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

Establishment of monitoring reference area in Besh-Tash, Talas oblast, the Kyrgyz Republic, 2006. TEMP-CA monitoring site No.4.

Tonje Økland[1], Nurbek Kuldanbaev[2], Jørn-Frode Nordbakken[1] & 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 Kyrgyz Republic 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 Besh-Tash monitoring site in Talas oblast in the Kyrgyz Republic was the fourth 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. At the site *Abies semenovii* and *Picea schrenkiana* were the dominant tree species. The size distributions of both species show a high proportion of individuals in the smallest size classes, suggesting that regeneration of the two coniferous species is not limiting. One reason for this could be that the two coniferous species are not preferred forage by domestic animals that might be grazing in the area. Defoliation of all the main species were moderately, whereas discoloration was not recorded for any of the species.

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. A total of 39 species of vascular plants were recorded in the 50 1-m^2 plots, along with 14 bryophytes and 2 lichens. 26 of the vascular plants were herbs. The total number of species in the in the 50 1-m^2 plots + ten 30x30m^2 plots was 58. Of the recorded vascular plants, 11 species are endemic to Central Asia: *Abies semenovii*, *Astragalus aksuensis*, *Carex turcestanica*, *Cerastium tianschanicum*, *Evonumus semenovii*, *Fritillaria walujewii*, *Galium turkestanicum*, *Hedysarum semenovii*, *Lathyrus gmelini*, *Sorbus tianschanica* and *Thalictrum sultanabadense*. One species, *Abies semenovii* is red listed. 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. Differences in altitude, aspect, influence of the tree layer on light and litter conditions, as well as nutrient conditions are of the most important environmental conditions influencing the species composition according to these results.

The watershed sampled is lying in a steep to very steep valley. The mountains in the surroundings are of dolomite origin, so the soil is calcareous. In general the slopes are built up from scree and weathered material. In macro plot 10 a massive iron ore was found. The soils are generally well developed and contain often deep organic layers. According to WRB they are Eutrisols. Plots in the old riverbed are characterised by Leptosols due to the many stones. The influence of the height differences shows clearly in both vitality of the trees (especially *Abies semenovii* in macro plot 6 and 7) and the humus form. At lower altitudes the humus form is often a mull humus. At higher altitudes moder is present (Macro plot 5) and moder–mor humus occur in the highest macro plot (7). The texture of the soil varied from sandy loam – silt loam – loam. In contrary with the other areas the litter/fermentation/humus layer was in many places intact. The pH is in general around and above 7. However some macro plots (6, 7, 8) are more acid. This shows also in the humus form, which is in the higher plots (6, 7) more a moder and mor.

The soils at Besh-Tash had a circum neutral pH and a high base saturation on the cation exchanger. The total nitrogen (N) content is the highest among the studied sites. This may be due to the relatively high organic content, as the total N is strongest related to the percent total carbon (% C_{tot}). The aluminium (Al) and iron (Fe) content at this site was negatively correlated to the % C_{tot}. The soil composition differ from the other TEMP study sites in that the content of calcium (Ca) is greater than Fe in the A horizon. The soil content of titanium (Ti) is relatively low, while the content of manganese (Mn) is relatively high at Besh-Tash (463 and 838 mg/kg in the B horizon, respectively). The content of arsenic (As) was rather high at Besh-Tash (47 ppm in the A horizon), especially in macro-plot 3 where the As content in the soil horizons varied between 22 – 153 mg/kg. The content of a majority of the 16 measured trace elements were strongly correlated to the Fe content, which again was strongly correlated to the Al content. Important exceptions are the typically soft (or type B) metals and the hard (type A) elements. Strong positive correlations were found within the soft, borderline and hard elements, while negative correlations where found between the groups. 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 more than half of the variation in the dataset. The PCA 1 axiis was mainly explained by the Al and Fe content relative to Ca and % C_{tot}, 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 = 0.579 and 0.481 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.

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NORWEGIAN FORESTRY GROUP

Cover Photo: Adilet Usupbaev, 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 Kyrgyz Republic 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 Besh-Tash monitoring site in Talas oblast in the Kyrgyz Republic was the fourth of ten monitoring sites established in forests in Central Asia:

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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.:

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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, 30. December 2010

Tonje Økland

Project leader

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INTRODUCTION

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

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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 Kyrgyz Republic is not large: forests cover c. 6.8% of the total area. The Concept for Forestry Development was approved by the Decree of the Government of the Kyrgyz Republic of May 31, 1999. Data from the TEMP-CA project gives valuable information to the State Agency on Environmental Protection and Forestry relevant for sustainable management of forests.

The forestry sector in the Kyrgyz Republic 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 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. More than 50% of the 10.6 million ha of arable land in the Kyrgyz Republic are affected by soil erosion. The situation is more or less similar for the neighbouring countries around the Fergana Valley. Besides this, the main land degradation processes include salinization, swamping, 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 Kyrgyz Republic 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 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 fourth monitoring site established in the TEMP-CA project, Besh-Tash in Talas oblast in the Kyrgyz Republic. This monitoring site was established and analysed in 2006. 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 BESH-TASH REFERENCE MONITORING AREA

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1.1 Geographical position of the reference monitoring area

The Besh-Tash monitoring site is located on the northern macro-slope of the Talas mountain range in the Tien-Shan mountain system. Administratively the investigation area belongs to Talas district of Talas oblast, the Kyrgyz Republic. The Talas district, which is distinguished by an arid type of landscape (Zinkova & Pushkareva 1987), is also one of the cultivation centres of the Kyrgiz Republic.

