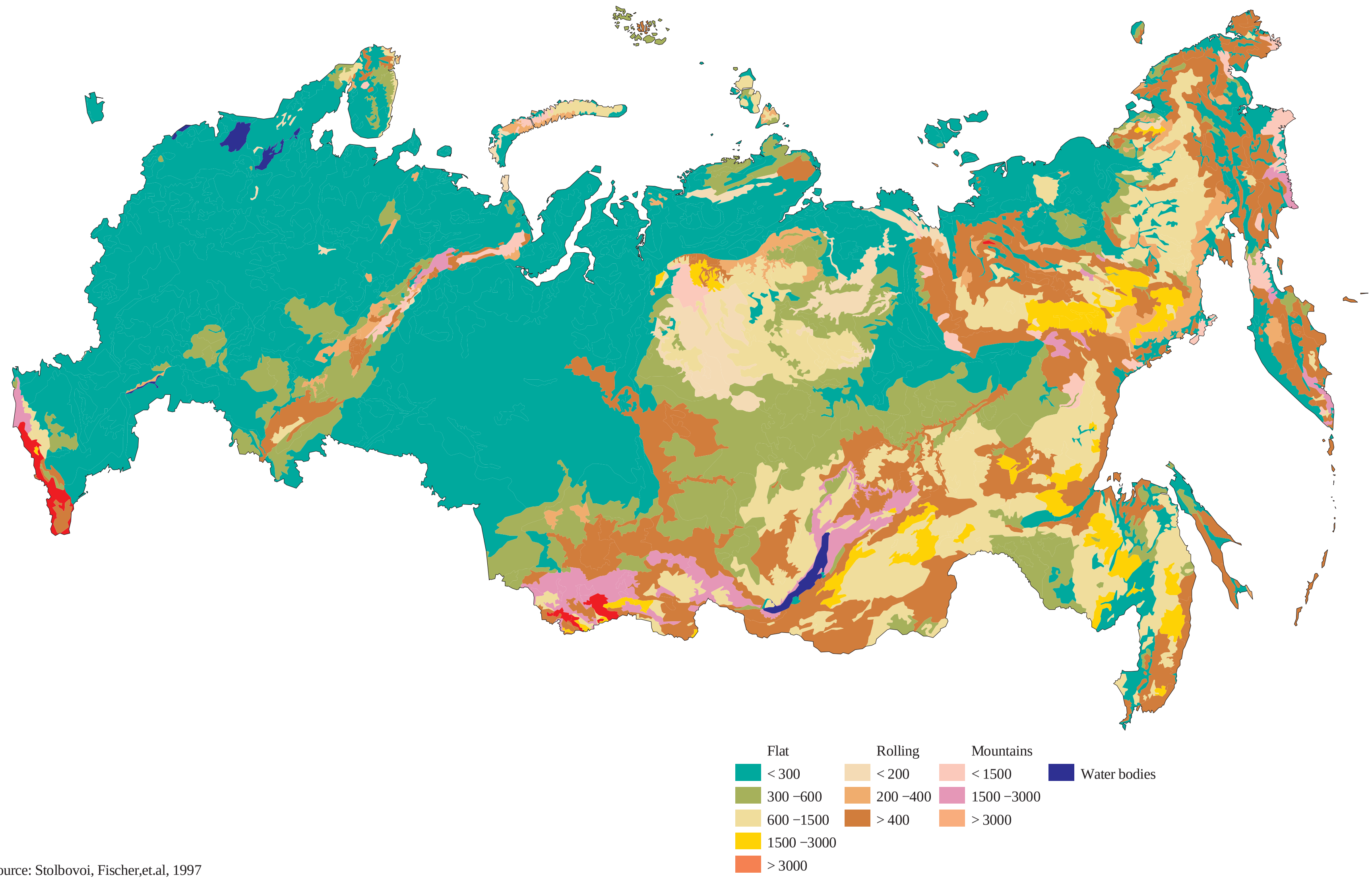
Figure 3. **Elevations of Russia**



Source: Stolbovoi, Fischer,et.al, 1997

