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REPORT FROM THE TERRESTRIAL ENVIRONMENTAL MONITORING PROJECT IN CENTRAL ASIA (TEMP-CA)

Establishment of monitoring reference area in Navobod, Sogdi oblast, the Republic of Tadjikistan, 2007. TEMP-CA monitoring site No.6.

Tonje Økland[1], Nurbek Kuldanbaev[2], Jørn-Frode Nordbakken & Odd Eilertsen[1†] (eds.)

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Sammendrag The collapse of the Soviet Union in the Central Asian countries has led to enormous challenges for them in ensuring a sustainable environment. Weak economies and lack of expertise in environmental sciences were important reasons for the Norwegian support to the environmental sector in this region. The State Forest Service of the Kyrgyz Republic and the Norwegian Forestry Group initiated the TEMP project, later renamed TEMP-CA, in the Kyrgyz Republic in 2004. Activities in the Republic of Tajikistan were included in 2007 and in the Republic of Uzbekistan from 2008. The forestry sectors in the Republic of Tajikistan and neighbouring countries in Central Asia, surrounding the Fergana Valley, are closely linked to the environmental and emergency planning sectors. Overgrazing and overharvesting have contributed to a dramatic decline in forest cover. The TEMP-CA project contributes to a better understanding of environmental problems and sustainable forestry in Central Asia. The TEMP-CA project has promoted institutional co-operation between Norway and the Central Asian countries as well as between different institutions both within and between the countries of Central Asia. Increased expertise for scientists, fieldworkers, laboratory staff and staff in different forest departments as well as institutional development in general are important outputs from the TEMP-CA project.

The Navobod monitoring site in Sogdi oblast in the Republic of Tajikistan was the sixth of ten monitoring sites established in forests in Central Asia:
1: "Kara-Koi" in the Osch oblast, the Kyrgyz Republic.
2: "Sogot in the Jalal-Abad oblast, the Kyrgyz Republic.
3: "Dugoba" in Batken oblast, the Kyrgyz Republic.
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10: "Umalak Teppa", Tashkent region, the Republic of Uzbekistan.

Ten plots of 30x30 m were placed subjectively in the area in order to represent the variation in the presumed most important environmental gradients. A 10x10 m plot was placed in the centre of the 30x30 m plots. Within each 10x10 m plot (macro plot) five plots of 1-m^2 were randomly placed. All trees within the ten 30x30 m plots were marked on a sketch map and a number of tree growth and tree vitality measurements were recorded. The Navobod site consists predominantly of the three *Juniperus* species: *J. semiglobosa* (41.5%), *J. seravschanica* (40.4%) and *J. turkestanica* (13.6%). Defoliation for the juniper species was noticeable and varied from about 23 to 34% (moderately damaged), a possible effect of climate and/or fungi. The proportion of discolorated trees was insignificant for all species. The size distribution of the three juniper species was approximately the same, although the total number of trees varied considerably between species. For all three species a high proportion of small individuals (<DBH 10 cm) suggest an adequate regeneration, while there was a considerable decrease in the number of trees with increasing size (18.1 – 26.0% of trees DHB > 15 cm).

Two abundance measures were recorded for all species in each of the fifty 1-m^2 plots: frequency in subplots (presence/absence of all species in sixteen subplots in the 1-m^2 plots) and percentage cover. All together 118 species was recorded in the 50 1-m^2 plots, and 85 of these were herbs and 10 bryophytes. The species diversity in the area is high compared to many of the other TEMP-CA sites, and the average number of species recorded in the 1-m^2 plots was 16.4. Vascular plants present in the 10x10 m plots and the 30x30 m plots were 114 and 117, respectively. Of the recorded plant species 9 are endemic to Central Asia: *Astragalus dendroides, Zizifora pamiroalaica, Antonina debilis, Aquilegia vicaria, Astragalus aphanassjievii, Galium pamiroalaicum, Oxytropis tachtensis, Valerianella turkestanica* and *Viola turkestanica.* Detrended Correspondence Analysis (DCA ordination) of the subplot frequency data for the fifty 1-m^2 plots was performed in order to reveal the most important vegetation gradients. The ordination axes, i.e. expressing the vegetation gradients, were interpreted by means of Kendall's non-parametric correlation coefficient. Depth of the organic layer, soil depth, aspect, aspect favourability, the micro topography variable *sum concavity/convexity 1-m^2*, and the heat index were some of the most important environmental conditions influencing the species composition according to these results.

The plots were situated in an area with (very) steep slopes. Signs of soil erosion were visible everywhere, probably triggered by grazing animals. The soil material originated from shales and limestones, and was fluvic in the riverbed. Soil moisture varied from 5 to 42% within and between the 10x10 m macro plots. Also pH varied, both within and between plots, ranging from just below pH 7 to pH 8,90. The observed soil types included Leptosols, Umbrisols and Cambisols.

The soils at Navobod had among the highest average pH values of the TEMP sites, though with a relatively low base saturation on the cation exchanger. There were relatively few significant correlations (r > 0.7) between the measured soil constituents. The soil composition in the A and B horizons are fairly similar with base cations (Ca, Mg, K) accounting only for 30% relative to acid cations (Al and Fe). Especially the content of iron (Fe) was high at this site, with 25% of the samples having Fe content greater than 50 g/kg. The content of Fe and aluminium (Al) was not strongly correlated (r = 0.440). The Fe content was in fact not found to be correlated to any major constituent nor oxide element. Instead the negative correlation between Al and calcium (Ca; r = -0.749) was stronger then found in the other sites. The soil content of manganese (Mn), phosphorous (P) and sink (Zn) were relatively high at Navobod (1038, 808 and 165 mg/kg in the B horizon, respectively). In addition the levels of barium (Ba) and molybdenum (Mo) were relatively high. There were only a few strong correlations found between the oxide- and trace elements as well as between the trace elements. Fe and Al were only strongly correlated to a few borderline metals. Furthermore, only 9 strong correlations were found between the 16 measured trace elements. As usual the borderline elements showed the largest number of correlations. Considering the important role Fe play in explaining variation of trace elements in these soils running a statistical analysis on the sample set from Novobad is problematic, due to the high number of samples given the maximum value of 50 g/kg for Fe. Still, a Principal Component Analysis (PCA) of the metal content and chemical characteristics of the A and B horizons gave a main principal component (PCA 1), explaining 34% and 43% of the variation in the dataset, respectively. The PCA 1 axis was mainly explained by the Al and Fe content relative to calcium (Ca) and total carbon (C) content, reflecting variations in the calcium carbonate content of the soil. The parameter loadings along the PCA 2 axis was to a certain extent correlated to the Covalent index (CI = X^2r) of the elements (r = 0.428 and 0.559 in the A and B horizons, respectively).

Ansvarlig signatur: *Jeg innestår for at denne rapporten er i samsvar med oppdragsavtalen og Skog og landskaps kvalitetssystem for oppdragsrapporter.*

Adm.dir./Avdelingsdirektør

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NORWEGIAN FORESTRY GROUP

Cover Photo: Navobod, Photo: Tonje Økland

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ABSTRACT

The collapse of the Soviet Union in the Central Asian countries has led to enormous challenges for them in ensuring a sustainable environment. Weak economies and lack of expertise in environmental sciences were important reasons for the Norwegian support to the environmental sector in this region. The State Forest Service of the Kyrgyz Republic and the Norwegian Forestry Group initiated the TEMP project, later renamed TEMP-CA, in the Kyrgyz Republic in 2004. Activities in the Republic of Tajikistan were included in 2007 and in the Republic of Uzbekistan from 2008.

The forestry sectors in the Republic of Tajikistan and neighbouring countries in Central Asia, surrounding the Fergana Valley, are closely linked to the environmental and emergency planning sectors. Overgrazing and overharvesting have contributed to a dramatic decline in forest cover. The TEMP-CA project contributes to a better understanding of environmental problems and sustainable forestry in Central Asia.

The TEMP-CA project has promoted institutional co-operation between Norway and the Central Asian countries as well as between different institutions both within and between the countries of Central Asia. Increased expertise for scientists, fieldworkers, laboratory staff and staff in different forest departments as well as institutional development in general are important outputs from the TEMP-CA project.

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PREFACE

TEMP-CA was initiated and planned by Odd Eilertsen, who was also the project leader up to his sudden death on 19 February 2010. All involved project partners and scientists in Central Asia and Norway had been working with the data and report chapters for the ten TEMP-CA sites according to his ideas and decisions up to his death. This report has thus been completed as far as possible accordingly.

Many scientists and colleagues in Norway and Central Asia as well as myself are very grateful to Odd for giving us the possibility to co-operate in this project.

On behalf of all authors and partners in TEMP-CA I want to give special thanks to the persons mentioned below who have contributed with fieldwork, laboratory work, translations, logistics, administrative work etc.:

Odilov Amanbay, Bakmurat Arabek uluu, Boturov Kodir Boturovich Aitkul M. Burhanov, Emma G. Beletskaya, Nicholas Clarke, Ishankulova Dilafruz, Kasirov Kokul Hasanovich, Raupov Holmurod, Nuriya S. Isakunova, Salamat B. Imanakunov, Azamat K. Jybykeev, Djumaev Kamron, Nurgul K. Kuldanbaeva, Rina Kumalova, Almaz B. Kurmankulov, Margarita Y. Kuznesova, C. Kysanov, Taalai K. Mekishev, Ajar K. Madieva, Bakyt A. Mamytova, N. Mairykova, Oleg R. Mujdabaev, Rahimov Nurali, Saltanat R. Narynbaeva, Svetlana G. Nesterova, Asel Orokbaeva, N. Polyanskaya Oktyabrin A. Sadyrov, Sharafutdinov Sadreddin, Eldar Shafiev, Beishekan Sultanova, Vladimir K. Schudro, Omurbek Smat uluu, and Maisobirov Vahob

My very special thanks to Halvor Solheim (leader of the Forest Health Section at NFLI), who supported me and helped me, especially in the last phase of the work with completing the TEMP-CA reports. I also want to give special thanks to Dan Aamlid (head of the Department for Biology and Environment at NFLI), Arne Bardalen (Director General at NFLI), Karl Thunes (project leader after Odd Eilertsen of the Ahangaran Forest Damage Project at NFLI) and Øystein Aasaaren (Managing Director of Norwegian Forestry Group), all of whom have, in different ways, given me support in the difficult situation that occurred when Odd died. Odd Eilertsen was the initiator and project leader of TEMP-CA, but he was also my friend and colleague.

Ås, 20 December 2010

Tonje Økland

Project leader

CONTENT

INTRODUCTION

Nurbek Kuldanbaev[1], Tonje Økland[2] & Odd Eilertsen,[2†]

1: The Public Foundation Relascope (Bishkek)
2: The Norwegian Forest and Landscape Institute/Norwegian Forestry Group

Various terrestrial monitoring programs in Europe, North America, East and Southeast Asia have shown that combined effects of anthropogenic and natural stresses affect soil, water, vegetation, and forests. Air, soil and water pollution as well as changes in climate are all regarded as important stress factors. The impact of pollutants and changes in climate vary geographically and with site and stand conditions. Different anthropogenic factors and their effects on terrestrial ecosystems are thus complex and difficult to isolate and quantify. A large number of stress factors that influence the ecosystem condition must therefore be taken into consideration and measured in the same plots; i.e. integrated monitoring should be carried out.

The International Co-operative Programme on Assessment and Monitoring of Air Pollution on Forests (ICP Forests) was established under the Geneva Convention - UN/ECE Convention on Long-range Trans-boundary Air Pollution (CLRTAP) in 1985. The Kyrgyz Republic, together with Kazakhstan, are the only countries in Central Asia to sign the Geneva Convention.

After the collapse of the Soviet Union the Central Asian countries have had enormous challenges in securing a sustainable environment. Weak economies and lack of human resources are two of the key factors. After the independence of the former Soviet republics in 1991 many of the Russian and other foreign scientists left Central Asia. The State Forest Service of the Kyrgyz Republic and the Norwegian Forestry Group initiated the Forest and Environmental Sector Programme in 2004. The program included the following two activities:

Activity 1 Terrestrial Environmental Monitoring Programme (TEMP). Implementation of a methodology for monitoring and studying terrestrial ecosystems in the Kyrgyz Republic.

Activity 2 Institutional Strengthening of the forestry sector including a stronger involvement of the private sector in the management of the natural resources. .

The project mandate was:

- To establish a methodological concept for monitoring effects of anthropogenic and natural stress factors on the condition and development of terrestrial ecosystems in the Kyrgyz Republic with relevance for other countries in Central Asia (the Republic of Tajikistan, and the Republic of Uzbekistan).
- To contribute to a better understanding of cause-effect relationships in terrestrial ecosystems in various parts of the Kyrgyz Republic and in Central Asia generally.
- To contribute to a better understanding of the relationships between the condition of terrestrial ecosystems and anthropogenic factors (in particular soil pollution from industrial activities) in a number of selected permanent observation plots.
- To provide policy-makers and the general public with relevant information related to the issues above, in order to reach these goals.

After the appraisal phase (2003-2004) and Phase I (2005-2006) of the project, forest and environmental activities in the Republic of Tajikistan and the Republic of Uzbekistan were included as well in Phase II, and the project was accordingly renamed TEMP-CA. The main objectives of the TEMP-CA project were to:

- Identify national expertise and make a survey of information requirements from the three Central Asian countries.
- Work out a suitable methodology for an integrated intensive monitoring based on international standards.
- Develop a framework for an integrated monitoring programme within the Fergana Valley region.

- Identify “hot spots” in the Fergana Valley and the surrounding mountains and establish monitoring sites in the Kyrgyz Republic (six from –2004-2009), in the Republic of Tajikistan (one in 2007) and in the Republic of Uzbekistan (two; in 2008 and 2009).
- Contribute with equipment to laboratories and education of personnel to undertake chemical analyses of soil, soil water, runoff water and plant samples for environmental monitoring programmes within the forest and land degradation and watershed management sectors.
- Enhance the environmental monitoring expertise and the general environmental expertise in academia.
- Prepare for the next phase of TEMP-CA, a “Programme for Environmental Risks and Security in Areas of Land Degradation” in the Fergana Valley.
- Institutional development within academia and the environmental and education sectors.
- Support to environmental reform processes aimed at strengthening co-operation and integration with the newly independent states of the former Soviet Union.
- Contribute to stabilisation and conflict prevention in the region based on establishment of transparent information on natural resources and the state of the environment.

The environmental degradation and resource scarcity has not been the catalyst of conflicts in any of the Central Asian republics, but have exacerbated existing political and social crises and ethnic tensions. In the Fergana Valley the situation is special; the area is overpopulated, the borders between the states are artificial, ethnic conflict is severe, the environmental pressure is enormous, and the struggle for natural resources make this area violent and with more tensions than any other parts of the region.

The Central Asian states face tremendous challenges to manage the process of political, economic, and social reforms towards competitive and open market economies. They still suffer from the legacy of the Soviet period, and collaboration between scientists and environmental managers from the different countries is more or less absent. The TEMP-CA project aims at bringing scientists and environmental managers from the Kyrgyz Republic, the Republic of Tajikistan, and the Republic of Uzbekistan together in a joint trans-boundary project.

The forest area of the Republic of Tajikistan is c. 3% is of the total area (according to information on http://www.tradingeconomics.com/tajikistan/arable-land-percent-of-land-area-wb-data.html). Data from the TEMP-CA project gives valuable information to the forestry sector in Tajikistan relevant for sustainable management of forests.