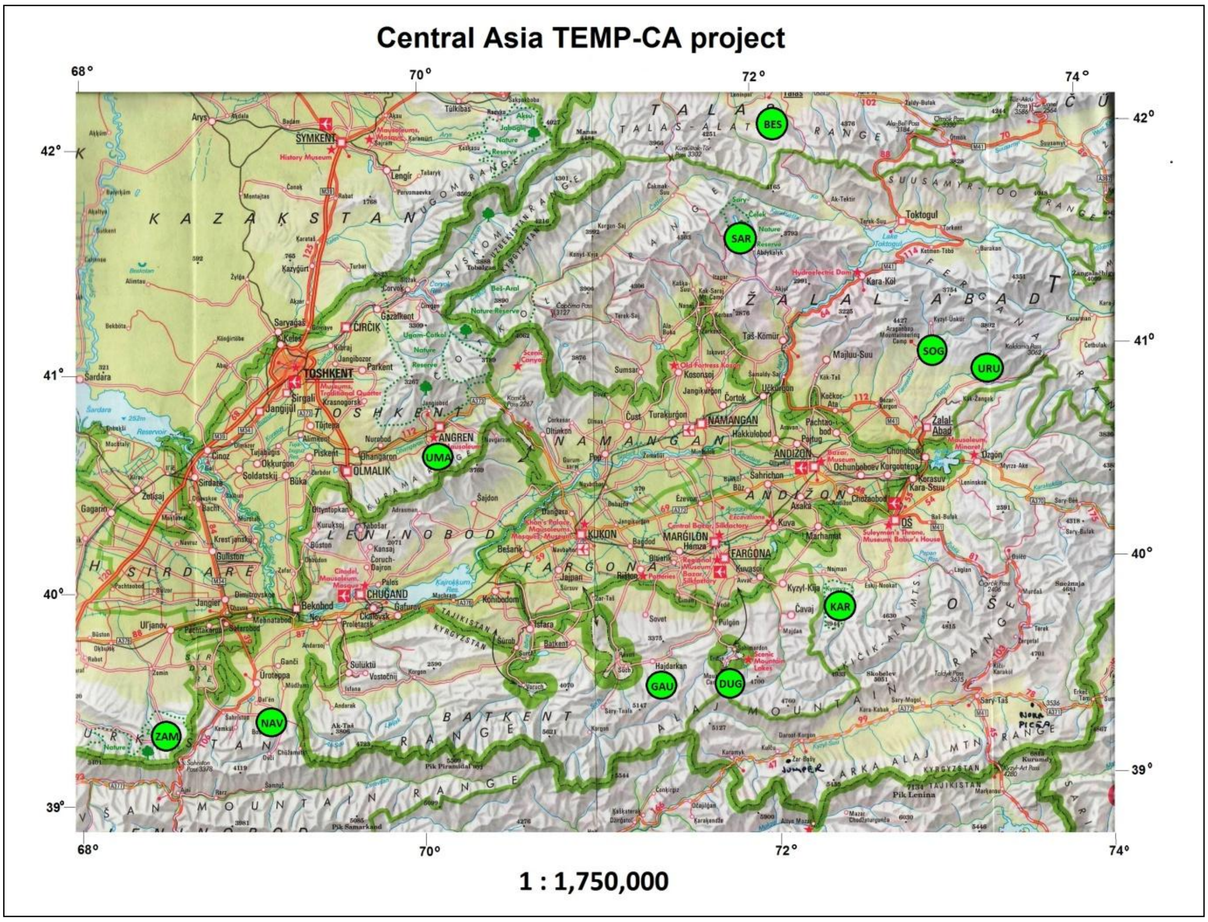

Fig. 1.1. Map of the Besh-Tash (BES) and the nine other TEMP-CA monitoring reference areas.