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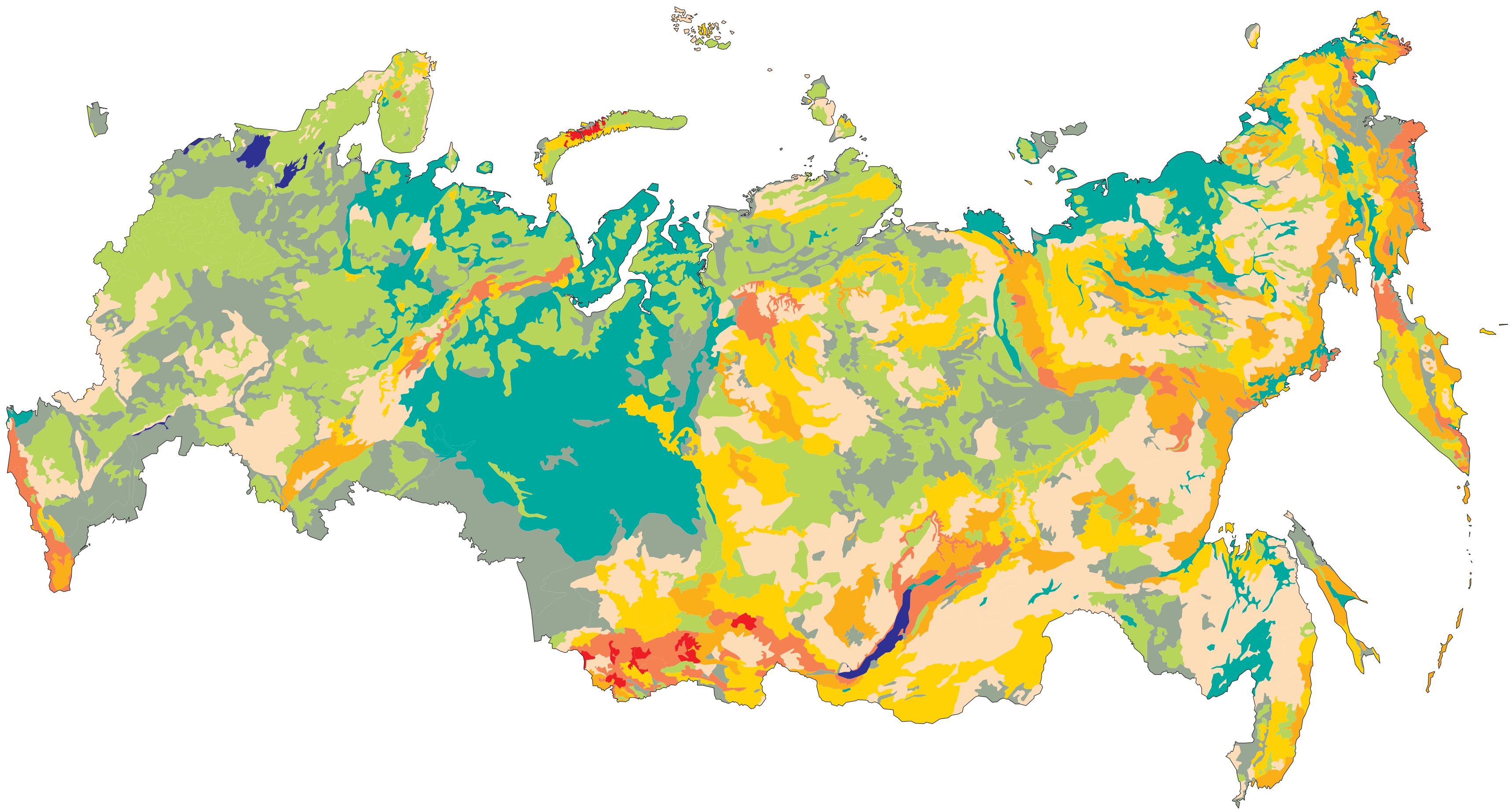
Figure 4. Slope Classes of Russia