The forestry sector in the Republic of Tajikistan and its neighbouring countries in Central Asia, especially for the area surrounding the Fergana Valley, are closely linked to the environmental and emergency planning sectors. Excessive grazing and harvesting have contributed to a dramatic decline in forest cover. The history of forestry in the region is broadly similar to that observed in Western Europe: The over-exploitation of the timber resources in the first half of the 20th century resulted in a dramatic decline in forest cover, and led to the establishment of institutions with a mandate to improve forest management and restore depleted mountain forests.

In contrast to Western Europe, the period of timber exploitation was followed by a period of severe overgrazing, which further degraded the forest cover and interrupted natural regeneration. Today, large areas are affected by soil erosion and land degradation. Besides this, the main land degradation processes include salinization, chemical pollution, and destructive changes in vegetation cover.

Forest resources play an important role in water regulation, protection from soil erosion, general conservation of biological diversity, and stabilization of the ecological balance. Strong dependence on the use of wood as fuel is challenging, and alternative energy sources need to be explored to prevent further deforestation. Pastures located on slopes with steepness of more than 20 degrees are severely degraded by wind and water erosion. The prevalence of small cattle ranches has led to the transition from pasturing of cattle at a distance from settlements to primitive shepherding, which has expanded the impact area and the forest degradation.

The institutional co-operation between Norway and the Republic of Tajikistan, the Kyrgyz Republic and the Republic of Uzbekistan provides the opportunity for education and training of numerous environmental field workers and scientists, laboratory engineers, forest and environmental experts and managers from the Central Asian region. The TEMP-CA project contributes to better understanding of environmental problems, as a first step to promoting a sustainable use of the forests in Central Asia. Thus, increased expertise in environmental monitoring methods and in environmental management as well as institutional development in general is the most important output from the TEMP-CA project. This output cannot be fully expressed in a report.

Recording of ground vegetation, tree variables, soil variables and other environmental conditions in the same permanent plots enables identification of the main complex gradients in vegetation and the environmental conditions. Identifying these gradients is necessary as a basis for interpretation of changes in the forest ecosystem due to both anthropogenic and natural stress factors. Regular re-analyses of these plots may reveal changes in tree vitality, species composition in ground vegetation, biodiversity changes and changes in soil chemistry, as well as relationships between changes in these components of the forest ecosystem.

Thus, integrated monitoring in permanent plots provides: 1) a better understanding of relationships between the different components of the forest ecosystems, 2) basic knowledge and data from the forest ecosystem necessary for identifying effects of anthropogenic as well as natural stress factors and 3) a contribution to different aspects of relevance for forestry policy at national, regional and global levels, such as effects of climate change on the forests, sustainable forest management and biodiversity in forests.

In this report we present the main results from the sixth monitoring site established in the TEMP-CA project, Navobod in Sogdi oblast, the Republic of Tajikistan. This monitoring site was established and analysed in 2007. Measurements of a lot of variables for forest tree condition, forest growth, soil chemistry, and soil classification, ground vegetation, and environmental factors were performed according to manuals based on ICP Forests, ICP Integrated Monitoring and the monitoring concept used in Norway since 1988 (Økland 1996, Lawesson et al. 2000).

1 DESCRIPTION OF THE NAVOBOD REFERENCE MONITORING AREA

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1: The Public Foundation Relascope, Bishkek
2: The National Academy of Science, Tasjkent

1.1 Geographical position of the reference monitoring area

The Navobod monitoring site is situated on the northern foot of the Kurganak range (Turkestan range) which is the southern mountain framing the Fergana depression.

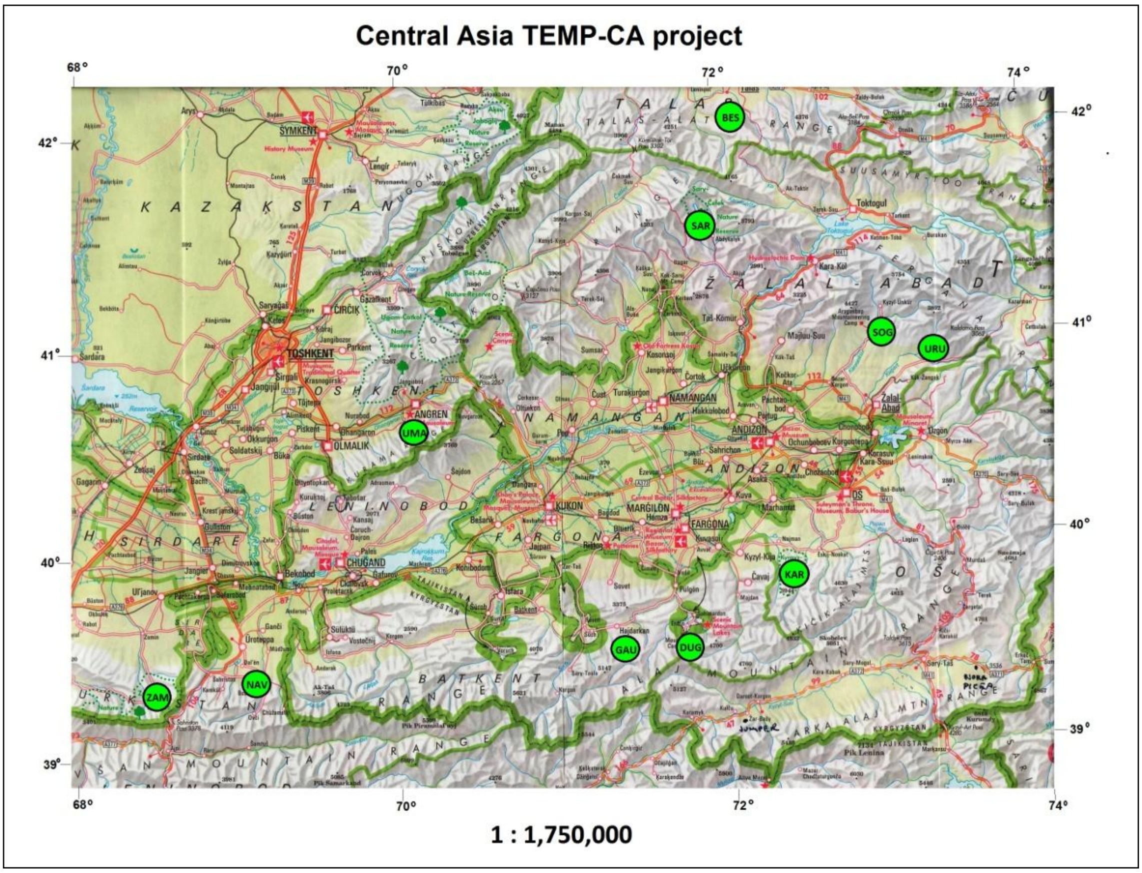

Fig. 1.1. Map of the Novobad area (NAV) and the nine other TEMP-CA monitoring reference areas.

The range is no more than 3000 m high, and is characterized by a very straight crest line without prominent peaks. It is separated from the major Turkestan range by a wide, flat-bottomed valley bordered by rather steep slopes. At present, rivers in this valley run dry, at least in summer.

Administratively this area belongs to Sogd Oblast, Navobod village, the Republic of Tajikistan.

Tab. 1.1. gives the latitude and longitude grid reference and altitudes for the 10 macro plots at Novobad

Tab. 1.1. GPS coordinates for the ten 10x10 m macroplots (see chapter 2.1.1).

Plot :	Elevation	N	E
NAV 1	2055 m	39°38.670′	068°55.254′
NAV 2	2087 m	39°38.617′	068°55.198′
NAV 3	2066 m	39°38.608′	068°55.160′
NAV 4	2071 m	39°38.597′	068°55.077′
NAV 5	2085 m	39°38.571′	068°55.010′
NAV 6	2132 m	39°38.545′	068°54.878′
NAV 7	2168 m	39°38.571′	068°54.871′
NAV 8	2126 m	39°38.597′	068°54.801′
NAV 9	2164 m	39°38.636′	068°54.801′
NAV10	2179 m	39°38.636′	068°54.758′

1.2 Forest type

The main woody vegetation is juniper forests that grow from the sub-mountain region up to the sub-alpine meadows. The forests are dominated by three juniper species: *Juniperus turkestanica*, *J. seravschanica* and *J. semigloboza*.

The altitude border of the forests varies with local conditions. In the most xerophytic areas *J. seravschanica* is common at the lower altitudes, from 2000 up to 2500 m a.s.l. On the northern slopes *J. semigloboza* is predominant up to 2500 m. Up to 3000 m on northern slopes and up to 3300 m on southern slopes *J- turkestanica* is predominant. Elfin wood formations of *J. turkestanica* are present from 3000 to 3700 m a.s.l.

1.3 Geology, topography, and quaternary deposits

The geological structure of the Kurganak range is dominated by a lower Paleozoic sandy-shaly suite with subordinate limestone interlayers, but limestone presents independent strata of great thickness in the sub-mountain region of the northern slope.

According to geomorphologic zones the Navobod site belongs to the Alai-Turkestan province. The relief is influenced by Epihercynian structures which experienced vertical movements of opposite sign in the Olegocene-Pleiocene-Pleistocene. The Navobod site is included in the South Tien-Shan group (Alai and Turkestan ranges).

The relief is made up mainly by Paleozoic and Proterozoic rocks and its structure depends on the altitude range, slope exposure and lithologic composition of rocks. Cliffy relief forms are widely developed. The tectonical-denudational relief is made up by Paleozoic and Paleogen-Neogen deposits. They are the former bends which experienced powerful tectonic rises. The relief is distinguished with the outcropping of Paleozoic and Proterozoic rocks.

The age of formation of the tectonic-denudational relief is mainly Neogen-Quaternary that still continues to develop.

1.4 Climate

1.4.1 TEMPERATURE

The average annual temperature at the lower and upper border of the region is about 10 °C and 0 °C, respectively. The winter is cold, windy and with little snow. The temperature drops to –27 °C in the lower part and to –34 °C in the upper part. Differences between day- and night-time temperatures, as well as between winter and summer temperatures are in greater contrast than in other regions of Tajikistan.

1.4.2 PRECIPITATION

The climate is rather arid, and the annual precipitation does not exceed 300 mm. There is considerable precipitation in the early spring time. The dry summer period is lengthy.

1.5 Vegetation zones

According to botanical-geographical zones, the territory of Navobod belongs to the ancient Mediterranean sub-kingdom of Holarctic, Central Asian province of the Fergana Valley region (Kamelin 2002). Juniper woodlands are formed by three species which dominates at different altitudes .

1.6 Forest history, forest structure, and external influence

1.6.1 HUMAN IMPACT

The main man-made impacts on the forest in this region, as well as in other forests, include:

1. Illegal cutting. Any cuttings, except “sanitary”, are forbidden in the forest area. However, the residents of the nearest villages break the law and cut down trees for firewood as they the last years have had no other sources of energy, and have been victims of a constant energy crisis.
2. The use of forest lands for tillage and hay-mowing**.** The local population uses flat areas for tillage and planting agricultural crops, and every year they engage in hay-mowing.

1.6.2 FOREST HISTORY

Because charcoal produced from juniper (archa) has very good energy qualities, a great numbers of archa trees were cut down to produce charcoal in the early 20th century. During the Second World War archa trees were cut down and floated down mountain rivers, and were used in industrial plants and partly in construction. Some of the collected timber was also stored as an emergency stock. As a result of this activity combined with the the slowly regeneration of junipers, the area with arch woods has been highly reduced.

In 1960 all types of cuttings were forbidden except sanitary cutting. But the local population frequently cut out quality trees under the mask of “sanitary” cutting. Moreover, the arch woodlands were intensively employed as pastures. All this led to intensification of erosion processes, mudflows, landslides and other phenomena that developed into natural disasters. The high number of emergency situations in the period 1997-2007 caused great loss for the forests of Tajikistan.

1.6.3 GRAZING

Almost all over the territory where monitoring plots are established there is a rather intensive grazing of domestic cattles. Constant extreme pasturing of cattle takes place in the whole of the forest territory of the republic. Grazing of domestic animals is seasonal. The droving of cattle to mountain forest pastures begins at the end of April – beginning of May, and they return from the end of September till the end of October. As the mountain zone becomes warmer and the cattle consume grasses cattlemen take animals further into the mountains.

2 FOREST STATUS AND TREE CONDITION

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2.1 Methods

2.1.1 SAMPLING DESIGN

The establishment of monitoring plots and field assessments where done in accordance with the ICP-Forest manual (ICP Forests 2006), revised for Central Asian conditions. Briefly, at each site 10 30X30 m plots were established in which the spatial coordinates for all trees > 5 cm DBH (vitality trees) were assessed. The individual trees were numbered consecutively at breast height within each plot for later reassessments.

Within each of the plots a central macro-plot of 10X10 m is defined in which more intensive assessments were done, such as measurement of tree heights, crown projections and crown heights.

2.1.2 TREE PARAMETERS

At each site standard crown condition parameters, such as social status, defoliation and discoloration were recorded. The classification of the defoliation follows ICP Forest: Class 0 shows healthy trees, with ≤ 10% defoliation; class 1, ”warning stage”, > 10 up to 25%; class 2, “moderately damaged”, > 25-60%; class 3, “severely damaged”, > 60% defoliation; and class 4, dead trees. Diameter at breast height was recorded on all trees > 5 cm DBH, whereas tree height was only recorded within the central 10X10 m macro-plot (cf. ICP Forests 2006). To take into account possible non-circular stem circumference, the diameter at breast height of all vitality trees was assessed in two directions.

In addition, regeneration (< 5 cm DBH) of all tree species were recorded as a part of the ground vegetation analysis in the 5 m^2 quadrants in each of the 10X10 m macro plots, making a total of 50 m^2 for the each site.

2.2 Results

2.2.1 TREE COMPOSITION

The Navobod site consisted predominantly of *Juniperus semiglobosa* (41.5%), *J. seravschanica* (40.4%) and *J. turkestanica* (13.6%). In addition, there were small amounts of *Lonicera microphylla* (4.6%) (Fig. 2.1).

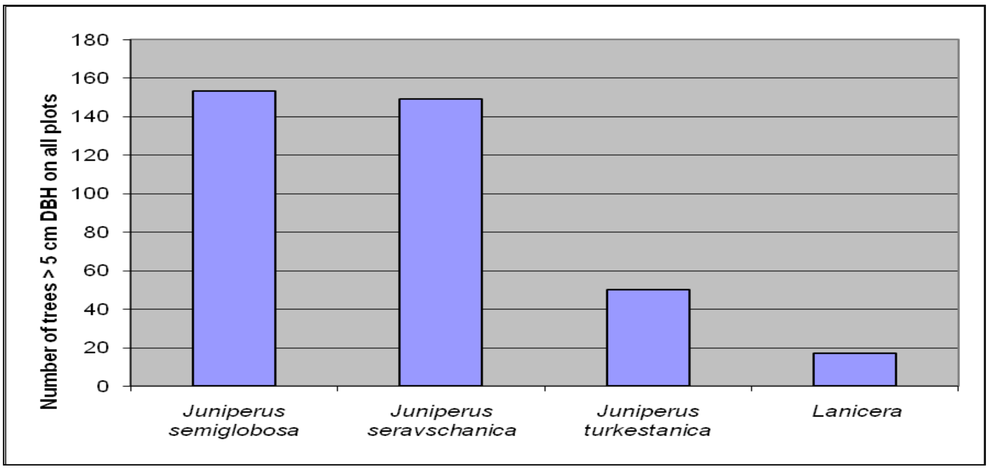

Fig. 2.1. Total number of trees of the different species > 5 cm DBH in all plots.

2.2.2 TREE CONDITION

Tree condition is presented for the main species where sufficient data is available. In general, defoliation for the juniper species was noticeable and varied from about 23 to 34% (Fig.2.2).

In contrast, the proportion of discolorated trees was insignificant; *Juniperus turkestanica* 2.9%, *J. semiglobosa* 1.8% and *J. seravschanica* 2.6%.