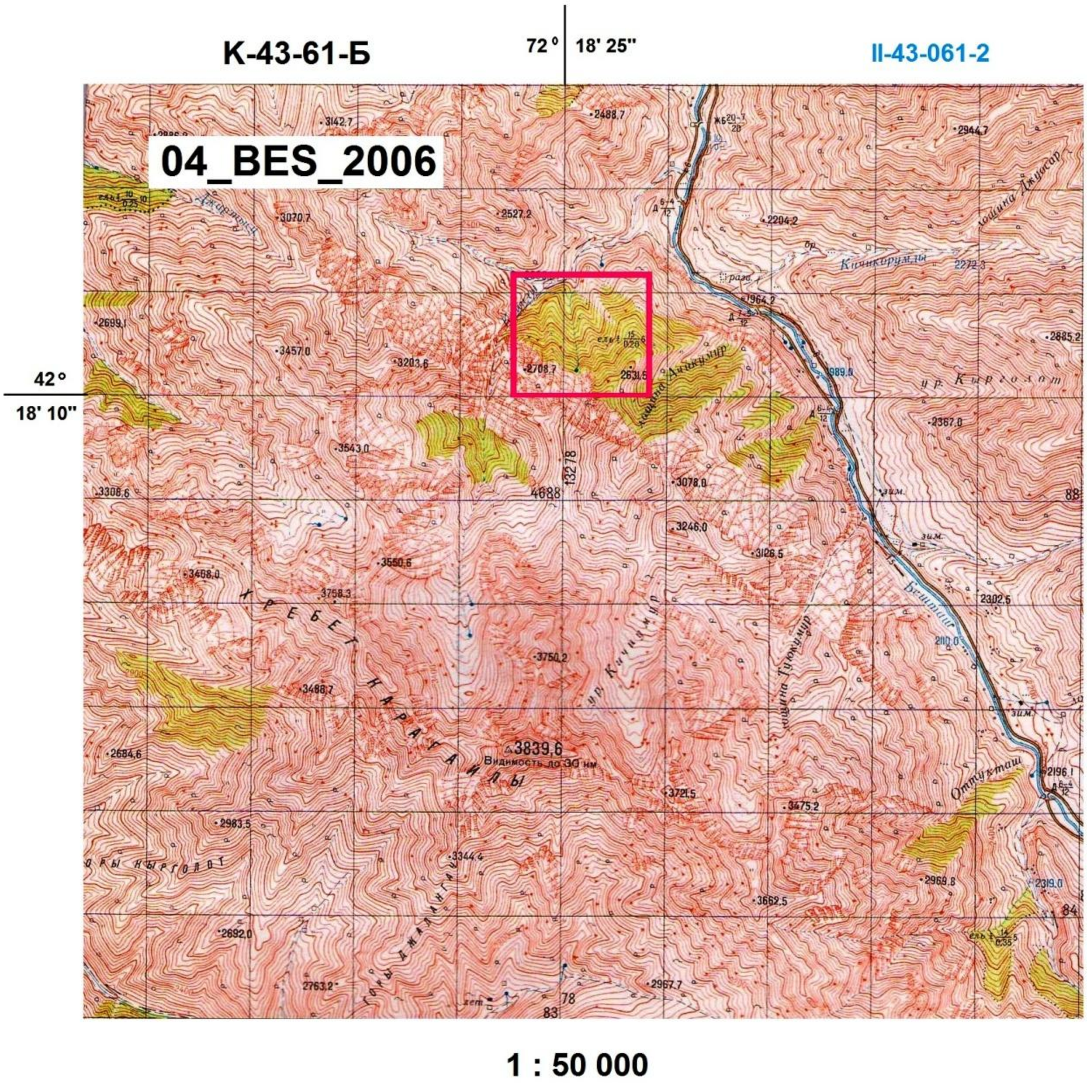

Fig. 1.2. Geographical position of the Besh-Tash (BES) monitoring reference area.

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

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

Macro plot	Elevation	N	E
1	2102m	42°18.864′	072°18.299′
2	2162m	42°18.735′	072°18.132′
3	2252m	42°18.723′	072°18.173′
4	2196m	42°18.728′	072°18.105′
5	2237m	42°18.674′	072°18.159′
6	2298m	42°18.635′	072°18.181′
7	2333m	42°18.609′	072°18.164′
8	2144m	42°18.788′	072°18.166′
9	2139m	42°18.814′	072°18.416′
10	2179m	42°19.004′	072°18.459′

1.2 Forest type, ownership, and conservation status

The monitoring site is positioned within the natural spruce and fir forests of the Besh-Tash National Park, which is a northern Kyrgyzstan biodiversity gene-fund preservation centre. The most prevalent woody vegetation in the area is the mountain coniferous forests that occur from sub-mountain areas up to the subalpine meadows.

The major forest-forming species are Semenov's fir (*Abies semenovii* = *Abies sibirica* ssp. *semenovii*), an endemic species of Kyrgyzstan (and included in the Red Data Book of Kyrgyz Republic 2006), and Tien-Shan spruce (*Picea schrenkiana*). The tree stand is mainly one- and two-layered, with fir and spruce in the first layer and birch (*Betula*), and rarely junipers, in the second layer; while the willow (*Salix*) occurs in the lower part. Trees of the first layer are well developed, with thick trunks, and height up to 26-28 m.

1.3 Geology, topography, and quaternary deposits

The Talas valley resembles a triangle with an apex in the east; the Talas and Kyrgyz Ala-Too ranges coming closer together in the east forming the mountain junction Ak-Suu. To the west the valley widens and in the north-west it borders the semi-deserts and deserts of the Turan lowland. Within the Talas valley and the surrounding mountains geomorphological complexes like mountains, sub-mountain-plains and plains can be distinguished.

The relief of the Talas and Kyrgyz Ala-Too has a composite structure. The mountain ridges are composed of Precambrian and Palaeozoic rocks. The high-mountain zone is characterized by formations of the structural-denudation relief type, and the medium- and low-elevation zone by the structural-erosive relief type. On the Neogene and Paleogene rocks in the sub-mountain zone of Talas Ala-Too, tectonic, erosive and accumulative types of relief have been formed . On the alluvial-proalluvial Quaternary rocks in the plain zone, steep- and gentle-sloped plains have been formed.

1.4 Climate

The climate in the Besh-Tash monitoring site is typical continental, characterized by considerable seasonal variation. The main wind directions for this area are west and south-west (Ryazantseva 1965).

1.4.1 TEMPERATURE

The average annual temperature of the forest zone of the Besh-Tash site depends on the altitude and fluctuates from 3 to 8 °C (Tab. 1.2). The average monthly summer temperature in the area is about 20.2 °C. July is the warmest month, while January is the coldest.

Tab. 1.2. The average temperature (°C). at the nearest meteorological stations, Kyzyl Adyr and Talas

Meteorological station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	Year
Kyzyl Adyr	-7	-5.1	1.6	10.3	15.1	20.1	22.2	19.9	14.4	7.9	1.7	-3.5	8.1
Talas	-5	-3.7	1.8	9.7	14.1	18.7	20.9	19.2	14.4	8.3	2.7	-1.9	8.3

1.4.2 PRECIPITATION

The amount of precipitation increases from west to east, from the foothills along the slope. The average annual precipitation amount to 300—400 mm, with maximum precipitation falling in April-May in the valley and in May-June on the slope. The summer is dry. The permanent snow cover usually appears in the middle of November in the sub-mountains and in December on the plains.

