ANNEX B.10

SOIL

B.10 SOIL

B.10.1 SOIL CONDITIONS

(1) Soil Map

In the 1950's, four soil classification systems existed, and agricultural and forest soils were classified separately. The fundamental data on the soils for the present soil classification system in the Slovak Republic were collected through the Soil Survey of Slovakian Soils carried out within the years 1961 – 1970 with the density of one profile per 15 hectare. Later, many other up-dates were done based on many theoretical and practical investigations. At the end of 1970's, the efforts to unify the soil classification had obtained a concrete shape.

A unified Morphogenetic Soil Classification System of the Czechoslovak Republic, as an originally consolidated system of both pedo-genetic system from the Russian School and morphological system from Germany and the USA, was approved during the Czechoslovak Soil Science Conference in 1985 and published in 1987. The new revised version of this system was published in 1991 based on the domestic and international comments and FAO proposal (Soil Map of the World, 1988). After division and independence of the Slovak Republic in 1992, a new approximation of the Morphogenetic Soil Classification System of the Slovak Republic was approved as an Official Soil Classification System of the Slovak National Agency, incorporating recent progress in this decade.

The present Soil Map of the Slovak Republic at scale 1 : 400,000 was published in 1993 based on

1) soil units nomenclature according to M.S.C.S., 1991,
2) soil units nomenclature according to the Elements of the Legend for the Soil Map of Europe (FAO 1970) and Key to Soil Units for the Soil Map of the World (FAO 1970), and
3) according to the FAO – Soil Map of the World － Revised Legend (1988).

(2) Soil Types

Major soil types found in the study area are 1) Dystric Regosols distributed mainly on the central plateau, 2) Eutric Regosols in the adjoining spots to the Dystric Regosols, 3) Rendzinas and Pararendzinas on the slope and foot plain of Male Karpaty, 4) Arenic Fluvi-gleyic Phaeozems along the small streams running on the plateau, 5) Eutric Fluvisols on the alluvial sediments of the Morava and Myjava Rivers, and 6) Eutric Cambisols to Dystric Cambisols adjoining to the Rendzinas and Pararendzinas. Each soil type can be presented by the following short explanation.

1) Dystric Regosols

Dystric means deficient, and Regosols present weakly developed soils from the Regolith, which means loose, unconsolidated and broken rock material covering bedrock. Dystric Regosols in this area are characterized as Carbonate deficient weakly developed soils formed from non-carbonate wind blown sand.

2) Eutric Regosols

Eutric means abundant. Eutric Regosols present Carbonate rich weakly developed soils formed from non-carbonate redeposited wind-blown sands. During the redeposition by small streams the wind blown sand was enriched in carbonates by the effect of running water.

3) Rendzinas and Pararendzinas

Rendzinas present a soil with dark grey or black organic surface-layer developed over soft and sticky weathered products from limestone, marl and chalk. Pararendzinas mean sub-ranked Rendzinas and they are formed on the redeposited materials of limestone, marl and chalk.

4) Arenic Fluvi-gleyic Phaeozems

Phaeo means brown. Arenic Fluvi-gleyic Phaeozems present the brown soils developed from light-textured non-carbonate alluvial sediments of the wind blown sands. These soils are found on the terraces of Morava and Myjava Rivers.

5) Eutric Fluvisols

Fluvisols occur only on the alluvium of the water flow of the Morava and Myjava. These soils have been influenced by flood and significant fluctuation of ground water level. Eutric Fluvisols contain, generally, high content of clay.

6) Eutric Cambisols to Dystric Cambisols

Cambisols were classified as Brown Soils in older classifications. The Brown Soils are typical zonal soils developed under broad leaved forest with annual precipitation of 500-700 mm, and can be found all over Europe. The Brown Soils can be divided into Luvisols with clay accumulated B horizon, and Cambisols without accumulation of clay.

Coverage of Soil Types in Study Area

Soil Type	Area of Coverage (100 ha)	Percent of Total Area (%)
Dystric Regosols	389.1	34.4
Eutric Regosols	131.6	11.6
Rendzinas, Para. Rendzinas	119.8	10.6
Are. Flu. gle.-Phaeozems	312.1	27.6
Eutric Fluvisols	75.3	6.7
Cambisols	79.7	7.1

(Coverage area is measured with planimeter from the Soil Map of the Slovak Republic)

(3) Soil Texture

The soil materials can be characterized in physical composition by a mass of congregation of particles with different particle sizes. Particle size composition is presented by the soil texture. The particles in soil mass are divided into 1) Gravel > 2, 2) Sand (coarse sand and fine sand) > 2-0.02, 3) Silt > 0.02-0.002, and 4) Clay < 0.002mm in the diameter in International Standard. In USDA and Slovak system, particle size is 1) Gravel > 2.0, 2) Sand 2-0.05, 3) Silt 0.05-0.002 and 4) Clay < 0.002mm. From the spot in the triangle diagram of Sand, Silt and Clay contents, each soil can be categorized in Sand, Loamy Sand, Loam, Clay Loam, Clay and some others.