Source: Stolbovoi, Fischer,et.al, 1997

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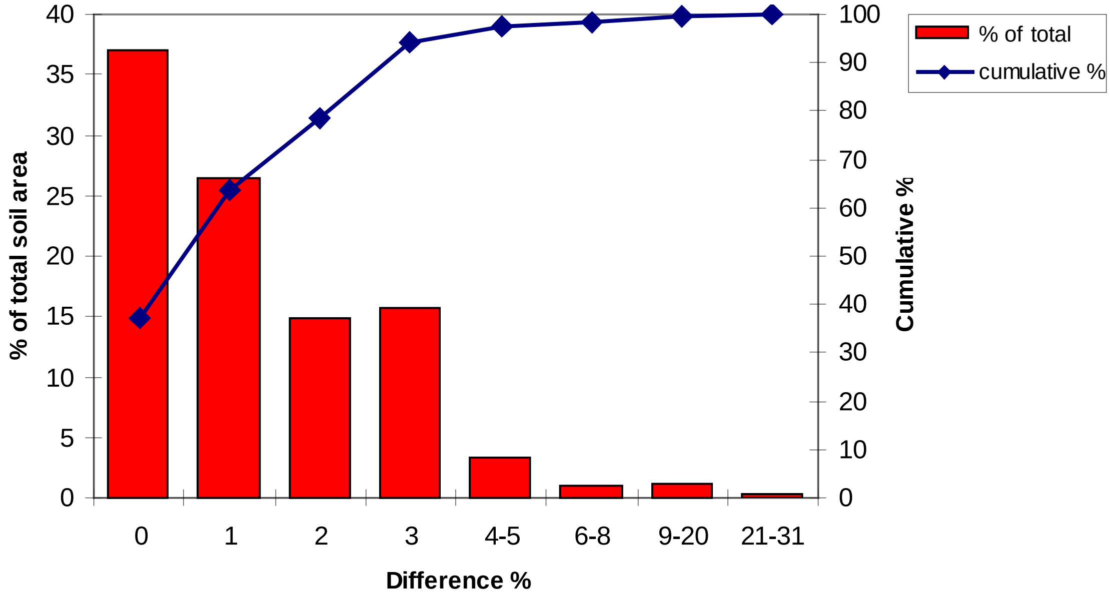
Figure 5. Difference between soil area derived from SOIL and SOTER coverages



Appendix 1. Correlation of SMR and FAO SMW legends.

Major soil groups	Soil unit in FAO Legend, symbol	Soil unit from the legend of Soil Map of Russia, 1:2.5M
FLUVISOLS	Eutric, FLe	Alluvials saline
		Alluvials saturated
	Dystric, FLd	Alluvials acid
	Umbric, FLu	Alluvials meadow
		Alluvials swamp meadow
	Thionic, FLt	Marshy saline and solonetzic
GLEYSOLS	Dystric, GLd	Gleyzems peaty and peat boggy
		Gleyzems taiga differentiated
		Gleyzems taiga
		Sod-gleys podzolized
	Mollic, GLm	Meadows solonetzic and solonchakous
		Meadow-boggy
		Meadow-boggy solonetzic and solonchakous
	Umbric, GLu	Sod-(muck-) gleys
		Meadows
	Gelic, GLi	Gleyzems arctic
		Gleyzems arctotundra muck-gley
		Gleysems peaty and peaty-humic tundra
		Gleyzems and weak-gley humic tundra
		Gleyzems tundra differentiated peaty-humic and peat
		Gleyzems tundra shallow and deep peat
		Gleyzems peaty-muck taiga
		Gleyzems weak-gley peaty-=humic taiga
REGOSOLS	Gelic, RGi	Arctic (Cryozems)
LEPTOSOLS	Dystric, LPd	High mountain sod-baldies
	Rendzic, LPk	Muck-calcareouses tundra
		Muck-calcareouses
		Sod-calcareouses
	Mollic, LPm	Chernozems shallow
		Mountain forest chernozemic
		Mountain meadow-steppe
		Mountain-meadow chernozem-likes
	Umbric, LPu	Mountain forest-meadows
		Mountain-meadow sods
	Lithic, LPq	Mountain primitive
	Gelic, LPi	Soils of spots (saline, arctic and tundra)
ARENOSOLS	Cambic, ARb	Greys sands
		Pine forest sands
ANDOSOLS	Haplic, ANh	Volcanic banded-ochric
		Volcanic dry-peaty
		Volcanic light-ochric (including podzolized)