Tab. 1.3. The average precipitation (mm) at the nearest meteorological stations, Kyzyl Adyr and Talas.

Meteorological station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	year
Kyzyl Adyr	18	21	30	44	44	24	13	3	11	23	28	22	281
Talas	16	20	35	48	50	34	16	9	13	26	29	21	317

1.5 Vegetation zones

The territory of Besh-Tash belongs to the ancient Mediterranean sub-kingdom of the Holarctic, Western Asian province, in the Fergana-Alay region of the Central Asian mountain area (Kamelin 2002). The most widespread vegetation types in the investigation area are coniferous forests dominated by *Picea schrenkiana* and *Abies semenovii.* The considerable areas with tall grass meadows, rocks and stony-rubbly slopes are typical for this region. Typical landscape features are northern flora elements, predominance of meadow and steppe communities, and the forest and meadows which are distributed according to the Northern-Tien-Shan type of altitudinal zone structures. Six vertical zones can be distinguished in the northern macro slope, which are most well-pronounced in the Talas range.

1.6 Forest history, forest structure, and external influence

1.6.1 HUMAN IMPACT

There are no populated areas in the territory of the Besh-Tash National Park. The park is used for recreation during the summer season, but the most prevalent human impact in the area is grazing of domestic cattle. According to reports from the staff of the National Park there is illegal cutting of trees for firewood in the summer time when families keeping cattle move on to the mountain zone for summer pastures. In addition, people gather medicinal plants and harvests hay.

1.6.2 FOREST HISTORY

Until the 20th century the impact of the local population on the forest was minimal. The local population had a nomadic way of life, and the forest was used mainly for procurement of firewood. Intensive tree-cutting began early in the 20th century, when migrants from Russia settled in the territory of Kyrgyzstan. The logged wood was mainly used to build houses. The most intensive wood cutting took place in the middle of the 20th century (during the Second World War); and as a result the forest areas were halved. In 1960 any tree felling, except sanitary cutting, was forbidden in all forests of Kyrgyzstan. Nevertheless, the local population continued to cut quality trees under the pretence of sanitary cutting. At present there is a tendency for better forest regeneration.

1.6.3 GRAZING

Grazing is the most prevalent and difficult problem to solve for the forest management and protection. Kyrgyzstan is a mountainous country, and at all times cattle-breeding has been a leading industry. The most intensive and extreme grazing took place in the times of the Soviet Union, from the 1950s to the 1990s, when all forests of Kyrgyzstan were used for grazing. The grazing pressure was greatly reduced after the dissolution of the USSR, but the grazing impact on the forest areas continues to this day. No intensive cattle grazing was observed in the monitoring area of this study, but non-forest areas within the Besh-Tash National Park are used as grazing pastures by the local population. There are no accurate data on the number of grazing cattle, but the guard workers of the park report a 35-40% excess of the grazing regulations.

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 Kyrgyz conditions. Briefly, at each site ten 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. The assessment of defoliation did not consider dead trees, trees heavily damaged by abiotic factors, or greatly suppressed trees referred to class 4 by Craft’s classification.

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, north-south and east-west.

In addition, regeneration (< 5 cm DBH) of all tree species were recorded as a part of the ground vegetation analysis in the five 1-m^2 plot 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 species at the Besh-Tash monitoring site consisted predominantly of *Abies semenovii* (53.6 %) and *Picea schrenkiana* (39.6 %) (Fig. 2.1). The remaining species included small amounts of *Sorbus tianschanica* (5.3 %) and *Betula turkestanica* (0.76%).

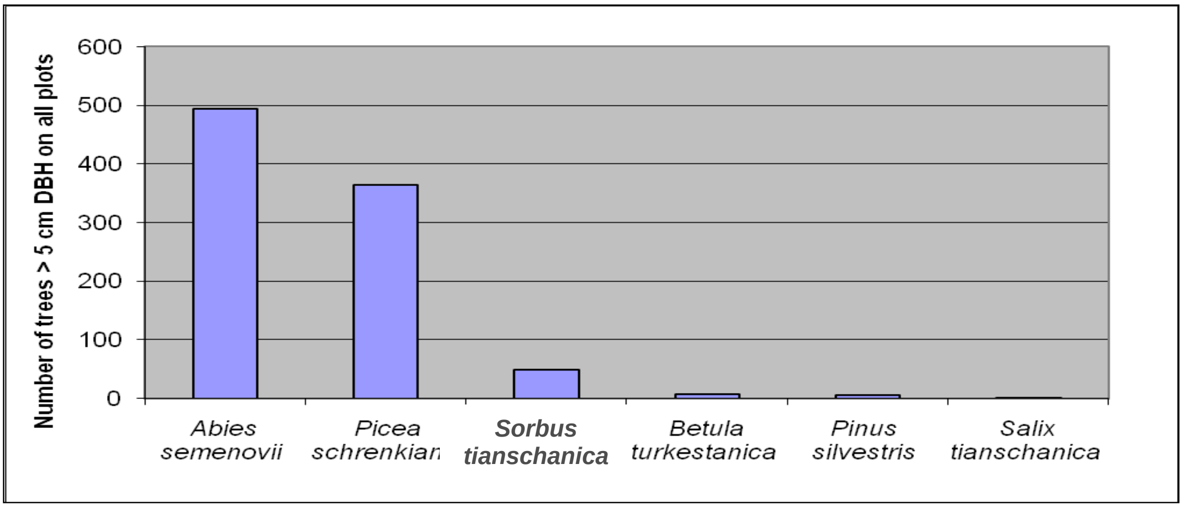

Fig. 2.1. Total number of trees > 5 cm DBH of each species in all plots.