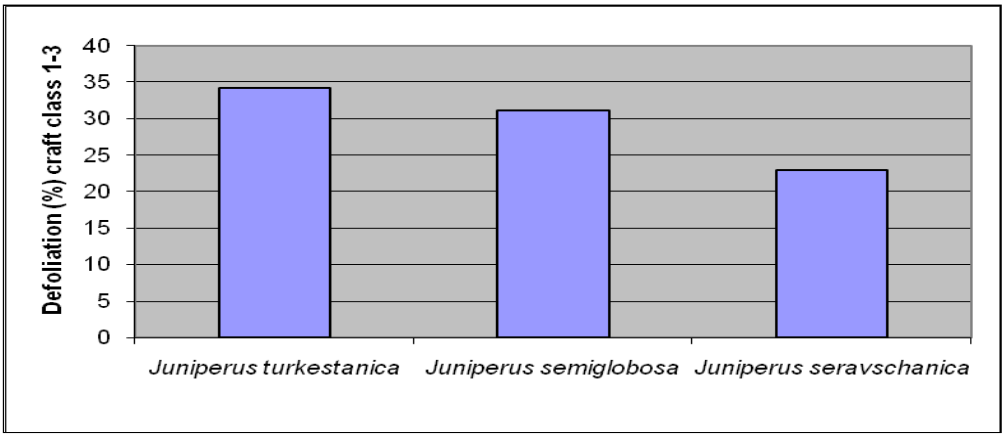

Fig. 2.2. Defoliation for the main species.

2.2.3. DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

The distribution of the juniper species by DBH was approximately the same, although the total number of trees for each species varied considerably. They had a high proportion of small individuals (< DBH 10 cm), and showed a considerable decrease in the number of trees with increasing DBH (Figs. 2.3, 2.4 and 2.5). Proportion of trees with DBH < 15 cm was 79.6% for *J. turkestanica*, 74% for *J. semiglobosa* and 81.8% for *J. seravschanica*.

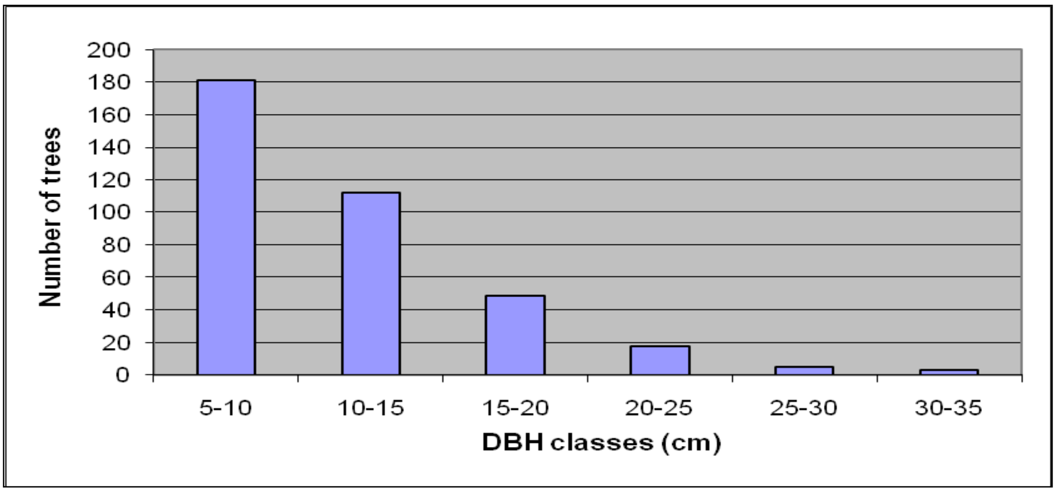

Fig. 2.3. Size distribution (DBH) for *Juniperus turkestanica* across all plots.

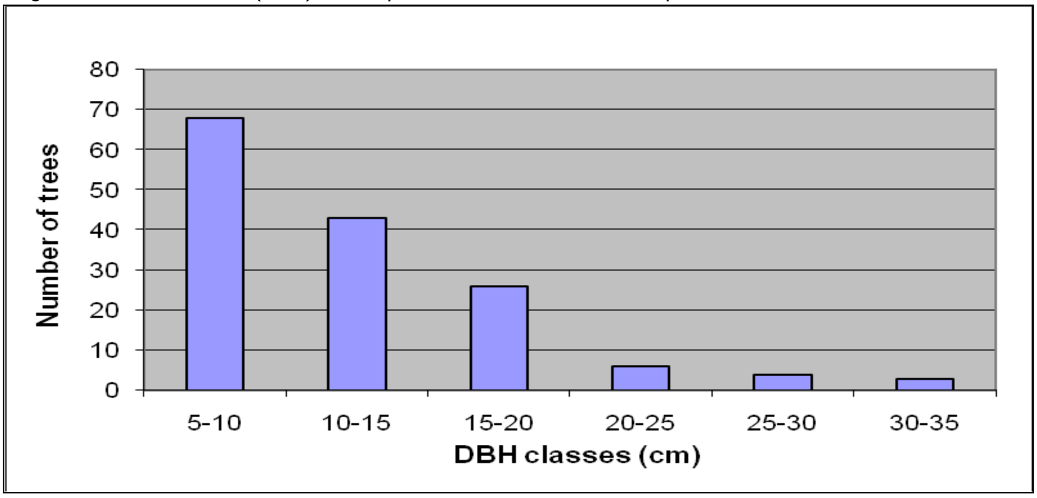

Fig 2.4. Size distribution (DBH) of *Juniperus semiglobosa* across all plots.

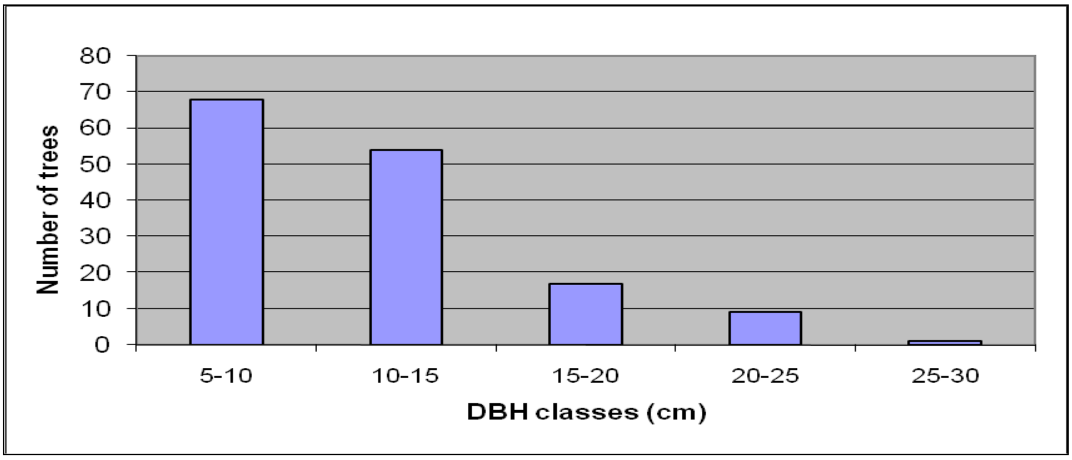

Fig 2.5. Size distribution (DBH) of *Juniperus seravschanica* across all plots.

2.3 Discussion

Forest condition was assessed using defoliation and discoloration of needles and leaves as the main indicators. Natural environmental factors such as climate and soil condition are known to be important for forest condition. In addition, grazing and cutting of firewood may affect both regeneration and susceptibility to diseases. Thus, forest condition is determined by a number of natural and anthropogenic factors, which implies that it could be difficult to single out the possible effect of pollutants on tree vitality at a given site. Similarly, it can be difficult to establish cause-effect relationships on tree vitality based on conventional forest monitoring not supported by experimental studies. Repeated assessments, which are the basic idea of monitoring will, however, always provide crucial information about temporal development in forest condition.

At this site the average defoliation was rather high, ranging from about 23 to 34%, and two of the juniper species are "moderately damaged" (> 25% defoliation) according to ICP Forest classification. The discoloration of needles, however, was insignificant. It can be speculated whether the defoliation is a consequence of very hot and dry summers during the past 2-3 years. Damage by insects and fungal diseases might also have contributed. The frequent cutting of branches for firewood in the area may represent entries for rot fungi, which could affect the tree vitality. It could be possible to compare trees which have been subjected to branch cutting with untouched trees. Accordingly, branch cutting should be recorded as a separate parameter during the next assessment in order to see whether tree vitality may refer to human interference. Similarly, wood and needle samples should be collected for pathological and entomological investigations when the injury cannot be assessed with certainty in the field. However, the harsh climate close to the tree line could also affect the defoliation, without any notable effect on the discoloration of the trees.

Sufficient regeneration is fundamental for sustainable forests. The *size distributions* of the juniper species show that the greatest number of individuals was found among the smallest size classes, suggesting a surplus of young individuals and adequate regeneration. To obtain scientific data on regeneration (< 5 cm DBH), however, more specific studies are needed.

3 BIODIVERSITY AND GROUND VEGETATION

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3.1 Methods

The sampling design and methods follow the Norwegian concept for forest ground vegetation monitoring (Økland 1996, Lawesson et al. 2000; see also Liu et al. 2008).

The key principles are summarised below:

(1) Study areas should be selected to represent the regional variation within the entire area of interest (for example region or a country), the intensity of impact factors (for example airborne pollutants), as well as climatic and other broad-scaled environmental gradients.

(2) Similar ranges of variation along all presumably important vegetation and environmental gradients within the pre-selected habitat type should be sampled from each study area, in similar ways.

(3) Ground vegetation, tree variables, soil variables, and other local environmental conditions of importance for the vegetation should be recorded in the same, permanently marked plots.

(4) Identification and understanding of the complex relationships between species distributions, the total species composition, and the environmental conditions in each study area form a necessary basis for interpretation of changes in ground vegetation, and for hypothesising relationships between vegetation change and changes in the environment.

(5) Observed changes in nature caused by anthropogenic factors not of primary interest for the monitoring study may interfere with and obscure trends related to the factors of primary interest. The influence of such factors should be kept at a minimum, for example by selecting areas in near-natural state.

(6) The sampling scheme must take into consideration the purpose of the monitoring and meet the requirements for data analyses set by relevant statistical methods which imply constraints on plot placement, plot number and plot size.

(7) All plots should be re-analysed regularly. For most forest ecosystems yearly re-analyses will impose too much trampling impact etc. to be consistent with the purpose of monitoring. The optimal time interval between re-analyses in different ecosystems may vary among ecosystems.

3.1.1 SAMPLING DESIGN

The following sampling scheme have been used for monitoring in each of Central Asian monitoring reference areas: Ten macro sample plots, each 10x10 m were placed subjectively in order to represent the variation along presumably important ecological gradients; in aspect, nutrient conditions, light supply, topographic conditions, soil moisture, etc. Each of the ten 10x10 m sample plots was positioned in the centre of one 30x30 m plot, to be used for recording of tree parameters. All plots were confined to one catchment area. All 10x10 m plots should allow placement of 1-m^2 plots in at least 20 of the 100 possible positions. Five 1-m^2 sample plots were randomly placed in each macro sample plot.

As far as possible, sites that were not visibly affected by external impacts were preferably chosen for placement of macro plots. Sample plot positions were rejected according to a predefined set of criteria. Positions for 1-m^2 plots were rejected if they (1) had a joint corner or side edge with another plot; (2) included trees and shrubs or other plants that physically prevented placement of the aluminium frame used for vegetation analysis of the plot; (3) were physically disturbed by man (by soil scarification, extensive trampling or crossed by a path, digging of pits, etc.); (4) were disturbed by earth slides; (5) were covered by stones for more than 20% of their area; or (6) when a vertical wall of 25 cm or more would be included or situated close to the corresponding plot. In case of rejection, a new position for the 1-m^2 plot was selected according to a predefined set of criteria. All plots were permanently marked by subterranean aluminium tubes as well as with visible plastic sticks.

3.1.2 VEGETATION PARAMETERS

Frequency in subplots was used as the main species abundance measure. Each of the fifty 1-m^2 plots was divided into 16 subplots, 0.0625 m^2 each. Presence/absence of all species was recorded for each of the subplots, and frequency in subplots was calculated for each species in each 1-m^2 plot. A species was recorded as present when it covers a subplot (Fig. 3.1). In addition to frequency in subplots, visual estimates of *percentage cover* was made for each species in each plot, since this additional information are obtained with very little extra time consumption.

Fig. 3.1. Recording species abundances in a 1-m^2 plot.

All vascular plant species present in the ten 10x10 m plots as well as 30x30 m plots were listed.

The number of vascular plant species within macro plots was calculated as: (a) the cumulative number of species recorded within the five 1-m^2 plots in each 10x10 m macro plot, (b) the total number of species recorded in each 10x10 m macro plot, and (c) the total number of species in each 30x30 m extended macro plot. The ratio a/b and a/c was calculated for each macro plot.

3.1.3 EXPLANATORY VARIABLES

Explanatory variables are environmental and other variables we use for interpretation of vegetation gradients; i.e. relationships between these variables and species composition along gradients. These variables all influence the ground vegetation by influencing the species composition along gradients and biodiversity, in different ways and to variable degrees. Explanatory variables are partly measured at field work, partly measured at laboratory by analyses of soil samples and partly calculated based on measured variables.

Several explanatory variables, of five main types were measured/calculated: (1) topographical; (2) tree influence; (3) soil physical; (4) soil chemical; and (5) grazing variables.

(1) Topographical variables include:

Inclination was measured in a way that is representative for each 1-m^2 plot by a clinometer compass.

Aspect un-favourability can be expressed as deviation of the recorded aspect measured representative for each 1-m^2 plot by use of a compass (0-360º) from SSW (202.5º). In the northern hemisphere, SSW is considered to be the most favourable aspect (Heikkinen 1991) due to high incoming radiation at times of day with high temperatures. However, it is more suitable for statistical analyses to recalculate to *aspect favourability*; thus we recalculated the values according to this formula:

ABS[180-ABS(202.5-aspect value)]

From the values of inclination and aspect we calculated the heat index (Parker´s index; Parker 1988) as:

COS(202.5-aspect value)*TAN(inclination value)

Indices of *concavity/convexity* in each 1-m^2 plot were calculated by assigning to each plot an index value for concavity/convexity of each subplot on the following scale: –2 (concave), –1 (slightly concave), 0 (plane),1 (slightly convex), 2 (convex). The same scale was used for the 9 subplots in a 3x3 m plot with the 1-m^2 plot in centre. Derived indices were calculated for both the 1-m^2 plots and for the 3x3 m plots by (a) summarizing the values, (b) summarizing the absolute values and (c) calculating the variance.

Maximum inclination was measured by a clinometer as the maximum measurable slope between two points in the sample plot, situated 10 cm apart.

(2) Tree influence variables include:

- Crown cover index
- Litter index
- Basal area

All trees that were (i) rooted within the macro plot; (ii) rooted within a 2-m buffer zone bordering on the plot; or (iii) covering the plot or the buffer-zone, were marked with numbers, in the field and on a sketch map of each macro plot with positions of the 1-m^2 plots, canopy perimeters and tree stems drawn in. *Crown area* for each tree, **cai**, i.e. the area within the vertical projection of the crown perimeter, was estimated from the sketch maps. The *tree heights* were measured in dm from normal stump height to the tree top and the crown heights were measured as the difference between total tree height and the distance from the ground to the point of the stem where the lowest green branch whorl (i.e. the lowest green branch whorl which is separated from the rest of the crown by less than two dry branch whorls) emerged. *Crown cover*, **cci**, is estimated as the percentage of the crown area (visible from below) covered by living phytomass.