		Volcanic ochric (including podzolized)
		Volcanic podzolized-ochric
	Vitric, ANz	Volcanic banded-ash
	Gelic, ANi	Volcanic alluvial-humic tundra
VERTISOLS	Eutric, VRe	Chernozems compact
CAMBISOLS	Eutric, CMe	Brownzems residual-calcareous
		Brownzems weakly-unsaturated
		Brownzems weakly-unsaturated podzolized
		Pales mucky
		Pales typical
		Sod-brownzems weakly-unsaturated and saturated
	Dystric, CMd	Brownzems acid
		Brownzems acid podzolized
		Brownzems raw-humic
		Brownzems raw-humic alluvial-humic
		Granuzems
		Pales podzolized
		Pales solodic
		Sod-brownzems acid
		Sod-brownzems ferrugenous
	Humic, CMu	Brownzems muck-humus-accumulative
		Grey-pales
	Calcaric, CMc	Cinnamonics calcareous
		Pales calcareouses
	Chromic, CMx	Cinnamonics typic
	Gleyic, CMg	Brownzems gleyic and gley
		Brownzems raw-humic gley
		Granuzems gley
	Gelic, CMi	Taiga peaty-muck high-humic non-gleyic
		Sod-brownzems gleyic and gley
CALCISOLS	Haplic, CLh	Browns
	Luvic, CLl	Browns solonetzic and solonchacous
SOLONETZ	Haplic, SNh	Solonetzes
	Gleyic, SNg	Solonetzes meadowish
SOLONCHAKS	Haplic, SCh	Solonchaks typic
	Gleyic, SCg	Solonchaks meadow
KASTANOZEMS	Haplic, KSh	Chestnuts deep
		Chestnuts
		Chestnuts leached
		Dark chestnuts
		Dark chestnuts deep
		Light chestnuts
		Light chestnuts deep
	Calcic, KSk	Dark chestnuts calcareous
	Luvic, KSl	Chestnuts solonetzic and solonchakous

		Dark chestnuts solonetzic and solonchakous
		Light chestnuts solonetzic and solonchakous
CHERNOZEMS	Haplic, CHh	Chernozems ordinary
		Chernozems leached deep
		Chernozems typic
		Chernozems washed
		Ñhernozems deeply-effervescing and non-calcareous on coarse parent material
	Calcic, CHk	Chernozems residual-calcareous
		Chernozems southern and ordinary mycelial-calcareous
		Chernozems southern
	Luvic, CHl	Chernozems leached
		Chernozems solonetzic
	Glossic, CHw	Chernozems leached glossic
		Chernozems ordinary glossic
		Chernozems southern glossic
	Gleyic, CHg	Meadow-chernozemics
PHAEOZEMS	Haplic, PHh	Meadow-chernozemics leached
		Meadow-chestnuts
	Luvic, PHl	Chernozems podzolized
		Meadow-chernozemics solonetzic and solonchakous
		Meadow-chestnuts solonetzic
	Gleyic, PHg	Meadow-chernozem-likes "Amur prairie"
		Meadow-chernozemics calcareous
GREYZEMS	Haplic, GRh	Brownish-dark-gray forest
		Dark-grey forest
		Greys forest residual-calcareous
		Greys forest
		Greys forest non-podzolised
		Greys forest with the second humic horizon
		Greys forest solodic
	Gleyic, GRg	Greys forest gleyic and gley
PLANOSOLS	Eutric, PLe	Solods
	Mollic, PLm	Chernozems solodic
		Meadow-chernozemics solodic
		Meadows differentiated (and solodic)
PODZOLUVISOLS	Eutric, PDe	Brownzemish-light-grey forest
		Light-greys forest
		Podzolics residual-calcareous
		Sod podzolics with the second bleached horizon
		Sod-pale-podzolics (and podzolised-brownzems)
		Sod-podzolics
		Sod-podzolics illuvial-ferrugenous