2.2.2 TREE CONDITION

Tree condition is presented for the main species for which there are sufficient amount of individuals to draw reasonable conclusions. According to the ICP Forest classification of defoliation, all the main species were moderately damaged (Fig. 2.2). *Sorbus tianschanica* had the most pronounced defoliastion; 49% in average By contrast, no discoloration was recorded for any of the species.

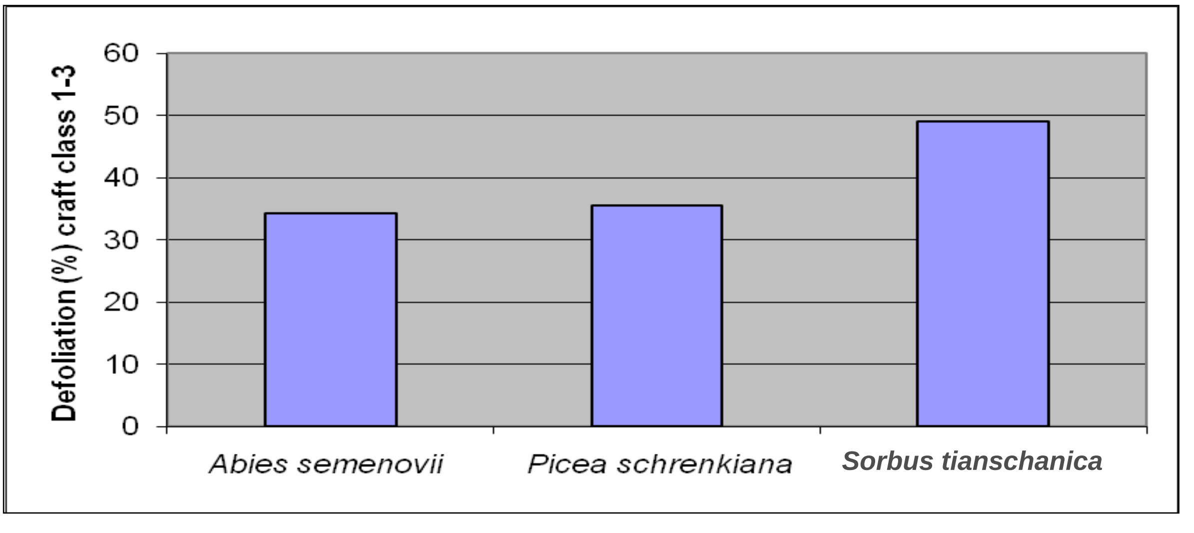

Fig. 2.2. Defoliation for the main species.

2.2.3 DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

Demography and regeneration was not assessed for *Sorbus tianschanica* due to its modest occurrence at the site. The size distribution of *Abies semenovii* and *Picea schrenkiana* (DBH) showed a decrease in the number of individuals with increasing diameter. The two smallest size classes (DBH < 15 cm) made up 56.2% for *A. semenovii* and 50.2% for *P. schrenkiana* (Fig. 2.3 and 2.4). For *A. semenovii* 66 saplings (< 5 cm DBH) were recorded in the 50 1-m^2 plots. The proportion of trees with DBH > 20 cm was 26% for *A. semenovii* and 31.5% for *P. schrenkiana.*

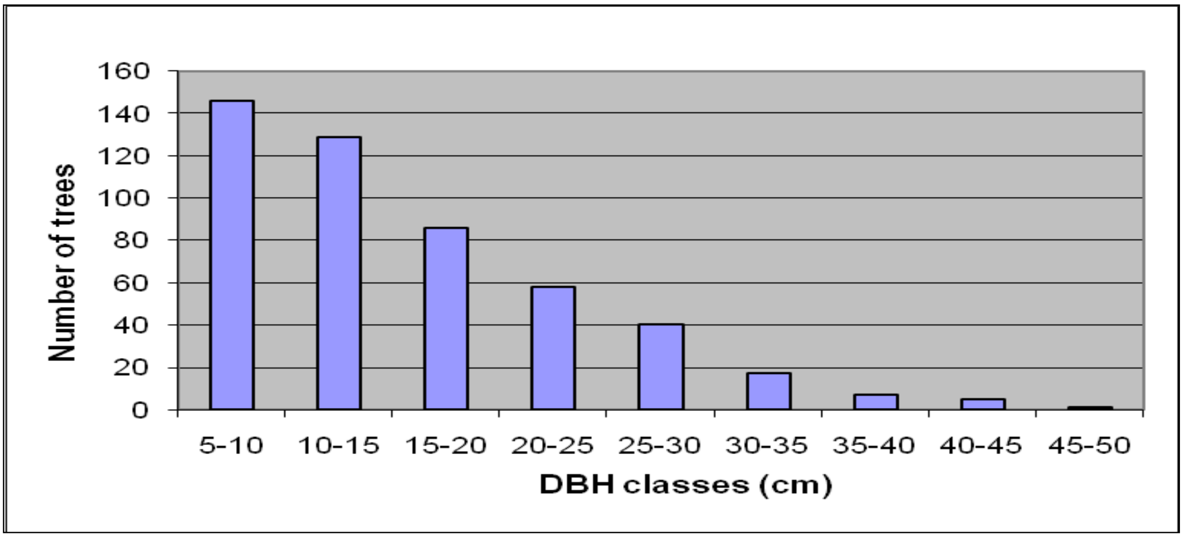

Fig. 2.3. Size distribution (DBH) for *Abies semenovii* (all plots).