Crown cover index was calculated by use of crown area, **cai,** and crown cover, **cci** for all trees i = 1,...,n covering inside a 25 m^2 (5x5 m) plot around each 1-m^2 plot (the 1-m^2 plot placed in the centre of the 25 m^2 plot):

$$CC = \sum_i \mathbf{cai} \cdot \mathbf{cci} / 25$$

Litter index may is calculated by modifying the index of Økland (1990, 1996) and Økland & Eilertsen (1993):

For each tree, the part of the crown area which is inside the 1-m^2 plot, **ca**, is measured and a line is drawn on the sketch map from the stem centre through the centre of the plot.

Four different cases were distinguished, the first three relating to trees with the stem centre within the crown perimeter, the fourth addressing eccentric trees.
(i) The line has one point of intersection with the sample plot margin within the crown perimeter (it intersects the crown perimeter once within the plot). This is the most usual case.

A distance **di** measured along the line from its point of intersection with the crown perimeter to the sample plot border (within the crown perimeter), *crown radius,* **cri** measured along the line as the distance from the stem centre to the line's intersection with the crown perimeter, the fraction of the crown area that is inside the 1-m^2 plot, **cai**; *crown cover*, **cci**; crown height, chi; tree height, **hi,** were used to calculate the litter index.

The contribution of a tree i to the litter index is:

LitterIi = (di / cri) × cci × cai × (hi - chi)

The litter index for each 1-m^2 plot was calculated as:

LitterI = ∑i (di / cri) × cci × cai × (hi - chi)

(ii) The line intersects the sample plot twice within the sample plot before intersecting with the crown perimeter (this may be the case for plots situated below large trees). A distance **di** measured along the line from its point of intersection with the crown perimeter to the proximal sample plot border (the border closest to the stem centre), crown radius**, cri** measured along the line as the distance from the stem centre to the line's intersection with the crown perimeter, the fraction of the crown area that is inside the 1-m^2 plot**, cai;** *crown cover*, **cci**; crown height, **chi,** and tree height, **hi** were used to calculate the index.

The contribution of a tree i to the litter index is:

LitterIi = (di / cri) × cci × cai × (hi - chi)

The litter index for each 1-m^2 plot was calculated as:

LitterI = ∑i (di / cri) × cci × cai × (hi - chi)

(iii) The tree crown covers a minor part of the plot only, and the line intersects the sample plot margin outside its point of intersection with the crown perimeter. The contribution to the litter index is by definition set to zero; **LitterI = 0**

(iiii) Eccentric trees (rooted outside the crown perimeter). The contribution of eccentric trees is calculated as:

LitterIi = cci × cai × (hi - chi)

The litter index for each 1-m^2 plot was calculated as:

LitterI = ∑i cci × cai × (hi - chi)

Basal area (relascope sum) is an expression of tree density on a relatively broad scale around each measurement point, i.e. the complement of light supply to the understory. Basal area was measured at breast height by use of a relascope from the corner of each 1-m^2 sample plot. We calculate:

(1) The relascope sum for coniferous trees
(2) The relascope sum for deciduous trees
(3) The sum of (1) and (2)

(3) Soil physical variables include:

- *Soil depth*; calculated by measurement of the distance a steel rod can be driven into the soil in fixed positions, 10-15 cm outside the plot border, eight single measurements are made for each plot. Minimum, maximum, and median values were calculated for each plot.

- *Depth of organic layer*; measured at four fixed points for each plot. Minimum, maximum, and median values were calculated.

- *Depth of litter layer* was measured in five fixed points within each 1-m^2 plots. Minimum, maximum, and median values were calculated.

- *Estimations of % cover of litter*.

- *Loss on ignition* (gravimetric loss after combustion, determined by ashing ca.1 g of sample at 550 °C in a muffle furnace; for details, see method description for soil analyses Chapter 5).

- *Soil moisture* was determined for volumetric soil samples, collected from the upper 5 cm of the humus layer. The samples were collected about 10 cm from the border of each meso plot, whenever possible below the plot. All samples from one reference area were collected on the same day, preferably after a period of some days without rainfall, with the aim of representing median soil moisture conditions, i.e. the normal soil moisture at the site (cf. Økland 1990, Økland & Eilertsen 1993). The samples were stored in paper bags kept inside double plastic bags and kept frozen until they were weighed in the laboratory. After drying at 110 °C to constant weight, the samples were weighed again and percentage moisture was calculated.

(4) Soil chemical variables include:

- *pH measured* in aqueous *solution*,
- *pH measured in* $CaCl_2$

- the content of *loss on ignition, organic C, total N* and *P-AL* and *exchangeable acidity* concentrations and the cations *Ca*, *Mg*, *K*, *Na*, *Al*, *Fe*, *Mn*, and *Zn, among others.* For detailed method descriptions; see Chapter 5.

(5) Animal impact variables include:

Some of the factors could be measured directly in the 1-m^2 plot, e.g. grazing intensity and % cover animal manure/dung. Other factors must be found by interviews of locals, e.g. *date/period of scything/hay-making* for the area and/or macro plot and *grazing period* (time period for grazing by horses, cows, goats, and sheep). Parameters measured directly in field descriptions/estimation values for:

a. Domestic animal grazing condition
b. Grazing intensity
c. Average grass height
d. Average herb height
e. % cover animal manure/dung
f. % cover animal traces/footprints
g. % cover animal tracks
h. % browsing damage on woody plants for each species
i. % cover of wild animal holes

Short descriptions of the *domestic animal grazing condition* and *scything/hay-making condition* and *wild animal grazing conditions* (grazing/browsing/digging) were given for each 1-m^2 plot.

Grazing intensity: Estimations were made for each 1-m^2 plot on a subjective scale with 4 levels: 0 = no grazing indications; no indications of grazing on the vegetation were seen. 1 = some grazing (patchily grazing); spots that were highly grazed and other spots that were not grazed could be seen. 2 = even grazing; even/plane grazing had removed much of the grass and herbs in the plot. 3 = extreme grazing (< 5 cm vegetation height); most of the grass- and herb-layer had been grazed and the field layer was very low, often below 5 cm.

Average grass height: The average height of the grass-cover in cm was measured for each 1-m^2 plot with a measuring rule.

Average herb height: The average height of the herb-cover in cm was measured with a measuring rule.

% cover animal manure/dung: The percentage cover of domestic animal dung/manure in the plot was estimated.

% cover animal traces/footprints: The percentage cover of domestic animal footprints in the plot was estimated.

% cover animal tracks: The percentage cover of domestic animal tracks in the plot was estimated.

Browsing damage on woody plants: A short description of the domestic browsing on each of the woody plants that were browsed upon by domestic animals was given: Species; name of the woody plant, s*tem%;* how much of the stem in % that are browsed, shoots*;* how many of the shoots that approximately have been browsed.
% cover of wild animal holes: Estimations of the percentage cover of traces and digging holes made by wild animals were performed for each 1-m^2 plot.

3.1.4 ORDINATION METHODS

Species abundances with a frequency lower than the median frequency (in the set of all species) were down-weighted by multiplying for each species the recorded abundances with the ratio of this species' frequency and the median frequency (Eilertsen et al. 1990) before ordination analyses.

Ordination methods are used to summarize the main gradients in the vegetation of the sample plots. DCA (Detrended Correspondence Analysis; Hill 1979, Hill & Gauch 1980), one of the most common used multivariate statistical methods, was performed on subplot frequency data on 50 plots by means of CANOCO Version 4.54 (ter Braak & Šmilauer 1998), which are debugged according to Oksanen & Minchin (1997). Standard options were used (i.e. no down-weighting of species, nonlinear rescaling of axes and detrending by segments).

3.1.5 INTERPRETATION OF GROUND VEGETATION GRADIENTS

Ordination axes express vegetation gradients. In order to elucidate the complex relationships between species composition and environmental conditions, these gradients were interpreted by means of the measured environmental variables. The interpretation of DCA ordination was performed by calculating Kendall's rank correlation coefficient τ between plot scores along DCA axes and environmental variables.

3.2 Results

3.2.1 GROUND VEGETATION BIODIVERSITY

The number of species, α-diversity, is reported in this chapter, while β-diversity (variation in species composition along gradients) will be reported in chapter 3.2.2. The total species list for the 50 1-m^2 plots is given in chapter 3.4.. The number of species within the plots was calculated as: (a) the sum of species recorded within the five 1-m^2 plots in each 10x10 m macro plot, (b) the total number of species recorded in each 10x10 m extended macro plot included the species in the 1-m^2 plots, and (c) the total number of species in each 30x30 m extended macro plot included the species recorded in the 1-m^2 plots (c), Tab. 3.1. The ratio a/b and a/c was calculated for each macro plot.

All together 118 species was recorded in the 50 1-m^2 plots. Of these, 9 species were endemic to Central Asia: *Antonina debilis*, *Astragalus aphanassjievii*, *Astragalus dendroides*, *Aquilegia* *vicaria*, *Galium pamiroalaicum*, *Oxytropis tachtensis*, *Valerianella turkestanica*, *Viola turkestanica* and *Zizifora pamiroalaica*.

The maximum number of species recorded in any 1-m^2 plot was 28, while the minimum number was 5.. The average number of species recorded in the 1-m^2 plots was16.4. The total number of vascular plant species recorded within the 50 1-m^2 plots + ten 10x10m^2 plots was 114. The total number of species in the in the 50 1-m^2 plots + ten 30x30m^2 plots was 117. The maximum number of species recorded in any of the 10x10 m macro plots (the five 1-m^2 plots included) was 38 and the minimum number was 25. The average number of species in the 10x10 m macro plots (the five 1-m^2 plots included) was 31.2. The ratio a/b varied between 0.88 and 0.97 (Tab. 3.1). The ratio a/c varied between 0.76 and 0.91 in the macro plots. The plant species were divided into species groups, tree species and bushes, ericoid species, herbs, ferns, graminoids, bryophytes and lichens (Tab. 3.2).

Tab. 3.1. Total number of vascular plant species in five 1-m^2 plots (a), five 1-m^2 plots + 10x10 m macro plot (b), five 1-m^2 plots + 10x10 m macro plot + 30x30 m extended macro plot (c), and ratios a/b and a/c.

Plot number	a Five 1-m^2 plots	b Five 1-m^2 plots + 10x10 m plot	c Five 1-m^2 plots + 10x10 m plot + 30x30 m plot	The ratio a/b	The ratio a/c
1	29	31	36	0.94	0.81
2	26	29	33	0.90	0.79
3	34	38	45	0.89	0.76
4	30	31	33	0.97	0.91
5	28	30	35	0.93	0.80
6	34	38	41	0.89	0.83
7	29	32	35	0.91	0.83
8	22	25	27	0.88	0.81
9	32	33	38	0.97	0.84
10	23	25	27	0.92	0.85
Total number	**109**	**114**	**117**	**0.94**	**0.91**

Tab. 3.2. Number of species in the field layer in different species groups within each 10x10 m macro plot and in total (tree species in the field layer).

Plot number	Tree species	Shrubs	Herbs	Ferns	Graminoids	Bryophytes	Lichens
1	0	2	22	1	4	7	1
2	0	3	19	1	3	6	0
3	0	2	29	0	3	4	0
4	0	1	24	0	4	3	0
5	0	3	20	1	4	7	2
6	0	3	24	1	5	5	2
7	0	4	17	1	6	7	2
8	0	1	17	0	4	3	0
9	0	2	22	0	8	6	0
10	0	3	14	0	5	2	0
Total number	**0**	**10**	**85**	**1**	**102**	**10**	**2**

3.2.2 MAIN GROUND VEGETATION GRADIENTS

DCA ordination of 50 plots is shown in Figs. 3.1 – 3.3. Gradient lengths; β-diversity, and eigenvalues for DCA 1-4 are given in Tab. 3.3.

TAB. 3.3. Eigenvalues and gradient lengths for DCA of 50 plots.

	DCA 1	DCA 2	DCA 3	DCA 4
Eigenvalues	0.471	0.299	0.189	0.122
Gradient lengths	2.917	3.417	1.969	1.629

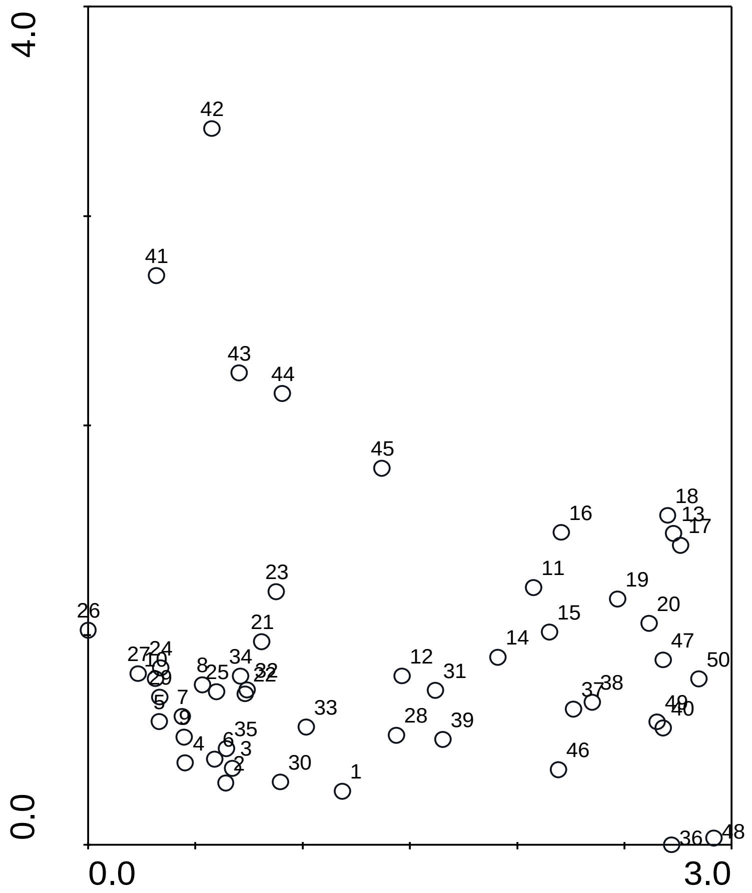

Fig. 3.2. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 2 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

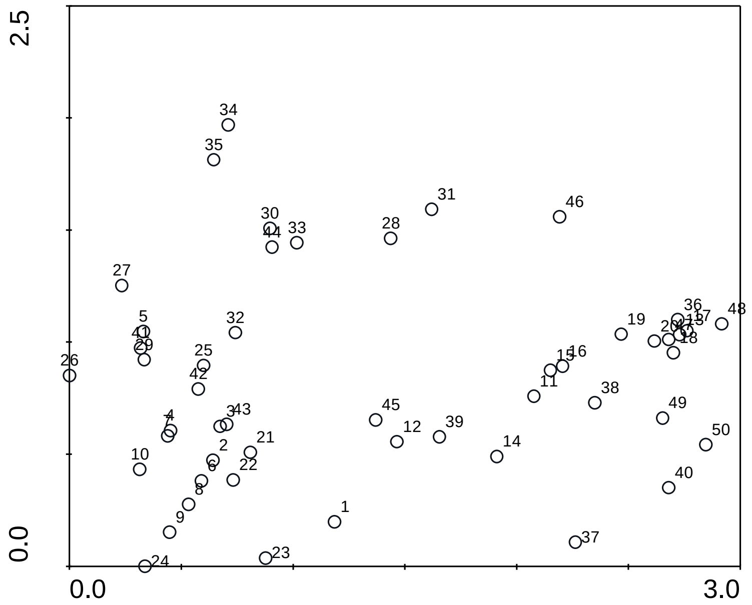

Fig. 3.3. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 3 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