In the Slovak System of Soil Texture Classification by Novak, the soils are divided into 7 categories depending on the content of particles less than 0.01 mm in diameter: Sand 0 - 10%, Loamy Sand 10 - 20%, Sandy Loam 20 - 30%, Loam 30 - 45%, Clay Loam 45 - 60, Clay 60 - 75%, and Heavy Clay >75%. Soil Quality Ecological Units (B. P. E U.) divides the soils in 5 Codes ; 1) Light Soils (Sand and Loamy Sand), 2) Medium Heavy Soils (Loam), 3) Heavy Soils (Clay Loam), 4) Very Heavy Soils (Clay) and 5) Medium Lighter Heavy Soils (Sandy Loam). In these systems, the particles smaller than 0.01 mm in diameter are categorized as the finest particle fraction for technical convenience. It is a pity that the content of particles less than 0.01 mm can not give useful information, at least regarding the particular sandy soils in this area. The sandy soils in this area contain very fine particles of quartz powders smaller than 0.01mm, and these do not have any surface activity.

The surface activity of clay minerals brings cations exchange capacity based on surface electric charge, adsorption and cohesion ability based on large relative surface areas of particles. Particular attention must be paid on evaluation of the soil texture data of the sandy soils in this area from this point of view. If possible, additional determination of the fine particle content smaller than 0.002mm or introduction of an alternative index, such as Cations Exchange Capacity or Ethylene- Glycol Absorption, are desirable to evaluate the physical properties of the sandy soils.

The most characteristic feature of the soils in this study area is the wide spread distribution of the light textured soils categorized in Sand and Loamy Sand. Particularly, the Dystric Regosols on the central plateau are formed from the sand deposit on the terrace and wind blown deposit of the sand. The sand had been deposited in narrow bands on the seaside and the fine particles were completely washed out by tidal waves. Actual clay contents of the sand deposits and the wind blown soil are very close to 0 %.

The wind blown sand deposit is composed mainly of silt particles of quartz powder with slight clay fraction. The redeposited sands contain certain amounts of clay particle supplied from the flow of the small stream. In some bottom spots along the former small stream heavy textured soils can be found point by point.

The fan deposits at the foot of Male Karpaty originally contains large amounts of clay derived from the deep-sea deposits in Paleozoic and Mesozoic. Since the amounts of the fan deposit were not sufficient to cover major areas of the foot, the bottom areas between the foot and the central plateau are covered by the wind blown sand and the fan deposit in competition with each other. Further, deep fan deposit covers only limited areas close to the mouth of the valley where residential areas have developed, and farm fields are located on the rim of the fan with narrow deposits. Consequently, the soil texture of farm fields in these fans have wide ranges of texture from Sand to Clay. Fan deposits are characterized by frequent abundance of large size gravels.

Alluvial plain deposits along the Morava and Myjava rivers are generally rich in clay and the soils have heavy texture as Clay Loam, Clay, and Heavy Clay.

(4) Soil Fertility

Natural soil fertility can be termed as the native ability to supply water and nutrient elements simultaneously to plants growing on the soil. The soil fertility can be analyzed from chemical, physical and biological points of view. Among the chemical properties of soil 1) cations exchange capacity, 2) the amount of exchangeable calcium and magnesium, and saturation percentage, 3) the amount of available phosphorus and potassium, 4) pH value, and 5) concentration of risk hazard elements are important. Physical properties are composed by 1) soil texture, 2) extent of soil aggregate formation, and 3) holding and supplying capacities of water, and 4) some others in soil mechanics as cohesion and adhesion related to the soil tilth. Both of the soil texture and extent of aggregate formation are basic characteristics and conclusively provide water regime, soil erodablity, soil compaction, and soil tilth.

Within the limited spread of the study area, climate and other soil forming factors are nearly the same, and the soil types are classified mainly according to the different parent materials. Fertility levels of the soils in this area are presented by the differences in texture and parent materials.

Dystric Regosols have very low level of fertility, because their clay contents are very close to zero and their fine particles are composed of fine quartz particles having the least levels of nutrient holding and supply, together with less water holding and supplying capacities. The area with these soils is ranked as category (1) Unsuitable for agricultural production.

Eutric Regosols have had some effect of water flow during redeposition, and contain some amounts of clay particles transported by the water flow. Clay contents vary spot by spot, and the fertility levels closely correspond to the clay contents. This group of soils can be divided into (2) Adaptive to grazing and pasture farming and, (3) Suitable for arable land depending on their clay contents.

Rendzinas and Pararendzinas are distributed mainly on the foot of Male Karpaty. Central parts of the alluvial fan with deep deposits are occupied by the residential areas of inhabitants. The circumferences or rims of the fan have been used for farm fields. When the soils in these areas have enough deep deposit and contain not so much gravels, they are good enough for (3) Suitable for arable land. When they have only narrow deposit or large amounts of gravels, they are ranked in lower levels of fertility of (2) Adaptive to grazing and pasture farming.

Arenic Fluvic gleyic Phaeozems originated from the water-flow deposit transported by small streams running on the terraces. The water flow deposits contain the wind blown sand and clay particle brought by the streams. Their soil textures vary spot by spot and the fertility levels closely correspond to the clay contents. The major part of this soil can be ranked in (3) Suitable for arable land.