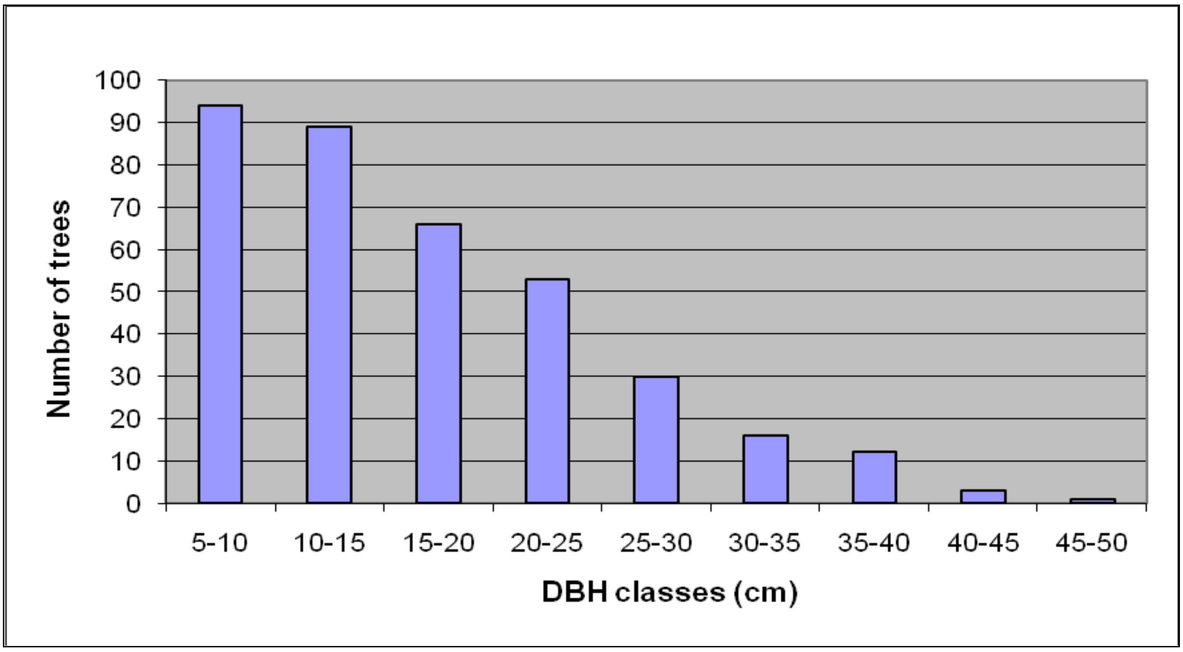

Fig 2.4. Size distribution (DBH) for *Picea schrenkiana* (all plots).

2.3 Discussion

The forest condition was assessed using defoliation and discoloration of needles and leaves as the main indicators. Natural environmental factors such as climate and soil conditions are known to be important for the forest condition. In addition, grazing and cutting of firewood may affect both regeneration and susceptibility to diseases. Thus, the forest condition is determined by a number of natural and anthropogenic factors, which implies that it may be difficult to single out the possible effect of pollutants on tree vitality at a given site. Nonetheless, the repeated assessments, which are the basic idea of monitoring, will always provide crucial information about temporal development in the forest condition.

The defoliation at this site was pronounced, particularly for *Sorbus tianschanica* (Fig. 2.2). The reason for this is not apparent, especially since no discoloration was recorded. Accordingly, wood and needle samples should be collected for further pathological and entomological investigations. Moreover, it is essential to establish which role human disturbance, such as cutting of firewood, could have on forest health. The present data does not allow us to speculate whether air pollution could affect forest condition at this site.

Sufficient regeneration is fundamental for sustainable forests. The *size distributions* of *Abies semenovii* and *Picea schrenkiana* (Fig. 2.3 and 2.4) both show a high proportion of individuals in the smallest size classes, reflecting similarities in *age class distribution* with a surplus of young individuals. In *A. semenovii* a rich regeneration is also indicated by the 66 saplings (< 5 cm DBH) found in the ground vegetation quadrants. Thus, although our data are limited they suggest that regeneration at this site is not limiting for *A. semenovii* and *P. schrenkiana.* One reason for this could be that the two coniferous species are not preferred forage by domestic animals that might be grazing in the area.

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.

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.

Fig. 3.1. Forest floor with bryophytes and herbs at the Besh-Tash monitoring site.

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 = ∑i **cai • cci** /25

Litter index 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 ℃ 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:

-Domestic animal grazing condition
-Grazing intensity
-Average grass height
-Average herb height
-% cover animal manure/dung
-% cover animal traces/footprints
-% cover animal tracks
-% browsing damage on woody plants for each species
-% 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 below. The total species list is given in Appendix 3.4. The number of vascular plant species in the 1-m^2 plots within each 10 x 10 m macro plots was calculated as the sum of species numbers in the five plots (a), as the total number of vascular plant species in each 10x10 m^2 macro plot included the species in the 1-m^2 plots (b), and as the total number of species in each 30x30 m^2 extended macro plot included the species in the 1-m^2 plots (c, Tab. 3.1). The ratio a/b and a/c was calculated for each macro plot. A total of 39 species of vascular plants, 14 bryophytes and 2 lichens were recorded in the 50 1-m^2 plots. Of these, 11 vascular plant species are endemic to Central Asia: *Abies semenovii*, *Astragalus aksuensis*, *Carex turcestanica*, *Cerastium tianschanicum*, *Evonumus semenovii*, *Fritillaria walujewii*, *Galium turkestanicum*, *Hedysarum semenovii*, *Lathyrus gmelini*, *Sorbus tianschanica* and *Thalictrum sultanabadense*. One of these species, *Abies semenovii* is listed in the Red Data Book of Kyrgyz Republic (2006).