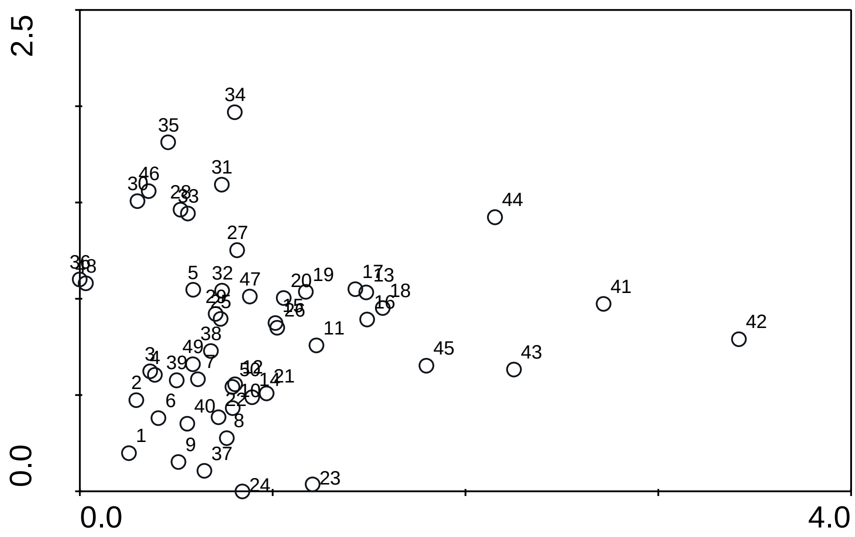

Fig. 3.4. DCA ordination of 50 1-m^2 plots, axes 2 (horizontal) and 3 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

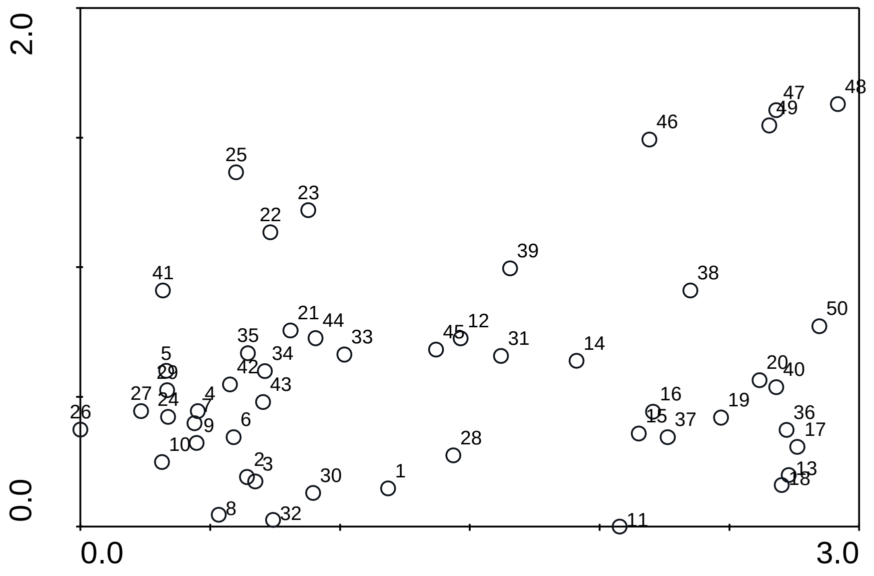

Fig. 3.5. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 4 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

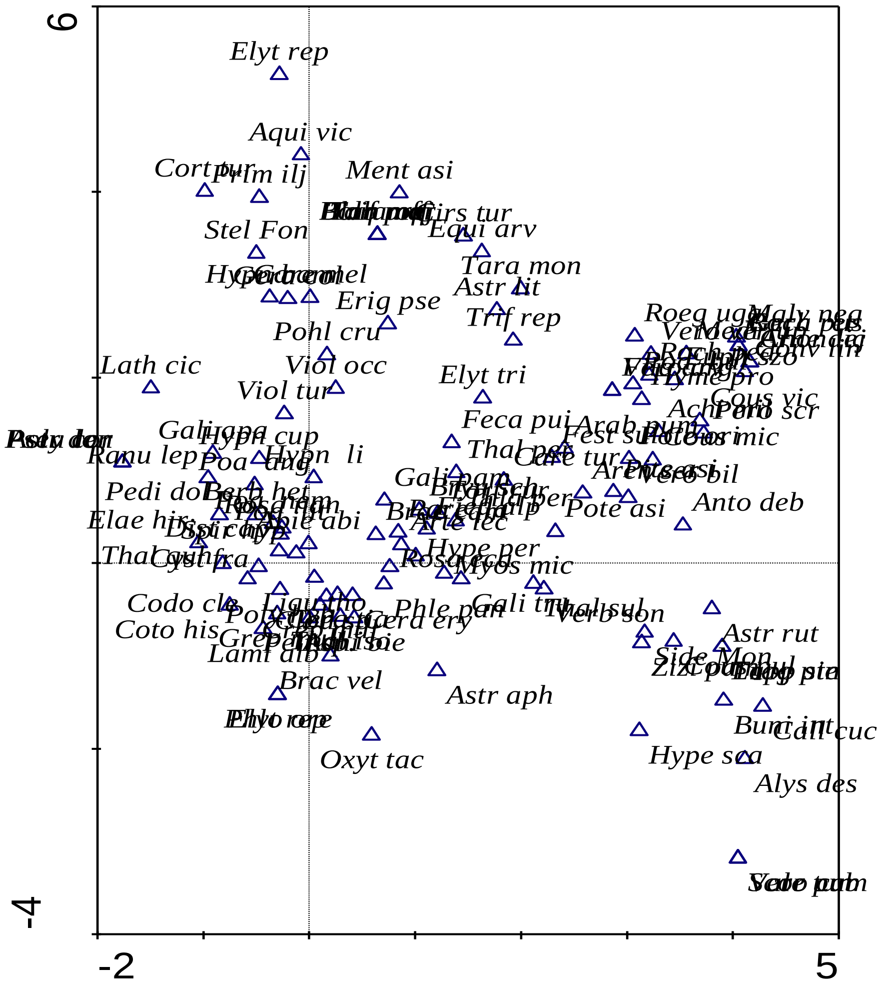

Fig. 3.6. DCA ordination of species in the 50 1-m^2 plots.

3.2.3 CORRELATION ANALYSIS BETWEEN EXPLANATORY VARIABLES AND DCA ORDINATION AXES

Kendall´s non-parametric correlation coefficient between DCA-axes and between DCA-axes and explanatory variables is shown in Tab. 3.4.

Tab.3.4. Kendall´s non-parametric correlation coefficient between DCA-axes and explanatory variables with P-values

	DCA 1	**P**	**DCA 2**	**P**	**DCA 3**	**P**	**DCA 4**	**P**
DCA 1	1.000	.	0.007	0.940	0.133	0.173	0.104	0.288
DCA 2	0.007	0.940	1.000	.	0.016	0.874	0.035	0.719
DCA 3	0.133	0.173	0.016	0.874	1.000	.	0.079	0.417
DCA 4	0.104	0.288	0.035	0.719	0.079	0.417	1.000	.
Soil moisture	-0.067	0.493	0.087	0.375	0.038	0.700	-0.162	0.098
Inclination	**-0.281****	**0.005**	**-0.391****	**0.000**	-0.047	0.642	-0.025	0.806
Aspect	0.016	0.874	-0.194*	0.049	-0.240*	0.015	-0.156	0.113
Aspect favourability	**0.429****	**0.000**	0.037	0.706	-0.021	0.834	0.097	0.327
Heat index	0.461**	0.000	0.104	0.288	-0.060	0.541	0.152	0.122
Max. inclination	**-0.276****	**0.006**	-0.356**	0.000	-0.039	0.699	0.054	0.590
Sum conc 1x1 m	0.087	0.383	-0.102	0.306	-0.077	0.440	-0.180	0.070
Var. conc 1x1 m	**-0.314****	**0.001**	-0.204*	0.037	-0.086	0.380	-0.002	0.980
Abs.sum conc.1x1m	**-0.344****	**0.001**	-0.131	0.188	-0.031	0.756	-0.016	0.873
Sum conc 3x3 m	0.143	0.153	-0.173	0.084	-0.035	0.724	0.099	0.322
Var conc 3x3 m	-0.231*	0.019	-0.183	0.064	0.137	0.167	0.022	0.821
Abs. sum conc 3x3 m	-0.152	0.134	-0.092	0.363	0.153	0.130	0.056	0.578
Rel. decid. trees	-0.147	0.191	0.046	0.686	-0.041	0.714	-0.188	0.096
Rel. conif. trees	**-0.299****	**0.003**	-0.101	0.319	-0.088	0.389	0.086	0.399
Rel. total	**-0.294****	**0.004**	-0.072	0.478	-0.089	0.379	0.057	0.577
Crown cover index	**-0.259****	**0.009**	-0.112	0.255	-0.229*	0.020	0.013	0.893
Litter index	-0.263*	0.013	-0.064	0.547	-0.245*	0.020	0.079	0.454
Average grass height	-0.254*	0.015	-0.128	0.224	-0.044	0.673	-0.204	0.052
Average shrub height	-0.263*	0.014	-0.052	0.627	0.146	0.172	-0.185	0.084
% cover animal dung	-0.285*	0.011	0.088	0.433	-0.164	0.142	0.063	0.571
% cover animal footprints	0.069	0.506	0.067	0.517	**-0.324****	**0.002**	-0.077	0.453
% cover animal tracks	-0.142	0.215	-0.162	0.160	0.206	0.072	-0.008	0.944
Max. soil depth	**-0.307****	**0.002**	-0.160	0.105	-0.175	0.077	0.024	0.808
Min. soil depth	-0.154	0.133	**-0.281****	**0.006**	-0.020	0.844	0.087	0.395
Med. soil depth	**-0.365****	**0.000**	-0.162	0.098	-0.159	0.105	0.011	0.907
Max. organic layer depth	**-0.335****	**0.001**	-0.194	0.055	**-0.328****	**0.001**	-0.103	0.307
Min organic layer depth	-0.170	0.114	-0.146	0.175	**-0.347****	**0.001**	0.007	0.948
Med. organic layer depth	**-0.354****	**0.000**	-0.210*	0.037	**-0.346****	**0.001**	-0.113	0.263
Max. litter depth	**-0.414****	**0.000**	-0.169	0.098	-0.138	0.177	0.022	0.826
Min. litter depth	-0.095	0.384	-0.072	0.512	-0.117	0.287	-0.010	0.930
Med. litter depth	**-0.342****	**0.001**	-0.128	0.213	-0.149	0.147	0.050	0.629
Altitude	0.055	0.584	-0.040	0.693	**0.289****	**0.004**	**0.336****	**0.001**
pH	0.109	0.266	-0.232*	0.018	-0.137	0.162	0.153	0.118
H+	-0.109	0.266	0.232*	0.018	0.137	0.162	-0.153	0.118
LOI	-0.227*	0.020	-0.202*	0.039	0.079	0.417	-0.089	0.362
Ctot	-0.158	0.106	**0.375****	0.000	0.082	0.398	-0.104	0.288
Ca	-0.140	0.153	-0.022	0.821	-0.060	0.541	**-0.337****	**0.001**
Mg	**-0.259****	**0.008**	**0.290****	**0.003**	0.017	0.861	-0.218*	0.026
K	-0.026	0.789	0.176	0.071	-0.150	0.124	**-0.307****	**0.002**
CEC	-0.002	0.980	-0.241*	0.014	0.231*	0.018	0.211*	0.030
Total N	-0.071	0.467	0.104	0.288	0.153	0.118	-0.117	0.232
PO4	0.042	0.669	0.180	0.067	0.121	0.219	-0.052	0.598
SO4, mkg/g	0.151	0.129	0.076	0.448	-0.050	0.613	0.020	0.840

Tab.3.4. continues. Kendall´s non-parametric correlation coefficient τ between DCA-axes and explanatory variables with P-values.								
	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
Ca, ppm	0.016	0.874	0.135	0.167	0.004	0.967	0.086	0.379
Mg, ppm	-0.066	0.498	-0.115	0.238	0.047	0.634	-0.244*	0.012
Na, ppm	0.025	0.795	-0.070	0.477	-0.045	0.645	-0.163	0.096
K, ppm	-0.110	0.259	**-0.254****	**0.009**	-0.115	0.238	-0.177	0.069
Al, ppm	-0.048	0.622	**-0.290****	**0.003**	0.078	0.427	-0.193*	0.047
Fe, ppm	**0.422****	**0.000**	-0.118	0.235	0.120	0.228	0.107	0.284
Mn, ppm	0.104	0.288	0.029	0.770	-0.055	0.575	-0.051	0.598
P, ppm	-0.032	0.744	0.105	0.281	-0.144	0.139	-0.242*	0.013
Zn, ppm	**0.424****	**0.000**	-0.011	0.913	0.076	0.437	0.099	0.311
Ca/LOI*100	-0.025	0.795	0.092	0.345	-0.174	0.075	**-0.291****	**0.003**
Mg/LOI*100	-0.074	0.447	**0.373****	**0.000**	-0.096	0.328	-0.151	0.122
K/LOI*100	0.073	0.457	0.226*	0.021	-0.154	0.114	-0.213*	0.029
CEC/LOI*100	0.060	0.541	-0.091	0.353	0.081	0.408	**0.254****	**0.009**
Total N/LOI*100	0.113	0.245	**0.254****	**0.009**	-0.038	0.694	-0.025	0.795
PO4/LOI*100	0.125	0.201	0.246*	0.012	0.022	0.821	-0.014	0.887
SO4, mkg/g/LOI*100	0.187	0.055	0.128	0.189	-0.092	0.345	0.087	0.371
Ca, ppm/LOI*100	0.159	0.103	0.208*	0.033	-0.091	0.353	0.112	0.252
Mg, ppm/LOI*100	0.151	0.122	0.167	0.086	-0.069	0.477	-0.069	0.477
Na, ppm/LOI*100	0.172	0.078	0.140	0.153	-0.113	0.245	-0.009	0.927
K, ppm/LOI*100	0.238*	0.015	0.012	0.900	-0.127	0.195	-0.002	0.980
Al, ppm/LOI*100	0.193*	0.047	-0.035	0.719	-0.076	0.437	-0.082	0.398
Fe, ppm/LOI*100	**0.332****	0.001	0.100	0.304	-0.035	0.719	0.105	0.281
Mn, ppm/LOI*100	0.218*	0.026	0.234*	0.016	-0.071	0.467	0.050	0.610
P, ppm/LOI*100	0.228*	0.020	0.100	0.304	-0.166	0.089	-0.019	0.847
Zn, ppm/LOI*100	**0.334****	0.001	0.154	0.114	-0.020	0.834	0.130	0.184

3.3 Discussion

3.3.1 GENERAL DESCRIPTION OF VEGETATION AND GROUND VEGETATION BIODIVERSITY

The main structuring species of the juniper forests at the Navabod monitoring site is *Juniperus seravschanica, J. semiglobosa* and *J. turkestanica.*

Species in the shrub layer includes *Astragalus dendroides, Berberis heterobotrys, Cotoneaster hissarucus, Rosa nanothamnus* and *Tragacantha pterocephala.*
The grass and herb layer is dominated by *Carex turkestanica* along with *Ligularia thompsonii* and *Arenaria serpyllifolia.* Other frequent species include *Aquilegia vicaria*, *Arabidopsis pumila*, *Arnebia dichroantha*, *Artemisia lechmanniana*, *Bolboschoenus maritimus*, *Chondrilla lejosperma*, *Codonopsis clematidea*, *Cerastium tianschanicum*, *Bunium intermedium* and *Cirsium turkestanicum*.