Eutric Fluvisols occur only on the alluvial flood along the Morava and Myjava rivers. This type of soil is rich in nutrients brought by abundant water flow and also contains large amounts of fine clay particles. Native fertility levels are generally very high when proper drainage can be done. Soil texture ranges from Clay Loam, Clay, to Heavy Clay. Soil compaction and degradation of soil tilth are very common in this area. These soils are ranked as (3) Suitable for arable land, but proper management is necessary.

Eutric Cambisols and Dystric Cambisols in this area have generally lighter soil texture and originated from the weathering products of non-carbonate rocks. Distributionis limited to the southern part of the foot of Male Karpaty. Fertility levels are ranked intermediate from (2) Adaptive to grazing and pasture farming to (3) Suitable for arable land.

The third category of (3) Suitable for arable land can be divided into two, three or four depending on the results of further investigation. Throughout the field observation and survey, appreciable degradation of the soil fertility is evident on many spots of soils all over the area. It might come from the long-term intensive cultivation of grain crops. Declining yields of crops due to the soil compaction in the clay rich soil areas, and also very poor yield in the sandy soil area are a certain warning of degradation of soil. Immediate improvement of fertilities of the soils is necessary, and introduction of a soil resting crop is recommended.

(5) Soil Moisture

Soil moisture contents are a reflection of the water balance in soil profile. Water can be supplied by precipitation and by capillary upward movement from ground water. Water can be retained only in micro-pores of soil against gravity. Water retention capacity of water available for plants is controlled by the composition of micro-pore size. The composition of micro-pore size depends on soil texture and extent of aggregate formation. Clay rich soils with well-developed aggregate can hold much more water and have higher water retention and supplying capacity. On the contrary, sandy soils with slight clay hold a small amount of water and have less capacity.

Under climate conditions of cold winter and hot summer with an annual precipitation of 500 – 700mm as in this study area, water retention capacity plays a key role in water balance for crop farming. When soils have a large retention capacity, for example around 40 %, enough to store most water from precipitation during winter, they can supply plenty of water to growing crop plants during spring and summer seasons. In this case, irrigation, in general, is not essential as long as it is for winter wheat. On the contrary, the sandy soils in this area have very small water retention capacity near to 15 %, (available water is only about 5 - 6 % in this case). The soil can retain only a small portion of the precipitation in winter and can supply only a limited amount of water to the growing plants, not enough to support growth of plants.

One of the characteristic aspects of water balance in this area is the probable occurrence of drying sand beds in the sub-layer of farm fields. Wide spread sand deposits are very common in this area, and medium and clay soils cover the thick bed of sand sometimes. Crop plants can start favorable growth in the early stage supported by water supplied from the top-layer of soil, but can not continue their vigorous growth from the limited supply of water from the sand bed in the sub-layer. Late period of growth, flowering, pollination and filling, requires large amounts of water supply to support the enlarged plant body, and is also a much more susceptible stage for water deficit stress. Failing of flowering, pollination and filling bring drastic damage to the yield of crops.

The following is a tentative working hypothesis and should be confirmed by successive survey and investigation. One problem is whether sand in the bed becomes gradually dryer under continuous cultivation of grain crop plants. The other problem is how we can recover the moisture content of the sand bed. Is it possible to recover it through introduction of soil resting crops in rotation leading to improvement of water balance of sand bed. Pasture and legume plants are originated from steppe and can develop great and deep root systems, sometime reaching the ground water level. Field spot survey indicates apparent evidence that they are taking up water from ground water level in sandy soils of this area.

Examples of Physical Properties of Sandy Soils in the Study Area

Contents			Water Retention (W%)			Av. Water(W%)
Location	Layer	< 0.01mm	pF 0	pF 1.75	pF 3.90	
Velke Levare	Top Soil	8.17	32.6	17.0	10.3	6.7
Ibid	Sub Soil	5.47	27.1	9.7	5.8	3.9
Stupava	Top Soil	5.77				
Ref, Bratislava	Top Soil	38.3				

（from K. Novakova 2000 ）

B.10.2 SOIL EROSION

Erosion of arable land is the most remarkable degradation process of soil by removal of the fertile surface soil with enriched nutrients from manure and fertilizer application. Soil erosion process is divided into 1) wind erosion by high-velocity wind, and 2) water erosion by surface running water.

(1) Wind Erosion

Under a planned economy, the Slovak Republic had achieved rapid development of large scale mechanized farming by collective and national farms. Over time, many wind protecting forests and tree belts had been cut and removed. Under present condition, large-scale cultivation of crops such as wheat, barley, maize, and sunflower, sometime exceeding several hundreds hectares for one plot, are very common all over the study area.

Frequent high velocity winds exceeding 20 m/sec, open large fields, dried sand particles on sandy soils, all of these factors are assumed to be responsible for high-risk potential of wind erosion. Particularly, sand particles of wind-brown sandy soils, which are fine particles of quartz and have the largest susceptibility to wind erosion nearly the same as particles on sand dunes in the desert.

Expected Wind Erosion (Wind Erosion Equation) is given as follows by Soil Conservation Agency of USDA.

E (Expected wind erosion tons/ha/year for a flat bare soil) = f (ICKLV)

where, f is the observed values of erosion on standard flat bare soil,
I is erodablity of soil reflecting texture and structure,
C is climate factor; K is ruggedness of field,
L is the length of a field in prevailing wind direction, and V is vegetative coverage factor.