The total number of vascular plant species recorded within the 50 1-m^2 plots + ten 10x10m^2 plots was 56. The total number of species in the in the 50 1-m^2 plots + ten 30x30m^2 plots was 58. The maximum number of species recorded in five 1-m^2 plots within a macro plot was 22, while the minimum number was 12. The average number of vascular plant species recorded in the 1-m^2 plots was 8.7. The maximum number of vascular plant species recorded in any of the 10x10 m macro plots (the five 1-m^2 plots included) was 26 and the minimum number was 16. The average number of vascular plant species in the 10x10 m macro plots (the five 1-m^2 plots included) was 21. The ratio a/b varied between 0.70 and 0.95 (Tab. 3.1). and the ratio a/c varied between 0.60 and 0.91 in the macro plots.

The plant species were divided into species groups, tree species, shrubs, herbs, ferns and 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 + 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	14	18	22	0.78	0.64
2	22	26	29	0.85	0.76
3	18	21	22	0.86	0.82
4	12	16	20	0.75	0.60
5	12	16	17	0.75	0.71
6	21	23	26	0.91	0.81
7	16	18	22	0.89	0.73
8	18	21	27	0.86	0.67
9	20	21	22	0.95	0.91
10	17	20	27	0.85	0.63
Total number	**39**	**56**	**58**	**0.70**	**0.67**

Tab. 3.2. Number of species in different species groups within the 1-m^2 plots in each 10x10 m macro plot and in total.

Plot number	Tree species	Shrubs	Herbs	Ferns	Graminoids	Bryophytes	Lichens
1	1	2	10	0	1	11	1
2	3	3	13	0	1	10	1
3	2	3	11	0	1	12	2
4	0	3	8	0	1	9	2
5	0	2	8	0	1	9	2
6	2	4	13	0	2	8	2
7	2	5	8	0	1	7	2
8	1	3	12	0	2	11	1
9	1	5	12	0	2	6	0
10	0	5	11	0	1	7	1
Total number	**3**	**7**	**26**	**0**	**3**	**14**	**2**

3.2.2 MAIN GROUND VEGETATION GRADIENTS

DCA ordination of 50 plots is shown in Figs. 3.2-3.4. 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	0.347	0.150	0.090	0.057
Gradient lengths	2.708	2.000	1.851	1.233

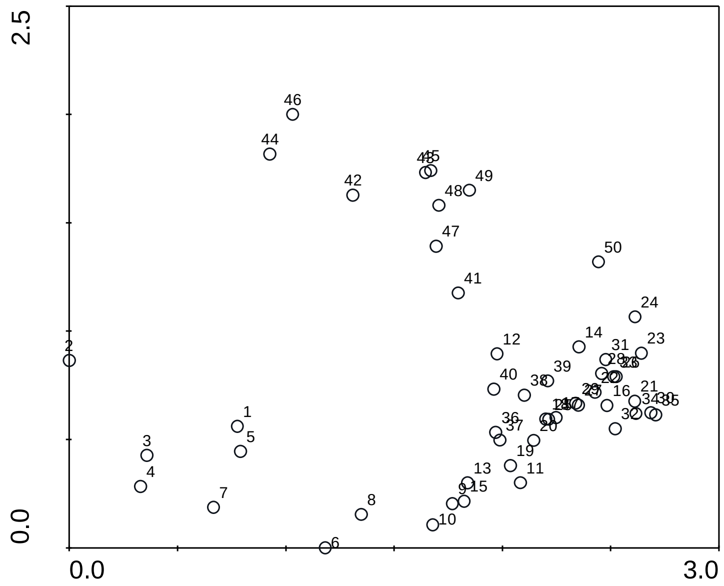

Fig. 3.2. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 2 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

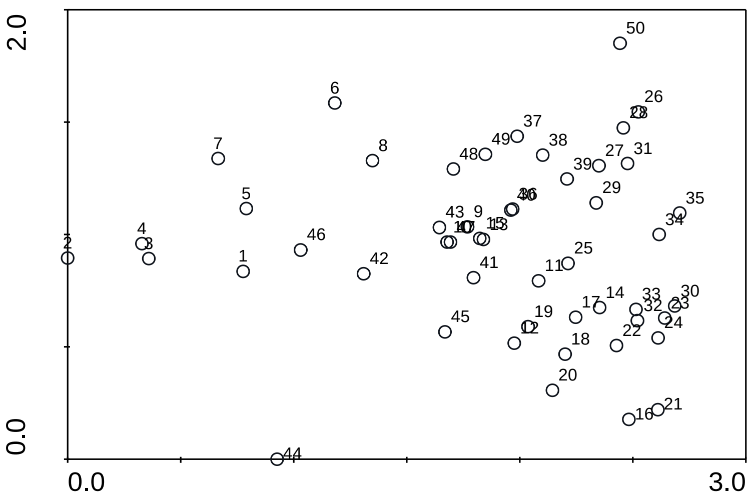

Fig. 3.3. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 3 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