Among the herbaceous plants there are xeromorphic and thermophytic species, as well as many steppe species. Most of the vascular plants are herbs, and they constitute 85 out of the 118 species recorded in the 50 1-m^2 plots. The number of bryophyte species was 10.

3.3.2 INTERPRETATION OF GROUND VEGETATION GRADIENTS

The environmental variables most strongly (positively) correlated with DCA 1 were *aspect favourability* and *heat index*, indicating that variation topographical conditions like *aspect* and *inclination* partly explain the variation in species composition along the main vegetation gradient expressed along DCA 1. Most plots at southern/southwestern aspects had lower bryophyte cover than plots with a north/northeaster/northwestern aspect. Variables with a negatively correlated with DCA 1 include *micro-topography*, *soil depth*, *depth of organic layer* and *litter depth*, indicating that sites on northern/northeastern aspects also had deeper soil and organic layer, more litter and more variation in micro-topography. Some cations i.e. concentrations of zink (Zn) in soil, were also correlated with DCA 1. However, these correlations are based on less data, because the A horizon in soil was missing for 18 of the 50 plots due to soil erosion caused by overgrazing (see chapter 4). Variables expressing grazing intensity, such as *average grass height*, showed a negative, but weaker correlation with DCA 1.

Inclination and maximum inclination both showed strong negative correlations with DCA 2, implying that inclination was smaller for sample plots with high scores along DCA 2. The total amount of carbon (C) and magnesium (Mg) in soil, on the other hand, increased along DCA 2. Many of the plots located on more steep sites (i.e. low DCA 2 scores) had northern/northwestern/northeastern aspects (i.e. low DCA1 scores).

Several variables were significantly correlated with DCA 3; including depth of the organic soil layer. However, two of these three organic soil variables were more strongly correlated with DCA 1. The *% cover of animal traces/footprints* was significantly correlated only with DCA 3.

Variation in species composition due to variation in *altitude* was expressed along borth DCA 3 and DCA 4 (both positive correlations).

Cation concentration, as well as other nutrient variables were to some degree correlated with all DCA axes. However, the A horizon of soil was only present in 32 of the 50 plots. A more pronounced gradient in nutrient conditions could possibly be identified if the A horizon was present for all plots.

The variation in species composition of the ground vegetation in the Navobod monitoring site is thus mainly due to differences in aspect, inclination, soil depth, litter depth and depth of the organic layer, even though other environmental conditions also contribute to the main vegetation gradient. This interpretation is similar to the interpretation for the juniper forest in the Dugoba monitoring site in Batken Oblast in the Kyrgyz Republic.

3.4 Appendix

Appendix 3.1. Scientific (Latin), Kyrgyz and Russian names of plant species.

Latin names of species:	Latin names of species:	Latin names of species:
Achilea millefolium	*Festuca sulcata*	*Rochelia pedicularis*
Achillea biebersteinii	*Fiedleria alpina*	*Rochelia retora*
Alyssum desertorum	*Filago arvensis*	*Roegneria ugamoca*
Antonina debilis	*Galium aparine*	*Rosa ecae*
Aquilegia vicaria	*Galium pamiroalaicum*	*Rosa nanothamnus*
Arabidopsis pumila	*Galium trucornutum*	*Scorzonera pubescens*
Arenaria serpyllifolia	*Geranium collinum*	*Sideritis Montana*
Arnebia dichroantha	*Geranium pusillum*	*Spiraea hypericolia*
Artemisia lechmanniana	*Grepis multicaulis*	*Stellaria Fontana*
Astragalus aphanassjievii	*Hymenolobus procumbens*	*Taraxacum monochlamydeum*
Astragalus dendroides	*Hypericum perforatum*	*Taraxacum officinale*
Astragalus litvinovianus	*Hypericum scabrum*	*Thalaspi perfoliatum*
Astragalus rutilobus	*Lamium album*	*Thalictrum isopyroides*
Berberis heterobotrys	*Lappula sinaica*	*Thalictrum quhistanicum*
Bolboschoenus maritimus	*Lathurus cicera*	*Thalictrum sultanabadense*
Bunium intermedium	*Ligullaria thomsonii*	*Thlaspi perfoliatum*
Callipeitis cucullaris	*Malva neglecta*	*Tragacantha pterocephala*
Carex melananta	*Medicago lupulina*	*Trifolium pretense*
Carex turkestanica	*Mentha asiatica*	*Trifolium repens*
Cerastium tianschanicum	*Myosotus micrantha*	*Valerianella turkestanica*
Cerasus erythrocarpa	*Oxytropis tachtensis*	*Verbascum songoricum*
Chondrilla lejosperma	*Parentucella flaviflora*	*Veronica arguteserrata*
Cirsium turkestanicum	*Pedicularis dolichorhiza*	*Veronica biloba*
Codonopsis clematidea	*Perovskia scrophulariifolia*	*Veronica campyllopoda*
Convolvulus lineatus	*Phleum paniculatum*	*Veronica verna*
Cortusa turkestanica	*Pitentilla asiatica*	*Viola occuta*
Cotoneaster hissarucus	*Phlomis oreophila*	*Viola turkestanica*
Cousinia microcarpa	*Plantago major*	*Zizifora pamiroalaika*
Cousinia pulchella	*Poa angustifolia*	*Abietinella abietina*
Cousinia vicrocarpa	*Poa bulbosa*	*Brachythecium campestre*
Crepis multicaulis	*Poa litvinoviana*	*Brachythecium velutinum*
Cystopteris fragilis	*Poa nemoralis*	*Bryum schleicheri*
Elaeosticta hirtula	*Polygala hybrida*	*Cladonia sp.*
Elytriga trichophora	*Polygonum coriarum*	*Distichium capillaceum*
Elytrigia repens	*Potentilla asiatica*	*Hypnum lindbergii*
Equisetum arvense	*Potentilla orientalis*	*Hypnum bambergeri*
Erigeron pseudoseravschanicus	*Primula iljinskii*	*Hypnum cupressiforme*
Euphorbia szovitsii	*Pseudosedum longidentatum*	*Peltigera sp.*
Fecasium puichellum	*Ranunculus leptorrhynchus*	*Pohlia cruda*
		Tortula ruralis

4 SOIL CLASSIFICATION AND SOIL DESCRIPTION

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4.1 Methods

The chemical composition of the soil layers is due to the biogeochemical cycling (Fig. 4.1). In the Kara-Koi area the following soil data are gathered:

- Soil profile development
- Chemical characteristics per soil horizon
- Soil texture
- Soil moisture content of the top soil.

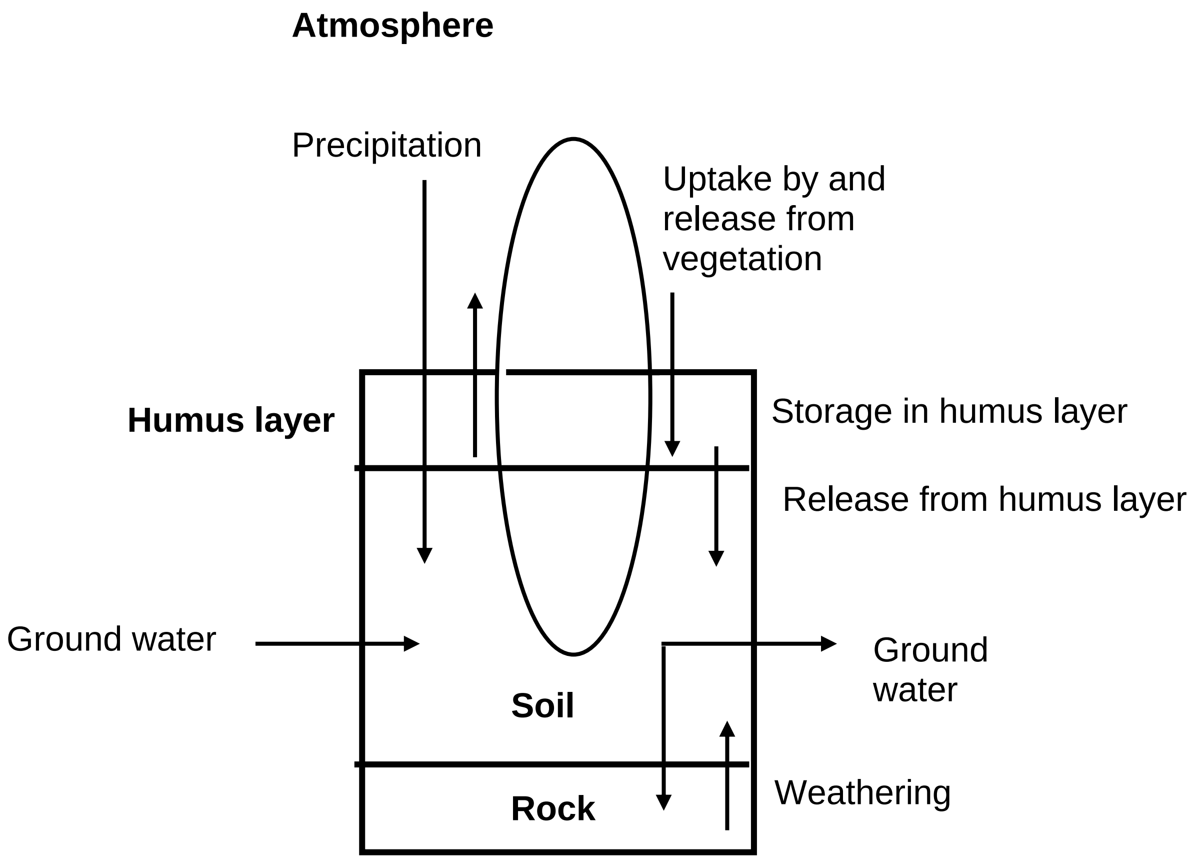

Fig. 4.1. Simplified model of biogeochemical cycling of elements.

The methodology for placing the macro plots and 1-m^2 vegetation plots is described in 3.1.1. During the 8th – 9th of June 2007 soil samples were collected from each micro plot. Field work was done under sunny circumstances. A few days earlier there were some thunderstorms. As it is important to get information from all the soil horizons for long term monitoring, the soil sampling was done per soil horizon. For each 1-m^2 plot the sampling horizon and the depth of sampling was recorded. Samples were taken (see chapter 5 for more details) from 3 sides outside each of the 1-m^2 plots. Soil samples were not collected at the slope above the 1-m^2 plots in order to avoid disturbances. Sampling was done with the help of an Edelman auger and the maximum reachable sampling depth was 1.20 m. In cases where the presence of free chalk was expected this was controlled with the aid of a solution of 1 M HCl. Per 1-m^2 plot one mixed soil sample was collected and put in a 0.5 litre sample box. After field work the boxes were stored at a cool and dry place.

Outside each macro plot a simplified soil profile description was made for the soil which should be considered as characteristic for the macro plot. Data on soil texture of each soil sample were not gathered. Soil texture data from the simplified texture descriptions can be used indicative.

4.2. Results

The origins of the soil parent material differed in the macro plots, and both shales and limestones were found. In the riverbed the soil was fluvic.

Signs of erosion were visible everywhere on the generally (very) steep slopes. It is likely that intensive grazing and trampling by domestic cattle trigger soil erosion in the area.

The altitude varied from 2055 – 2179 m, and the macro plots had southern, western and northern exposition. The forest was dominated by junipers, and the observed soil types included Leptosols, Umbrisols and Cambisols.

In the river bed (macro plot 3 and 4) the soils were made of a mixture of river deposits and colluvium/erosion material. Elsewhere the soils mainly had originated from weathered shales and consisted of loamy to clay soils. Except for macro plot 9, which contained a rocky limestone outcrop that reacted strongly with HCl, there was no reaction between soil and HCl.

Drainage was good and there were no signs of gleyic/stagnic properties. Soil moisture varied from 5 to 42% within and between the macro plots. Macro plots 8 and 10 were dry, whereas macro plot 9, with a little stream passing through, had the highest soil moisture, with seepage visible from the sides.

pH varied within and between macro plots, ranging from just below pH 7 to quite basic (pH 8,9). The macro plots with more weathered shales showed lower pH values (macro plots 5, 6 and 7). High pH values were found in macro plot 8 and 10.

A litter/humus layer was not present. The A horizon was eroded away many places, resulting in variable C total values. Macro plot 8 had the lowest C total value (1,3%), and macro plot 4 had the highest value (11,3%).

The values of heavy metals like arsenic (As) varied, with highest values in macro plots 1, 2, and 10. Cadmium (Cd) and mercuty (Hg) showed low to very low values. The values of Sb were very low, except for in macro plot 1 and 10. Strontium (Sr) and zink (Zn) both had variable values. While most Sr were found in macro plots 8 and 9, most Zn were found in 1, 4, 9 and 10.

4.3 Discussion

Due to the slightly more acid conditions (shales) in the watershed (macro plots 5, 6 and 7) this area will be more prone to acidification. However, due to the nutrient situation this will take quite a long time. The biggest challenge for the area will be the reduction of the erosion caused by overgrazing.

With changes in heavy metal content in the topsoil one should also look at the effects of biogeochemical cycling. As some of the soils originate from weathered parent material some surprises may show up (as shown by the soil chemical data).

Data on soil texture of each soil sample were not gathered, but soil texture data from the simplified texture descriptions can be used.

5 SOIL CHEMISTRY

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5.1 Methods

5.1.1 SAMPLING DESIGN

Soil samples were collected close to each of the 1-m^2 plots in order to produce soil data that are representative for the ground vegetation analysis. For details in sampling design, see chapter 3.1.1. The sampling design, restricted random sampling, also permits the use of statistics on the soil data.

Sampling spots were selected not to disturb leakage of water. The soil samples are therefore collected at a distance of 20-30 cm from the left, right and down-slope side of each 1-m^2 plot, i.e. not above any of the 1-m^2 plots. Apart from that, the spots were distributed evenly around the 1-m^2 plots, to make a representative sample. Soil was collected by genetic horizon, based on location and appearance. The soil from each soil horizon of the three spots at each 1-m^2 plot, were bulked into one composite sample of the soil horizon. It was attempted to collect equal amounts of soil from each spot, especially when the horizons were thick, i.e. in the B and C horizons. Two or more generic mineral soil horizons (usually A and B horizons) are sampled. The O horizon (mixing of the fermentation (F) and humic (H) horizons) were not sampled at all sites since the O horizon was lacking in several of the 1-m^2 plots. The actual classification of the horizons at which the soil was collected can only be done after sampling and analysis. Due to the lack of data, especially regarding particle size distribution, a proper classification is still not conducted. However, an examination of the organic content, gave a good indication that the soil was collected as intended and correctly classified. The horizon notations mentioned are therefore used.

The soil from the A horizon was sampled by hand and with a small plastic spade. For the collection of B horizon samples, an Edelmann auger was generally applied. There are several uncertainties connected with the soil sampling:

- It was sometimes difficult to separate the horizons due to similarities in colour or diffuse boundaries.
- Some places the A horizon was quite thin, which gives a high risk of contamination of the A horizon sample by soil from the O or B horizons.
- The use of the auger could produce mixing of horizons when they were thin.
- The bulking of the samples produces a risk of mixing of soil from different horizons due to spatial variation in soil profiles. This problem was attempted minimized by only bulking soil of equal colour.

Minimum and maximum soil horizon depths were noted, but the measurements were approximate as it was difficult to see down in the augered hole to determine where the borders between the different horizons were. Horizon colours were set subjectively using a Munsell colour chart.

5.1.2 SOIL CHEMISTRY PARAMETERS

The samples are to be analysed in duplicates (i.e. two parallels). In case of small sample size the parallels can be dropped and the parameters are to be prioritised in the listed order as given in Tab. 5.1.