Lyles, a member of the Wind Erosion Group of USDA, reported the minimum critical wind velocity at which the soil particles began to fly in wind tunnel test ; 6.6 m/sec of desert sand, 7.7m of fine sandy loam, and 11.1 m of clay soil.

As written above, all factors related to the wind erosion risk potential can be found in a wide range of the study area. Pasak and Jenecek reported that the sandy soils around the central plateau were ranked with the highest risk potential of wind erosion over all the Czechoslovakia Republic. Later, Slovak Soil Science Research Institute calculated the wind erosion risk potential all over the Slovak Republic based on the Jenecek Method. Their results also ranked major parts of Zahorska Lowland in the rank 4) of 75tons and more per year.

Jenecek method gives the next general formula based on the wind tunnel test by Pasak, and gives the four ranks of wind erosion risk potential 1) 25tons and less, 2) 50tons and less, 3) 75tons and less, and 4) 75tons and more per year.

$$Ev = 1.54 - 0.188J - 0.102Wv + 1.38R$$

Where Ev is soil erodablity,
J is the content of soil particles <0.001mm (%),
Wv is actual soil moisture expressed in volume percentage,
R is expected wind velocity at the surface (m/s)

These values are, of course, not real in actual farm fields but only the potential values which can be expected on plain bare farm soils without any protection measure.

In order to achieve sustainable land use and agricultural production in this area, further investigation of the wind erosion should be carried out not only of the risk potential but also of the reality. The reality of wind erosion, wind damage, specification of damaged areas and the degree of damage, remains unclear.

The most effective countermeasure is coverage of soil surface by cover crops or residuals after harvesting as stubble and straw. Coverage of surface protects the soil from drying and also from exposure of soil surface to strong wind.

During winter season, the soil surface can be expected to remain wet due to the water balance. The wind erosion risk can be actualized in a case when soil surface is kept uncovered and bare during the spring season when temperature goes up day by day and the soil becomes dry. Wind barriers such as protection forest and tree belts are also effective but the effect is limited to within the distance of ten times the height of the tree.

Jenecek and Pasak calculated the contribution values of the prevailing wind direction at Malacky and Borsky Mikulas; 42 % of wind erosion in Malacky with the prevailing direction swayed 72 degrees from North-South, 65 % in Borsky Mikulas with the direction swayed 45 degree from North-South. Conclusively, they recommended that setting of protection measures, such as protection tree and ridge of planting, in a perpendicular line is recommended to achieve greater effects.

Higher velocity of wind is frequently observed during winter and spring season, and the survey and investigation of the actual field situations, such as wind velocity, coverage by growing plants and residues, scattering of sand, and damage to crop plants, have great importance.

(2) Water Erosion

Water erosion of soil is the removal of soil by running surface water and it is divided into three categories; sheet erosion, rill erosion, and gully erosion in classic classification. Sheet erosion means almost equal removal of soil surface less than 20tons/year/acre. Removal and loss of topsoil in this level does not mean degeneration of soil, and can be considered rather preferable for renewal of soil, for weathering products of parent material is incorporated gradually into soil layer and serves as an additional source of nutrient supply. Rill erosion means that it produces countless small and narrow slots the surface the field about 6 inches wide and 4 inches depth. Gully erosion is categorized as the occurrence of deep and wide slots in arable land which farming machinery cannot run over.

Anyway, throughout our survey and observation, no apparent evidence of water erosion could be found in the area. In some spots we could find stagnant water in bottoms of lowland plain but running surface water could not be observed. Water erosion, if it happened, may occur within limited spots on the slope of a hill in the study area.

B.10.3 SOIL POLLUTION

Mining activity in Slovakia can be traced back to the Bronze Age (3,000 B.C.). Banska Stiavnica and Banska Bystrica in the Central Slovakia are well known for their long history of mining activities such as copper, silver and gold production. Scale of the mine ores was limited due to their origin of heating by a volcano and the main activity was over already.

After 1992, the project of Area Survey of Soil Contamination had been carried out and the results were presented in the publication "Geochemical Atlas of the Slovak Republic" (Curlik J. and P. Sefcik 1999). In the soils surrounding the old mines, high levels of copper, zinc, arsenic and cadmium contents were detected.

One spot was detected as contaminated soil with cadmium in the level of 0.6 – 2.0 mg Cd/kg around the Baumit Cement Factory in Rohoznik district. The cement industry treats large amounts of limestone in heating kiln. Since cadmium has the boiling point of 768℃, certain amount of cadmium in the raw materials can be evaporated during the heating process and leave through the chimney. Cadmium in the fumes precipitates and accumulates in the soils near the factory by the weight of the particles. The level of contamination by cement industry is generally not very high and the area is also limited.

Cadmium level of 0.6 – 2.0 can be categorized as the critical range for the soils on which growing crops can accumulate cadmium content level as high as the critical standards for food.

The Ministry of Agriculture of the Slovak Republic issued the circular notice on the allowable levels of cadmium in 1996. The critical levels in foodstuffs are 0.003 mg/kg in milk products for baby, 0.1 in vegetables and cereal products, 0.5 in oil crops, 1.0 in mushroom and lever of livestock, respectively. These values are comparable with the international standards of FAO and WHO.