		Sod-podzolics residual-calcareous
		Sod-podzolics with the second humic horizon
		Sod-podzolics with the second humic horizon deep-gleyic
	Dystric, PDd	Podzolics
		Podzolics with the second bleached horizon
	Stagnic, PDj	Podzolics surface-gleyic
		Sod-podzolics surface-gleyic
	Gleyic, PDg	Gley-podzolics
		Gley-podzolics with the second bleached horizon
		Podzolic-gleys peat and peaty
		Podzolics deep-gleyic and gley
		Sod-pale-podzolics gleyic and gley
		Sod-podzolic-gleys
		Sod-podzolic-gleys with the second humic horizon
		Sod-podzolics deep-gley and gleyic
	Gelic, PDi	Podzolics over-permafrost-gleyic
PODZOLS	Haplic, PZh	Podzols dry-peaty
		Podzols humic-alluvial
		Podzols alluvial-humic-ferrugenous (without subdivision)
		Podzols ochric
		Podzols with the second bleached horizon
	Cambic, PZb	Podburs taiga (without subdivision)
		Podburs dry-peaty
		Podburs ochric
	Ferric, PZf	Podburs tundra (without subdivision)
		Podzols alluvial-ferrugenous
	Gleyic, PZg	Podzols gleyic
	Gelic, PZi	Podburs dark tundra
		Podburs light tundra
HISTOSOLS	Terric, HSs	Peat-ashes banded boggy
		Peat low moor
		Peat transitional moor
	Fibric, HSf	Peat high moor
	Histosols, HS	Peat boggy (without subdivision)
Rock outcrops	R	Rock outcrops
Sands	S	Sands
Glaciers	I	Glaciers

Appendix 2. Phases distinguished in the soil coverage of Russia

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

Gilgai: Gilgai is the micro-relief typical of clayey soils, mainly Vertisols, that have a high coefficient of expansion with distinct seasonal changes in moisture content. This micro-relief consists of either a succession of enclosed micro-basins and micro-knolls in nearly level areas, or of micro-valleys and micro-ridges that run up and down the slope. The height of the micro-ridges 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 lithe 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. Though 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 25°C. 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 which have more than 6 percent 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 which crack into polygonal elements when dry and form a platy or massive surface crust.

Yermic: The yermic phase applies to soils which have less than 0.6 percent organic carbon in the surface 18 cm when mixed, or less then 0.2 percent 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 percent or more of the sand fraction having a diameter of 0.25 mm or more.
3. presence of 2 or more palygorskite in the clay fraction in at least some sub-horizon 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.

Appendix 3. Classification used in terrain coverage of Russia

Table 3.1 Landform classes

Index	Landform
P	Plain
H	Hills
M	Mountains
T	Plateau
R	ridge(s)
S	escarpment zone
A	valley floor
I	isolated mountain
D	Depression
L	mountainous highland
C	composite landform
G	uniform mountain slope

Table 3.2 Elevation classes

Index	For landforms P, T, A, D, C: m above sea level	Index	For landforms H, R, I, L, G: m above local base level	Index	For landforms M, S: m above local base level
1.	<300m	6.	<200m	9.	600-1500m
2.	300-600m	7.	200-400m	10.	1500-3000m
3.	600-1500m	8.	>400m	11.	3000-5000m
4.	1500-3000m			12.	>5000m
5.	>3000m				

Table 3.3 Slope classes

For simple landform:	
w 0-2%	flat, wetland
f 0-2%	Flat
g 2-5%	gently undulating
u 5-8%	Undulating
r 8-15%	Rolling
s 15-30%	moderately steep
t 30-60%	Steep
v >=60%	very steep

Table 3.4 Suffixes used for complex landforms

Suffixes for complex landform:	
cu	cuesta-shaped
do	dome-shaped
ri	Ridged
te	Terraced
in	inselberg covered
du	dune-shaped
im	with inter-mountain plains
we	with wetlands
ka	strong karst