Tab. 5.1. Description of chemical methods to be used for the soil analysis.

Parameters	Methods and comments	Reference
1. Dry matter	1. Gravimetric loss after drying at 105 °C	1. ISO11465
2. $pH_{H2O,KCl,CaCl2}$	2. pH in extracts of the soil	2. ISO10390
3. Total C	3. Manually or by HCN analyzer	3. ISO10694
4. Total N	4. Kjeldahl N	4. ISO11261
5. Effective exchangeable Ca,Mg,Na,K,Fe, Mn & Al and CEC	5. $BaCl_2$ at pH 8.1 extraction and the extractant analysed for Ca, Mg; Na, K, Fe, Mn and Al by FAAS. CEC found by replacing Ba with Mg and detecting loss of Mg	5. ISO13536
6. Loss on ignition (LOI)	6. Gravimetric loss after combustion	6. Krogstad 1992
7. Adsorbed PO_4	7. Extraction with H_2SO_4 and HCl or HCO_3^-; determination by CM	7. Olsen & Sommers 1982, Olsen 1953
8. Adsorbed SO_4	8. Extraction with PO_4. CM determination of SO_4	8. Tabatabai & Dick 1979
9. ICP-AES metal scan	9. Aqua regia sample digestion	9. Alex Stewart method
10. Adsorbed SO_4	10. HCl and water extracted SO_4 and the amount determined gravimetrically	10. ISO11048

Parameters 7 - 9 are only meant to be measured on mineral soil and not to be conducted on organic soils (i.e. LOI more than 20% w/w).

5.1.3 SOIL CHEMISTRY ANALYSES

Samples from Navobod were analyzed at Alex Steward Laboratories, Kara Balta, the Kyrgyz Republic.

5.1.3.1 Dry matter

The dry matter content (w_{dm}) or water content on a dry mass basis (w_{H2O}) is determined as described in ISO11465 using air-dried (20 ºC) soil passed through a 2.00 mm aperture sieve. Soil samples are dried using a Gallencamp Drying oven to constant mass at 105 ± 5º C for 12 hr. The difference in mass of an amount of soil before and after the drying procedure is used to calculate the dry matter and water contents on a mass basis. The factor w_{dm} and w_{H2O} are used in all the following methods (except: 8. Particle size distribution and 2. Soil pH) to correct for humidity in the air-dried sample.

5.1.3.2 Soil pH

A suspension of the air-dried soil passed through a 2.00 mm aperture sieve is made up in five times its volume of water. The pH of the suspension is measured using a pH meter (Mettler Toledo Seven Easy) as described in ISO10390.

5.1.3.3. Total and organic carbon (C)

Total C includes both inorganic and organic C. Inorganic C is principally found in carbonate minerals, whereas most organic C is present in the soil organic matter fraction.

The measurement of total C is conducted according to ISO10694 on air-dried soil passed through a 2.00 mm aperture sieve. This is conducted by a dry combustion technique on a LECO carbon analyzer (SC-225). The soil sample is oxidized to CO_2 at 940 ºC on CuO in a flow of oxygen-containing gas that is free from carbon dioxide; the released gases are scrubbed; and the CO_2 in the combustion gases is measured using an infrared (IR) detector.

Organic C is measured on 10% of the samples, making sure to include a broad span of LOI (see chapter. 5.1.3. 6) in the selected samples. The measurement of organic C is also conducted according to ISO10694. For the determination of organic carbon content, any carbonates present are previously removed by treating the soil with hydrochloric acid.

5.1.3.4 Total nitrogen (N)

Total N is determined as nitrogen of organic matters in the form of ammonia after digestion of organic matters by heating with sulphuric acid and mercury sulphate as catalist. Ammonium was determined using a Spectrophotometer Camspec.

5.1.3.5 Effective CEC

The potential CEC is determined as described in ISO 13536, determining also the sodium, potassium, calcium and magnesium in the barium chloride extracts of the soil. In strongly acid soils (i.e. pH_{H2O}< 5.5) also manganese, iron, boron and aluminium must be determined in the barium chloride extracts of the soil.

The CEC of the soil samples is determined in barium chloride solution buffered at pH = 8.1 using triethanolamine. The soil is first saturated with respect to barium by treating the soil three times with buffered barium chloride solution. Subsequently, a known excess of 0.02 M magnesium sulphate solution is added. All the barium present, in solution as well as absorbed, is precipitated in the form of highly insoluble barium sulphate and the sites with exchangeable ions are then readily occupied by magnesium. The excess magnesium is determined.

All elements were determined using an Atomic emission spectrometer with inductively coupled plasma ICP-AES Optima 5300DV.

5.1.3.6 Loss on ignition (LOI)

Procedure from Krogstad (1992):

Weigh a porcelain crucible using an analytical balance (m_1). Approx. 3 to 5 g air-dried soil passed through a 2.00 mm aperture sieve is weighted accurately using an analytical balance in the crucible (m_2) and glowed in a furnace at 550 ± 25 °C using a Carbolyte Muffle furnace for more than 3 hours. The crucible with dried soil must cool down for more than 30 minutes in an excicator before weighing (m_4).
Be aware that soils containing high amounts of organic matter easily get “blown away” when opening the excicator.

Calculations:

$$\%LOI = 100 - \frac{m_4 - m_1}{m_2} \cdot 100 - w_{H_2O}$$

Where m_1 = weight of crucible
m_2 = weight of air dried soil before heat-dried in chamber
m_4 = weight of crucible and soil after glowing
w_{H2O} = water content from (see chapter 5.1.3.1)

5.1.3.7 Available phosphate (P)

Principle:

The phosphate in acid and neutral soils (i.e. soil samples from 1-m^2 plots with an A-horizon having a pH_{H2O} < 7.5) is extracted using Mehlich's method and in alkaline soils (i.e. soil samples from 1-m^2 plots with an A-horizon having a pH_{H2O} > 7.5) using Olsen-P method.

The Mehlich's method uses a mixture of sulphuric and hydrochloric acid to de-sorb the phosphate according to the method described by Olsen & Sommers (1982). This method is effective in extracting Ca-P, Fe-P and Al-P in acid and neutral soils.

In the high pH soils (>7.5) the acid extractants become less effective. These soils contain free calcium carbonate which neutralizes the acid and prevents the extraction of P into solution. Instead, the Olsen's extractant (Olsen 1953) uses a buffered 0.5 M sodium bicarbonate solution ($NaHCO_3$ at pH 8.5) which is alkaline and designed for use on calcareous soils. This extractant suppresses Ca^{2+} by both the high HCO_3^- concentration and high pH, allowing phosphates to dissolve out of calcium phosphate minerals (by the common ion principle). This extractant is therefore excellent at extracting calcium-P, the dominant form of P in calcareous soils.

Reagents:

1. Extracting solution, Mehlich's :

Add 12 mL of conc. sulphuric acid (H_2SO_4) and 73 mL of conc. hydrochloric acid (HCl) to 15 litres of ion exchanged water. Dilute the solution to 18 litres with Milli-Q or double distilled ion exchanged water. This extracting solution is approximately 0.05N HCl and 0.025N H_2SO_4.

Extracting solution, Olsen's :

Dissolve 84.008 g dry $NaHCO_3$ with approx. 1.8 L of Milli-Q or double distilled ion exchanged water. Titrate the solution with NaOH to pH 8.5. Dilute the solution to 2 L in a volumetric flask. This extracting solution is approximately 0.5 M $NaHCO_3$.

2. Molybdate-vanadate solution:

Dissolve 25 g of ammonium paramolybdate [$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$] in 500 mL of Milli-Q or double distilled ion exchanged water. Dissolve 1.25 g of ammonium vanadate (NH_4VO_3) in 500 mL of 1 N nitric acid (HNO_3). Mix equal volumes of these solutions. Prepare a fresh mixture each week.

3. Standard phosphate solution:

Dissolve 0.1098 g of potassium dihydrogen phosphate (KH_2P0_4) in 500 mL of extracting solution, and dilute the solution to 1L with the extracting solution. This solution contains 25 ppm of P.

Procedure:

Mehlich's

Add accurately approximately 5 g of air-dried soil passed through a 2.00 mm aperture sieve and about 200 mg of PA charcoal to a 50 mL flask or bottle, and then add 20.0 mL of the extracting solution. Shake the flask for 5 min in a mechanical shaker, and filter the mixture through Whatman No. 42 filter paper.

Olsen's

Add approximately 5 g of air-dried soil passed through a 2.00 mm aperture sieve and about a teaspoon of PA charcoal (carbon black) to a 200 mL flask or bottle, and then add 100.0 mL of the extracting solution. Shake the flask for 30 min in a mechanical shaker, and filter the mixture through Whatman No. 42 filter paper.

Detection:

Measure 4.00 mL of the extract into a glass vial, and add 1.00 mL of Milli-Q or double distilled ion exchanged water. Add 1.00 mL of reagent 2, and allow the tube to stand 20 min.

Prepare a standard curve from aliquots of reagent 3 in the range of 0.5 to 4 mL. Follow the same procedure described for the soil extract. Concentrations of P in the extract equal to 1 and 4 mL of reagent 3 give 25 and 100 ppm of P in the soil, respectively. Dilute the extracts ten times if the sample absorbency falls outside the standard range. Use acid washed glassware.

Use 420 nm incident light in the photoelectric colorimeter if no interference from interfering colour (e.g. from humic material). In case of organic material present in the extracts it is possible to clean the extracts by use of active coal, but the best is to measure the absorbency of the complex at 700 nm as the yellow colour of the humic material does not absorb radiation at this wavelength. Adjust the galvanometer to 100% transmission using a tube containing all the reagents except P.

Calculation:

$$\text{mmol "Adsorbed" } PO_4^{3-} \text{ kg}^{-1} = \frac{(a-b)\cdot D\cdot V}{W\cdot \frac{w_{dm}}{100}}$$

where:

a	= concentration of PO_4^{3-} in diluted sample extract (mmol L^{-1})
b	= concentration of PO_4^{3-} in diluted blank (mmol L^{-1})
D	= dilution factor
V	= volume of extractant reagent used (20.0 or 100.0 mL)
W	= air-dry sample weight (mg)
w_{dm}	= moisture correction factor (see section 1)

5.1.3.8 Inorganic Sulphate adsorption

Principle:

The adsorbed and dissolved sulphate is extracted using 100 ppm of P (as $Ca(H_2PO_4)_2$) electrolyte according to Tabatabai & Dick (1979). The dissolved sulphate is extracted using 0.15% $CaCl_2$ described by Tabatabai (1982) Adsorbed sulphate is found by the difference between sulphate concentration in these two extracts.

Reagents:

Calcium phosphate monohydrate solution [$Ca(H_2PO_4)_2 \cdot H_2O$], 100 ppm of P:
Dissolve 0.41 g $Ca(H_2PO_4)_2 \cdot H_2O$ in about 700 mL ion exchanged water, and make to volume of 1.000L with ion exchanged water.

Calcium chloride dihydrate ($CaCl_2 \cdot 2H_2O$), 0.15%:
Dissolve 1.5 g of $CaCl_2 \cdot 2H_2O$ in about 700 mL ion exchanged water, and make to volume of 1.000 L with ion exchanged water.

Procedure:

Extract the adsorbed and soluble inorganic sulphate from the air-dried soil passed through a 2.00 mm aperture sieve by shaking 5 g of soil (< 2 mm) with 50.00 mL of 100 ppm P, and the soluble inorganic sulphate by shaking 5 g of air-dried soil (< 2mm) with 50.00 mL of 0.15% $CaCl_2$. Shake the $CaCl_2$-extracts for 30 min and the $Ca(H_2PO_4)_2$-extracts for 1 h. Filter the extracts through a Whatman no. 42 filter paper.

The sulphate in the extracts is determined using ion chromatography for major anions.

Detection:

When using IC to determine the sulphate concentration in the extracts the high concentration of organic matter and phosphate in the sample matrix will cause difficulties. Parts of the organic matter will adsorb to the analytical column and reduce its efficiency. This is avoided by pumping the sample to be run on the IC through a OnGuard cartridge that removes this organic matter. In order to separate the phosphate and sulphate peaks a more dilute (e.g. 75%) mobile phase has been found preferable.

Calculation:

$$\text{mmol "Adsorbed and soluble" } SO_4^{2-} \text{ kg}^{-1} = \frac{(a-b)\cdot D\cdot V}{W\cdot \frac{w_{dm}}{100}}$$

$$\text{mmol "Soluble" } SO_4^{2-} \text{ kg}^{-1} = \frac{(x-y)\cdot D\cdot V}{W\cdot \frac{w_{dm}}{100}}$$

$$\text{Adsorbed } SO_4^{2-} = \text{"Adsorbed and soluble" - "Soluble"}$$

where:
a = concentration of SO_4^{2-} in diluted sample calcium phosphate extract (mmol L^{-1})
b = concentration of SO_4^{2-} in diluted calcium phosphate blank (mmol L^{-1})
x = concentration of SO_4^{2-} in diluted sample calcium chloride extract (mmol L^{-1})
y = concentration of SO_4^{2-} in diluted calcium chloride blank (mmol L^{-1})
D = dilution factor
V = volume of extractant reagent used (50.0 mL)
W = air-dry sample weight (g)
w_{dm} = moisture correction factor (see section 1)

5.1.3.9. ICP-AES metal scan

The sample is dissolved in aqua regia and the solution is determined for Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, La, Mg, Mn, Mo, Na, Ni, Pb, Sb, Sc, Sr, Ti, Se, V, Y, Zn and Zr on the Atomic emission spectrometer with inductively coupled plasma ICP-AES Optima 5300DV according to the standard method used at Alex Stewart laboratories. Detection limit for Hg using ICP-AES (0.5 ppm) is similar to the maximum permitted limit in rural areas. In samples exceeding this limit (i.e. showing a significant concentration in the ICP scan) an expanded Hg analysis, using cold vapour adsorption, should be conducted.

5.1.3.10 Extractable sulphate

The water-soluble and acid-soluble sulphate is determined as described in ISO11048. The samples are extracted with dilute hydrochloric acid and water and the sulphate content in the extracts is determined by gravimetric method in which barium chloride is added to the extracts and the precipitate of barium sulphate is dried and weighted.

5.2 Results

Average soil chemical data for each horizon are presented in Table 5.2. Circum neutral pH conditions prevailed in the plots, though this site had the highest average pH values of the TEMP sites. As commonly found, the pH increased with depth, though at this site there was no clear decrease in organic content with depth, based on Loss on Ignition (LOI). There were relatively few significant correlations (r > 0.7) between the measured soil constituents. Furthermore, no significant correlation was found between LOI and the Carbon content (% C_{tot}), despite a low content of calcareous minerals (see below). There was no strong correlations (i.e. r > 0.7) between %C_{tot}, adsorbed phosphate (Ads. PO_4^{3-}), adsorbed sulphate (Ads. SO_4^{2-}), total nitrogen (N), and base cations. As commonly found, %C_{tot} showed a poor negative correlation to the acid cations Al (r = -0.354) and Fe (=-0.591), and to a few trace elements (e.g. Ni; -0,720). The values of Adsorbed PO_4^{3-} (Table 5.2) were negatively correlated to average soil

pH_{H2O} (r = -0.505). Adsorbed sulphate (Ads. SO_4^{2-}) were below the detection limit (0.01 g/kg) in 10 A horizon and 12 B horizon samples.

Table 5.2. Average and quartiles of soil chemical characteristics. LOI denote Loss on Ignition.