On the other hand, the Highest Admissible Concentration of Pollutants in Soil (Regulation of MP, SR, No 531, 1994-540) sets the critical values as follows: 0.8 mg Cd /kg in soil as the reference of non-contamination, 5.0 of B value for detectable contamination, 20 of C value for sanitary standard. Only if cadmium level in soil exceeds 20 mg /kg, administrative countermeasure should be done from a sanitary point of view. These values for soils cannot be compared with the data in other countries.

One problem of cadmium regulation in the Slovak Republic is the lack of data and information about possible correlation of cadmium contents in crops and soils. Based on scientific investigation about the correlation, reasonable and acceptable standard values for the soil should be set.

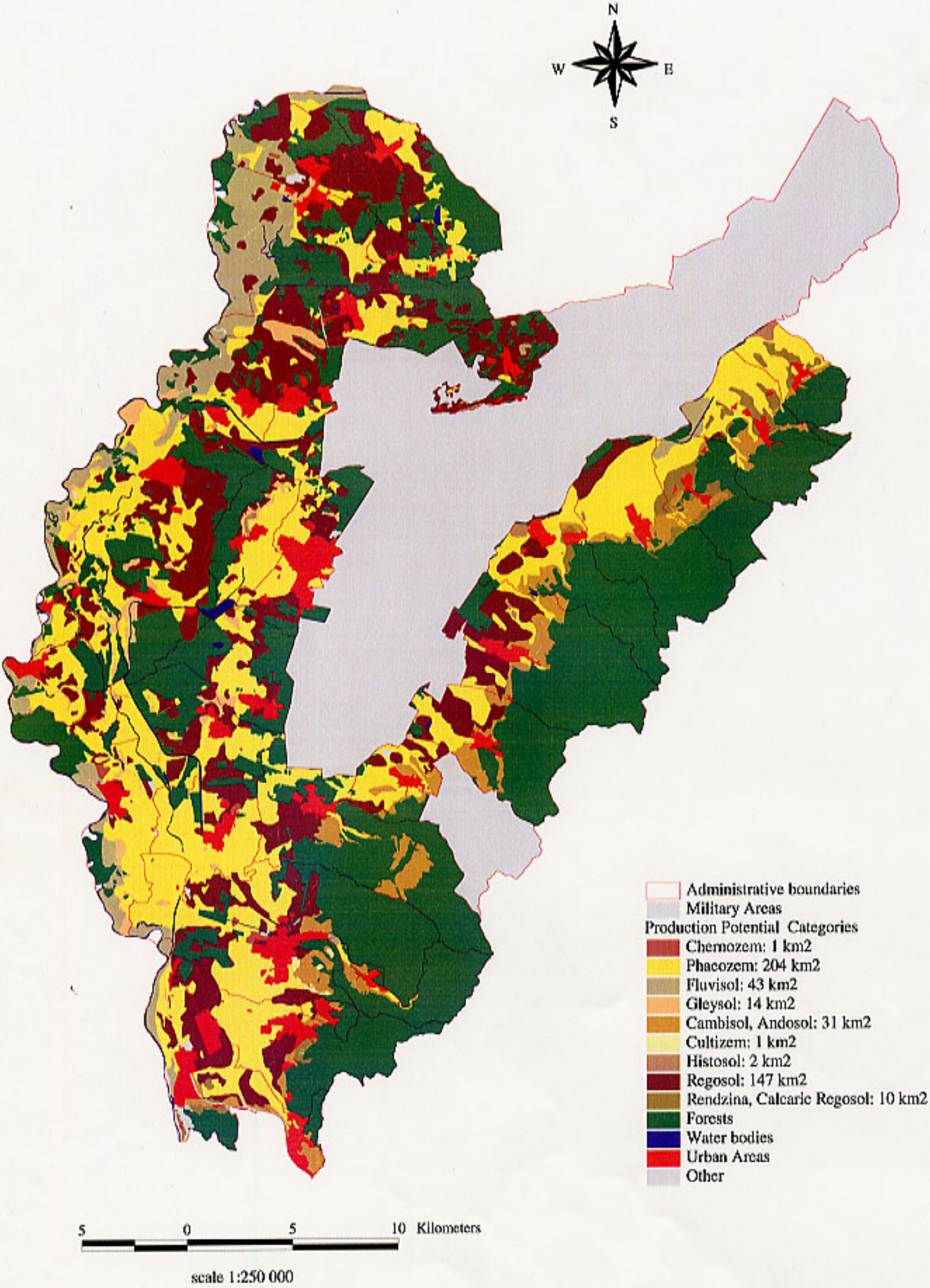

Figure B.10.1 Soil Type Map

Source: SSCRI, original map scale 1:5 000

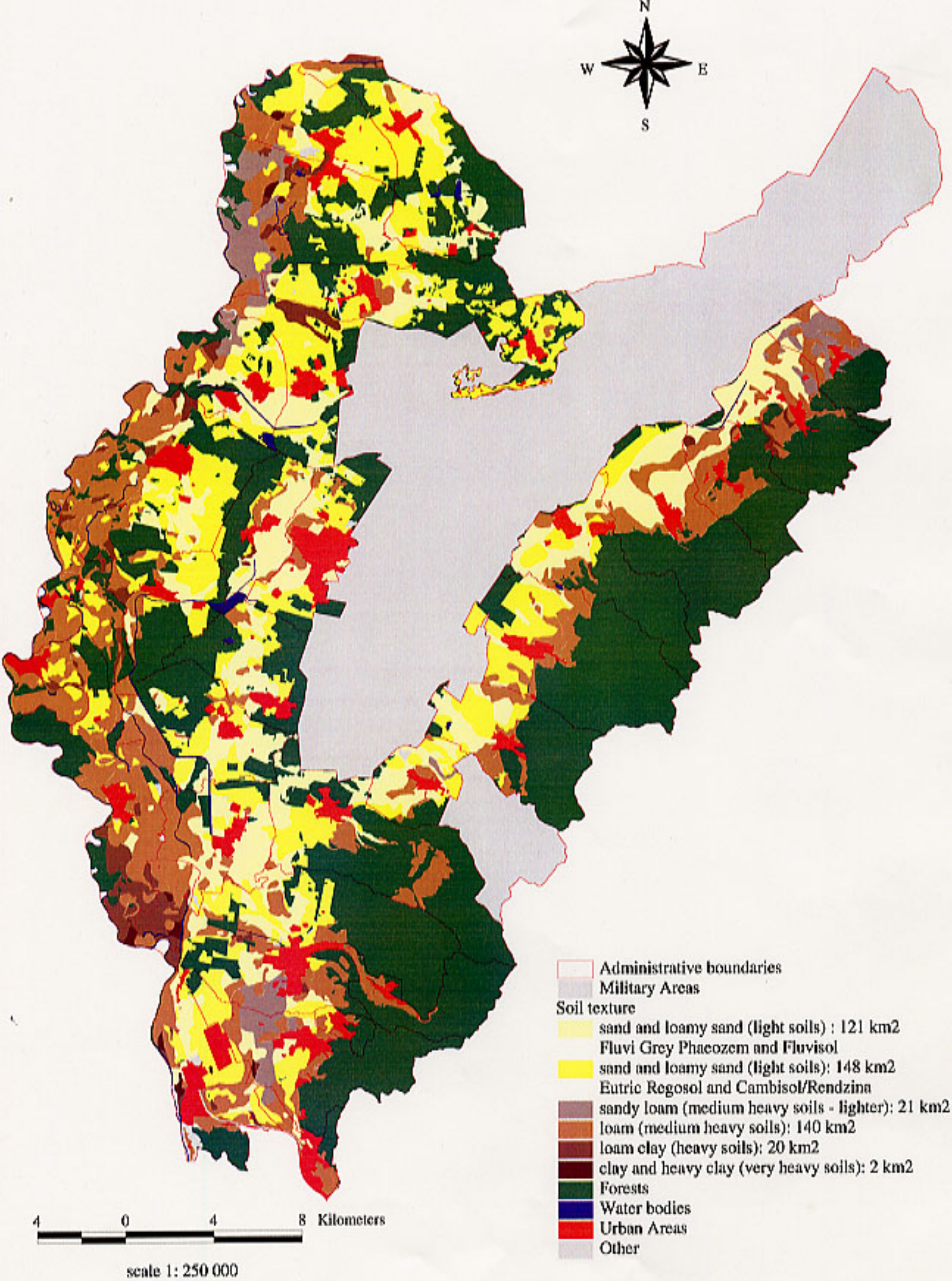

Figure B.10.2 Soil Texture Map

Source: SSCRI, original map scale 1: 5 000