Horizon	Samples	pH_{H2O}	LOI	C total	Total N	Ads. PO_4^{3-}	Ads. SO_4^{2-}
	#		w/w %		µg/g		
A	32	7,18	11,2	6,5	4081	66,6	58,7
		7,1 – 7,7	7 - 14	5 -7	3130 - 5290	11 - 85	0 -94
B	81	7,42	11,7	3,3	2293	48,8	77,2
		7,3 – 8,4	7 - 15	2 - 4	1715 - 2750	5 - 14	9 -92

In addition to SiO_2 (not measured) the main (avg. value > 3.5 mg/g) oxide composition of the mineral soils (Figure 5.1) was made up by iron (Fe), followed by aluminium (Al), calsium (Ca) and magnesium (Mg). The base cations (Ca, Mg, Na, K) constituted only 29 and 31% of the oxide composition in the A and B horizons. The values were somewhat misleading as samples with an elemental content greater than a maximum analytical value, e.g. 50 mg/g for Fe and Ca, were set to this analytical maximum value. This was the case for 20 Fe samples that accounted for 38% of the Fe data in the B horizon. Probably this average value was lowered further due to the greater number of samples with Fe content out of range than for Ca. Nevertheless, the data indicated that the soil mineral base cation content in the A horizons in Navobod was the lowest among the studied sites. To some extent the B horizon follows the same trend, except that Ca was slightly more abundant than Al. The Fe showed the greatest variation in abundance among the oxide elements, with highest values (about 50%) for both horizons.

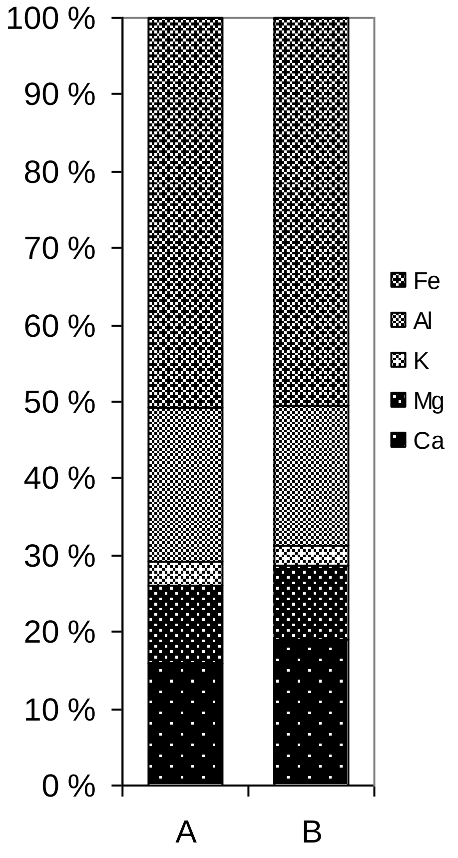

Figure 5.1. Main (avg. value > 3,5 mg/g) oxide composition of the mineral soils.

The content of Fe and Al was not strongly correlated (r = 0.440). This poor correlation was partly due to the large number of samples with Fe content above the maximum analytical limit (see Figure 5.4). The Fe content was in fact not found to be correlated to any major constituent nor oxide element, though there were poor negative correlations to % C_{tot} (r = -0.591) and Ca (r = -0.469). Instead the negative correlation between Al and Ca (r = -0.749) was stronger then found in the other sites.

The major oxide elements presented in Figure 5.1 were followed in abundance by phosphorous (P), manganese (Mn) and titanium (Ti) (Table 3). Ti was correlated to lanthanum (La; r = 0.738). The variation in La was on the other hand correlated to the trace elements scandium (Sc; r = 0.731) and vanadium (V; r = 0.834). Sodium (Na) which was below detection limit in 12 samples was only significantly correlated to molybdenum (Mo; r = 0.726). No strong correlations were found for P. Mn was only significantly correlated to strontium (r = 0.798).

Table 5.3. Average and quartile soil content of less abundant oxide elements in 32 A horizon and 81 B horizon soil samples.

Horizon	P mg/kg	Mn	Ti	Na	La
A	965 854 - 1060	853 721 - 943	183 119 - 256	135 109 - 154	13.2 12 - 15
B	808 742 – 907	1038 710 - 1123	207 106 - 291	148 107 - 167	16.1 12 - 19

Soil composition of measured trace elements along with the composition of continental crust (Taylor and McLennan, 1985) and selected heavy metal contamination norms (Lacatusu, 1998) are presented in Table 5.4. The bedrocks in the studied sites were generally secondary minerals (sandstone, clay and limestone) that were apparently partly transformed to shale and marble by metamorphosis. The contents of trace elements were therefore generally depleted compared to continental crust, except for soft (type B) elements arsenic (As), lead (Pb), molubden (Mo) and cadmium (Cd) in addition to barium (Ba) and Zinc (Zn) at this site. The contents of Ba, Zn, and Mo were especially high at this site compared to earth crust and the other studied sites. The heavy metal contents were generally high relative to normal background levels typically found in soils and the values lies between the normal maximum levels and the various maximum allowable limits (M.A.L.) adopted by different countries (see e.g. Naturvårdsverket, 1997 for relevant values for forest soils) (Table 5.4).

Table 5.4. Soil content of measured trace elements elements in 32 A and 81 B horizon samples from Novobad, along with reference values.

Site	Hor	As	Ba	Sr	Pb	Cd	Cu	Cr	Zn	Ni	Co	V	Sc	Y	Zr	Be	Mo
		mg/kg															
Earth crust[1]		1.0	250	260	8.0	0.1	75	185	80	105	29	230	30	20	100	1.5	1.0
Normal Min[2]					0.1	0.1	1	2	3	2	1						
World mean[3]		6		300	10	0.06	20	100	50	40	8						
M.A.L. (PI) [2]					100	3	100	100	300	100	50						
Novobad	A	11	309	58	23	0.7	41	29	155	41	20	45	5.1	9.4	6.1	1.1	1.8
	B	13	336	71	19	0.8	44	28	165	46	22	50	6.0	11	6.4	1.1	1.9

[1] Taylor and McLennan, 1985.
[2] http://eusoils.jrc.it/esdb_archive/eusoils_docs/esb_rr/n04_land_information_systems/5_7.doc
[3] World mean concentration in uncontaminated soils (Allaway,1968)

Only a few strong correlations were found between the oxide- and trace elements as well as between the trace elements (see below). Fe was only strongly correlated to copper (Cu; r = 0.711) and cobalt (Co; r = 0.759) (Figure 5.2) in addition to scandium (Sc; r = 0.829) and zirconium (Zr; r = 0.755). The cause for this low number of correlation was undoubtedly that 20 samples had Fe concentrations above the maximum limit (50 000 ppm) for the analysis. This is clearly seen in Figure 5.4 where a large number of data are on the 50000 ppm. This does not explain all of the lack of correlation as Al was only correlated to chromium (Cr; r = 0.972) and beryllium (r = 0.835). Ca was negatively correlated to Cr (r = -0.745) and beryllium (Be; r = -0.756), and positively correlated to the content of hard element (type A) strontium (Sr; r = 0.778).

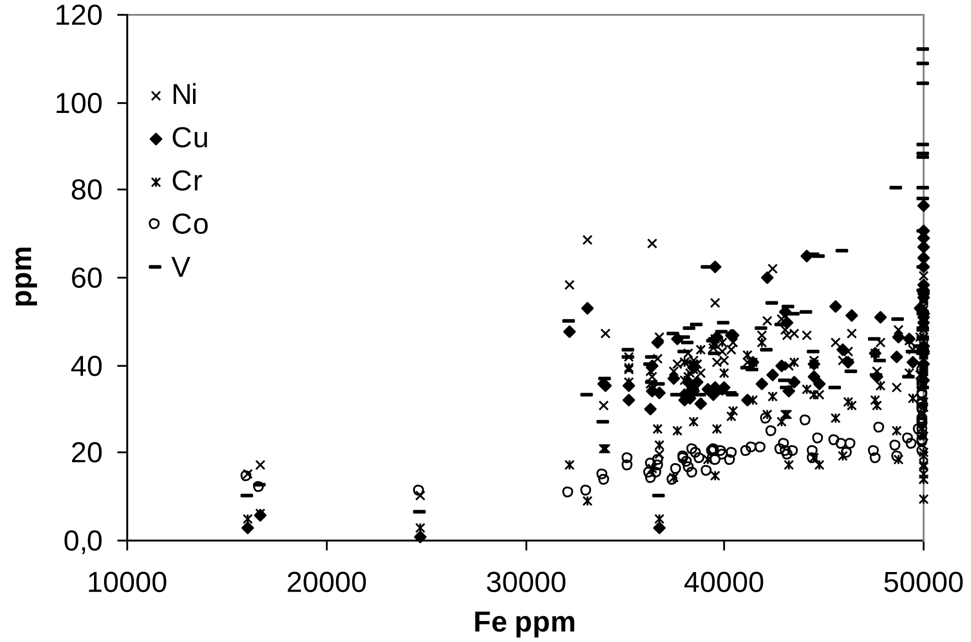

Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements nickel (Ni), copper (Cu), chrome (Cr) cobolt (Co) and vanadium (V).

Furthermore, only 9 strong correlations were found between the 16 measured trace elements (Table 5.5). As usual the borderline element cobalt (Co) showed the largest number of correlations, though Cu and Sc instead of Ni and Vanadium (V) showed a large number of strong correlations. The type B (Pb, Mo and As) and type A (Ba) elements were, as found in the other sites, poorly correlated to the other trace elements. That the amount of no element was especially high compared to earth crust, the low number of Zn correlations, and that the Zn concentration was higher in the top horizon than deeper in the soil profile (Table 5.4) may indicate an anthropogenic deposition of zinc at this site.

Table 5.5. The strongest sets of correlations (i.e. $r > 0.700$) found for each of the measured 16 trace elements in 32 A and 81 B horizon samples from Novobad. The elements are sorted in the order of their covalent index with type B elements on the top and type A elements in the bottom. - indicates no strong correlations.

Elements	# of correlations	Versus	r
Pb	0	-	-
Mo	0	-	-
Cd	1	Zn	0.844
As	0	-	-
Cu	4	Ni	0.765
Co	3	Sc	0.824
Ni	1	Cu	0.765
Zn	1	Cd	0.844
V	1	Sc	0.779
Be	1	Cr	0.808
Cr	1	Be	0.808
Sc	3	Co	0.824
Y	0	-	-
Zr	1	Cu	0.729
Ba	0	-	-
Sr	1	Co	0.746

5.3 Discussion

When considering the important role Fe play in explaining variation of trace elements in these soils, running a statistical analysis on the sample set from Novobad is problematic due to the high number of samples given the maximum value of 50 000 ppm for Fe. Nevertheless, keeping this in mind, the role of Fe content as a governing factor for the soil chemical content of trace elements can still be illustrated by a Principal Component Analysis (PCA) (Minitab®).

The same pattern is found in all the studied sites. In the plane of the first two principal components (PC1 and PC2) in both the A and B horizons the Fe is clustered together with Al and most trace elements (except Sr, Mo, As and Cd) (Figure 5.3). Negatively loaded to this cluster along the PC1 we find a cluster of Ca and Sr, often close to % C_{tot}.

In the B-horizon, despite the many out of range Fe data, the PC1 and PC2 explains 43 and 20% of the variation in the data set, respectively. The PC1 is mainly explained by the loading of Fe and Al content on the one hand and Ca on the other.

The PC2 at this site may partly be explained by the Covalent index ($CI = X^2r$) of the elements. Elements with low CI, commonly referred to as hard or type A elements, prefer to bind to carbonates, while elements with high CI, commonly referred to as soft or type B elements, forming more stable complexes, e.g. with sulphides.

Type A elements (Ca, Mg, Na, K) have generally opposite loading to more Type B elements (Pb, Cd, As). Borderline metals have generally low loading along the PC2. Instead they are strongly clustered with Fe. In the A and B horizons PC2 is correlated to the Covalent index with an $r = 0.428$ and 0.559, respectively.

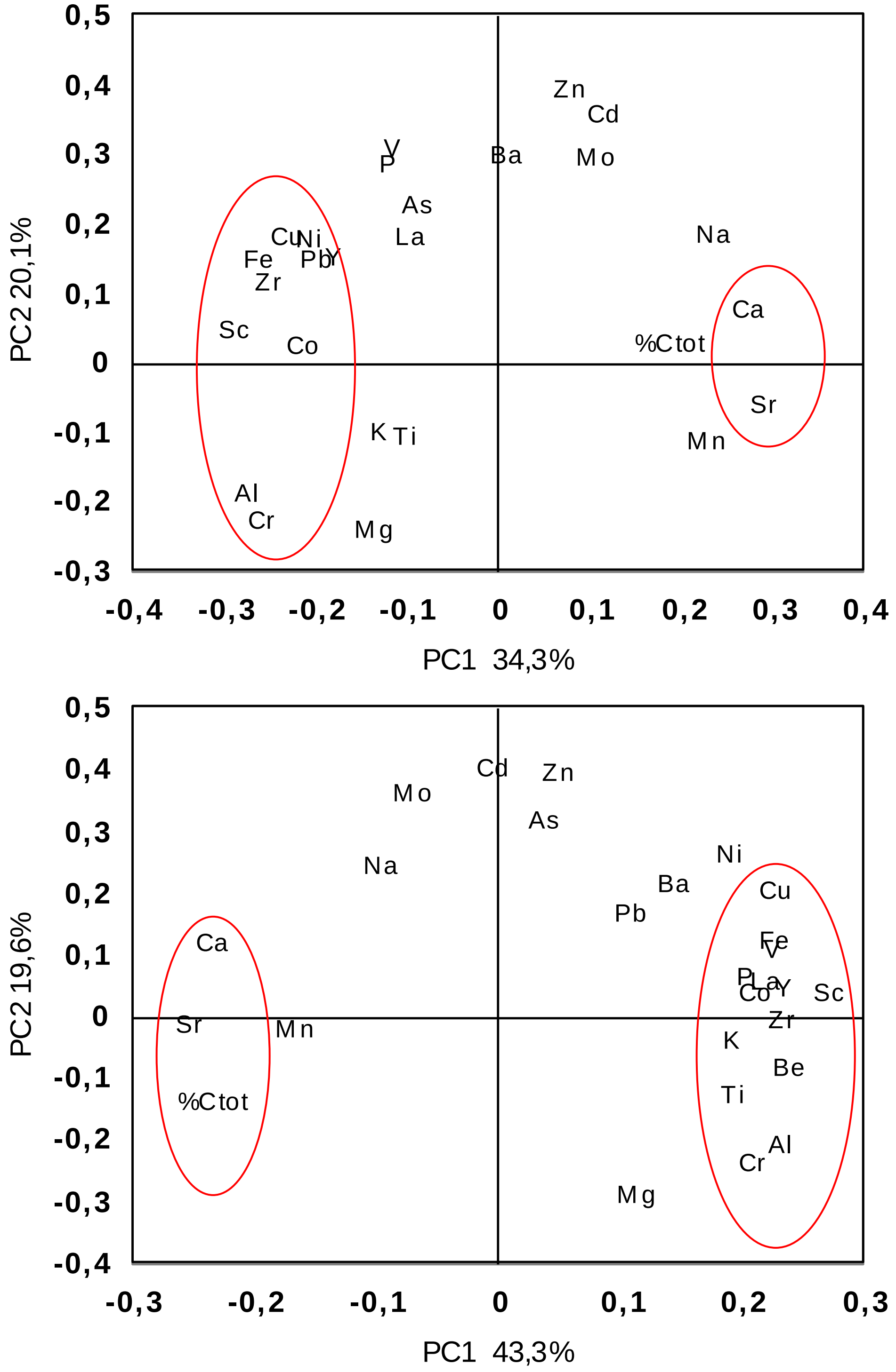

Figure 5.3. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 54.4 and 62.9% of the variation in soil elemental composition, respectively.

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