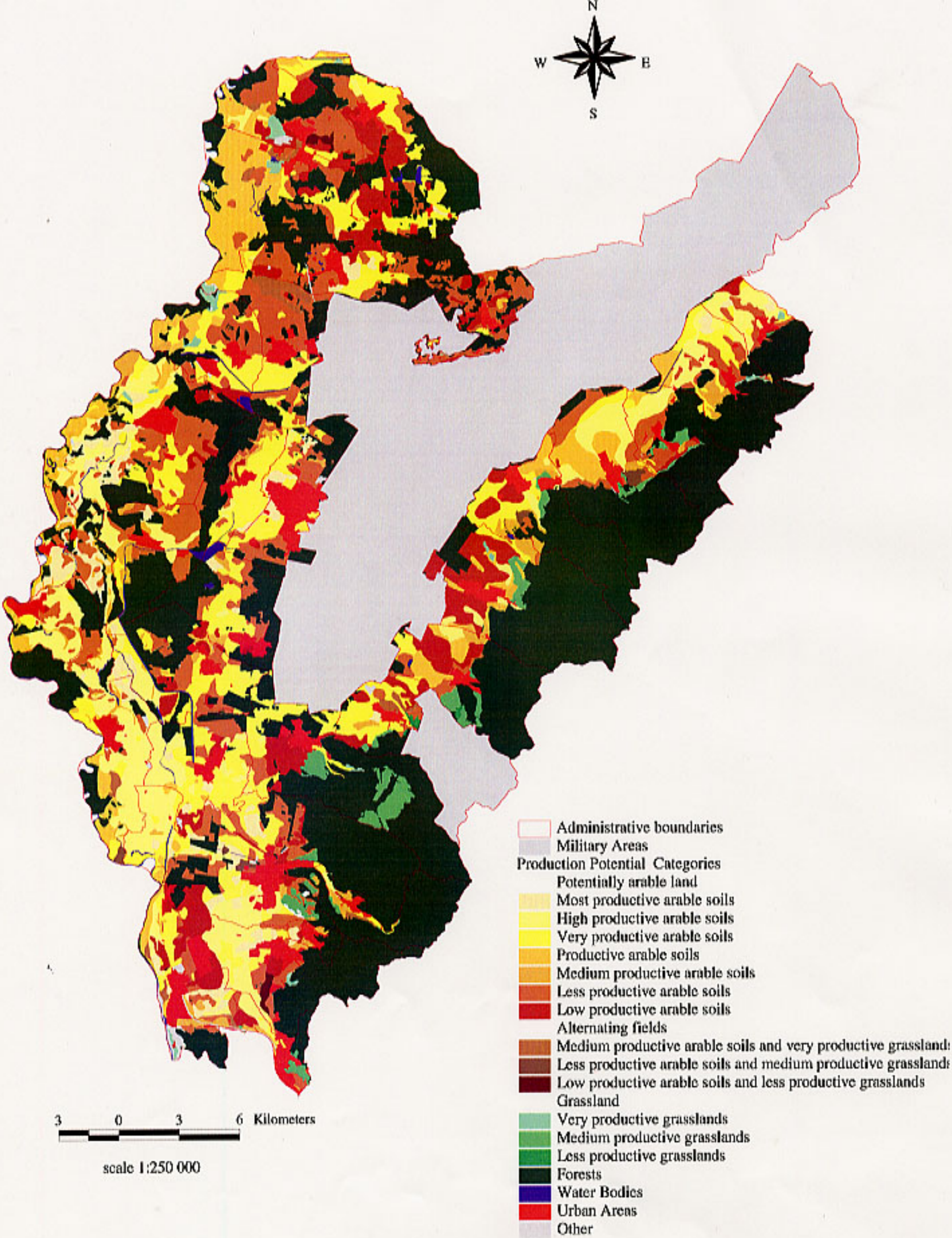

Figure B.10.3 Soil Productivity Map

Source: SSCRI, original map scale 1:5 000

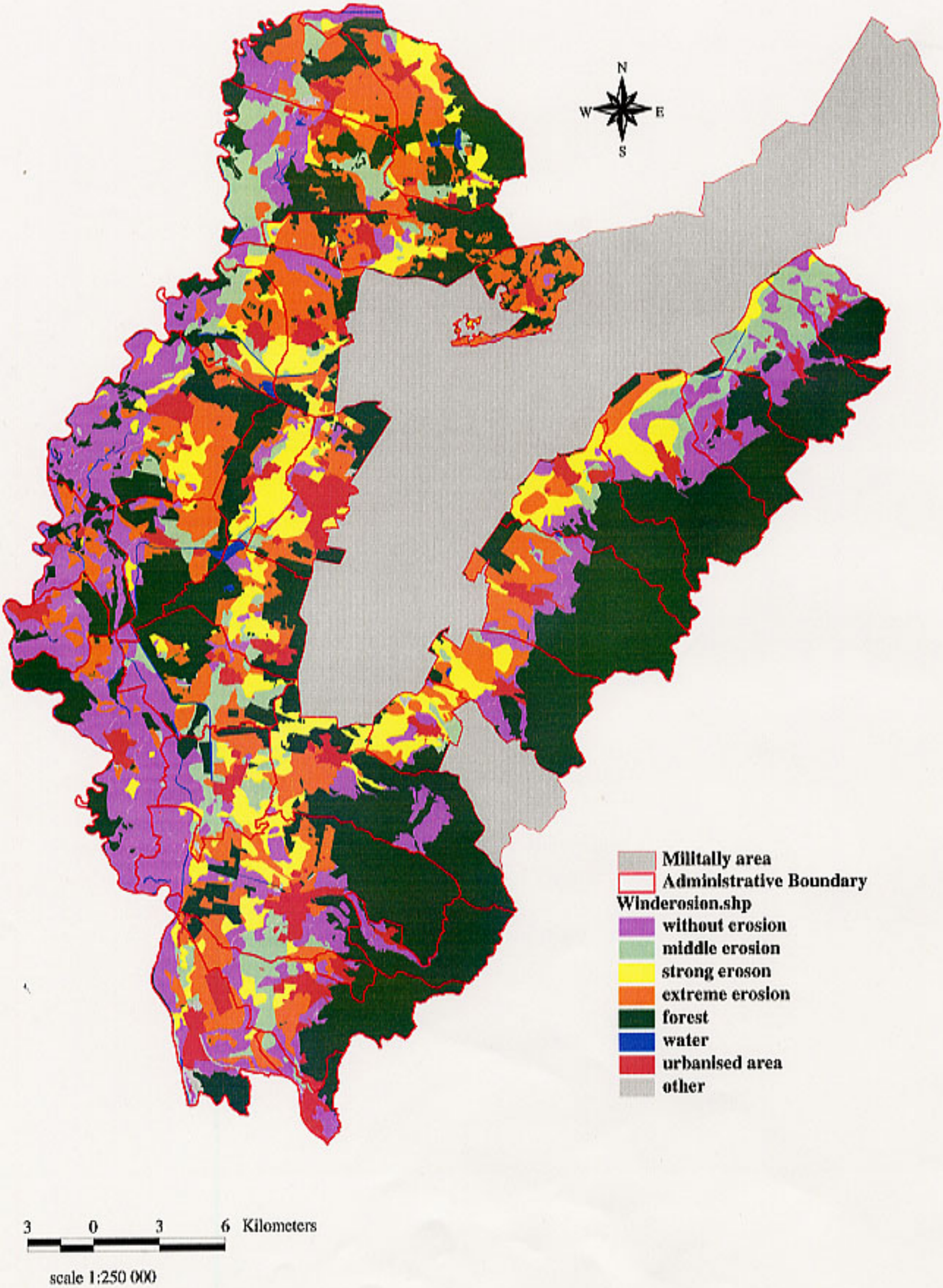

Figure B.10.4 Wind Erosion Potential Map
source: SSCRI

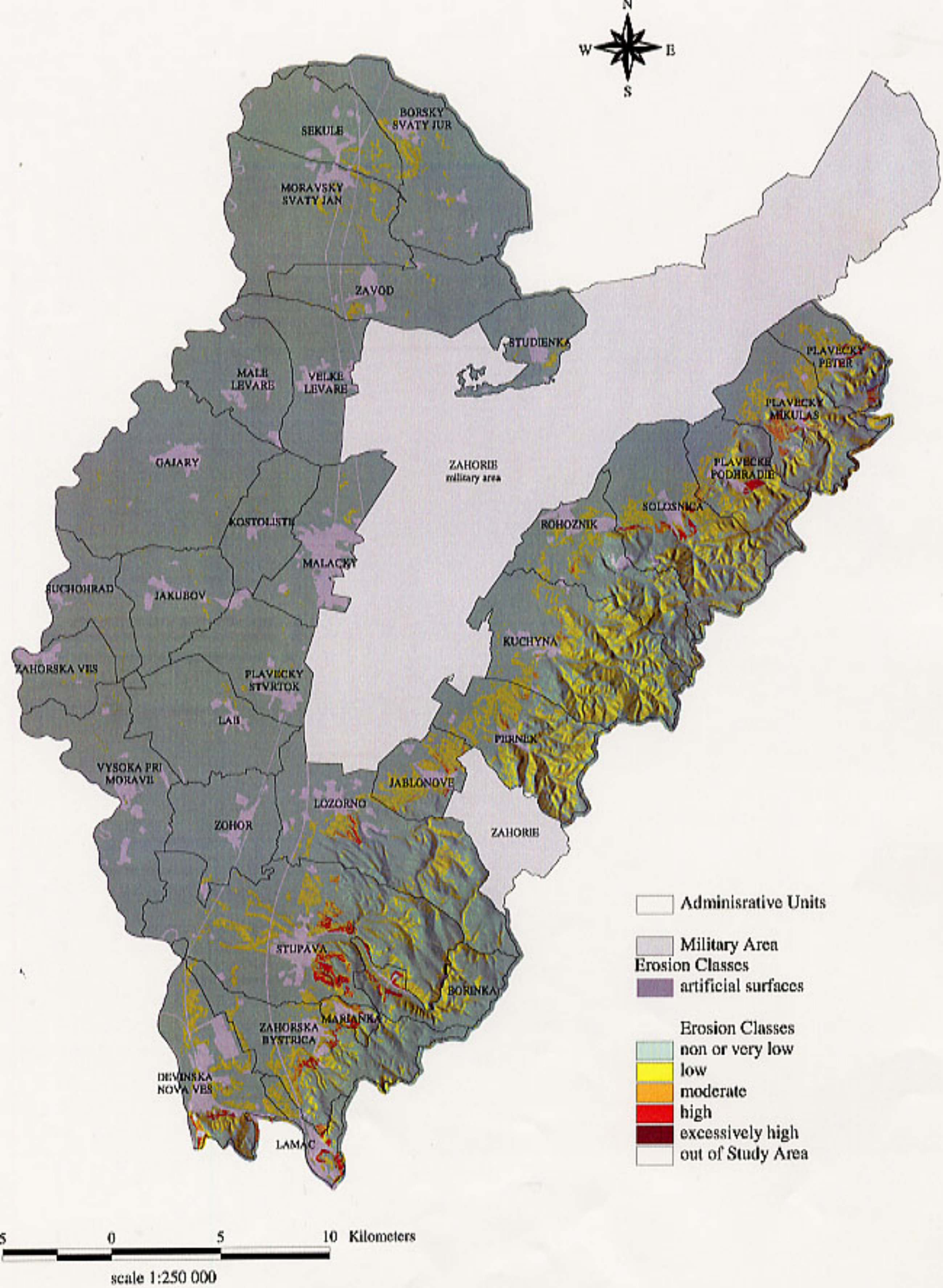

Figure B.10.5 Water Erosion Potential Map

source: Study Team