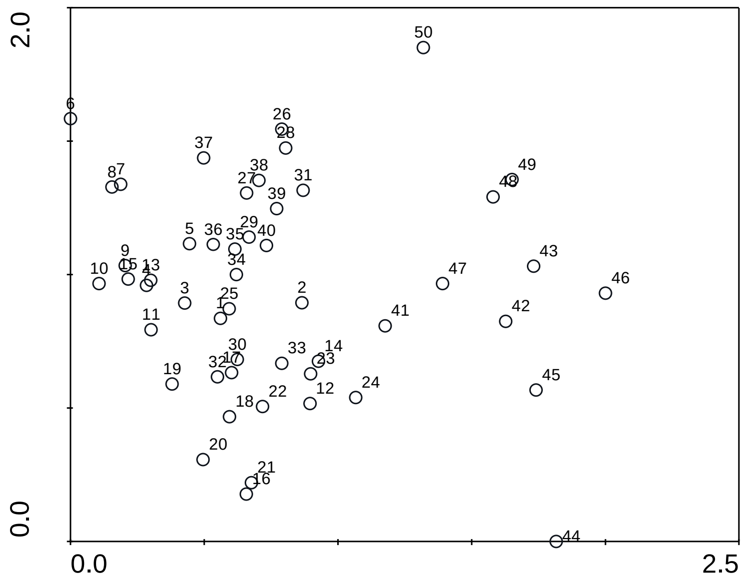

Fig. 3.4. DCA ordination of 50 1-m^2 plots, axes 2 (horizontal) and 3 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

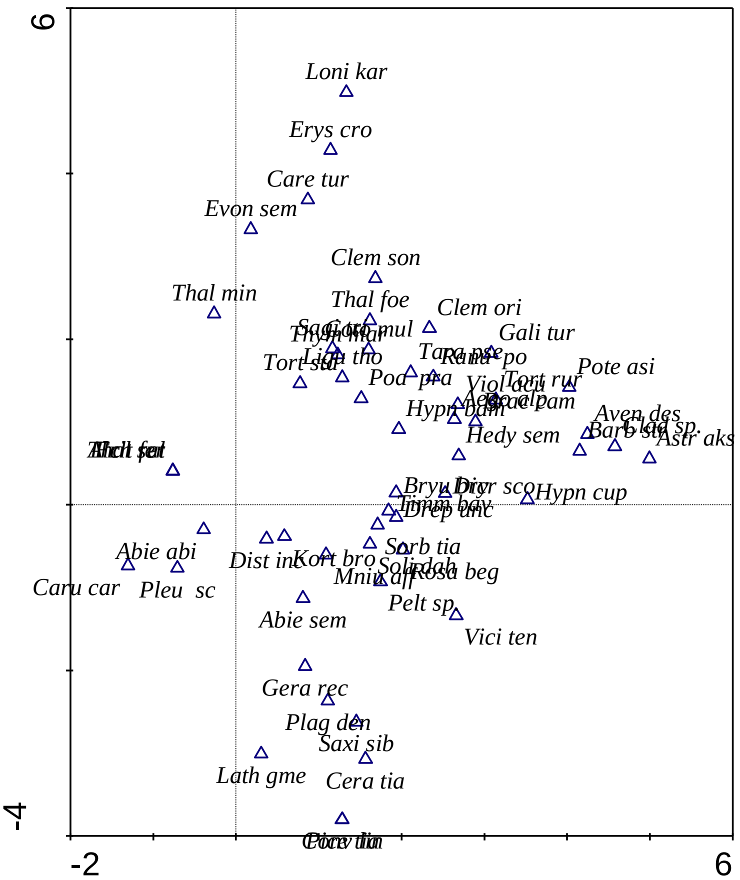

Fig. 3.5. DCA ordination of species in the 50 1-m^2 plots.

3.2.3 CORRELATIONS BETWEEN EXPLANATORY VARIABLES AND DCA ORDINATION AXES

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

Variable	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
DCA 1	* * *	* * *	0.102	0.296	-0.074	0.447	0.112	0.252
DCA 2	0.102	0.296	* * *	* * *	-0.078	0.427	-0.055	0.575
DCA 3	-0.074	0.447	-0.078	0.427	* * *	* * *	0.030	0.757
DCA 4	0.112	0.252	-0.055	0.575	0.030	0.757	* * *	* * *
Soil moisture	0.141	0.148	0.014	0.887	0.125	0.201	0.047	0.634
Inclination	-0.122	0.220	-0.184	0.065	-0.094	0.347	-0.167	0.093
Aspect	**0.404****	**0.000**	-0.196*	0.045	0.069	0.482	0.201*	0.040
Aspect fav.	**0.392****	**0.000**	-0.126	0.200	0.060	0.541	0.170	0.083
Heat index	0.123	0.207	**-0.278****	**0.004**	-0.040	0.682	-0.001	0.993
Max. incl.	-0.218*	0.033	-0.200*	0.050	-0.048	0.640	-0.164	0.108
Sum conc. 1x1 m	-0.196	0.055	-0.034	0.742	0.085	0.403	-0.092	0.366
Var. conc. 1x1 m	-0.240*	0.015	-0.101	0.307	0.076	0.441	0.093	0.348
Abs. sum conc. 1x1 m	**-0.266****	**0.008**	-0.074	0.459	0.112	0.267	0.056	0.579
Sum. conc, 3x3 m	0.082	0.432	0.007	0.946	-0.189	0.070	0.217*	0.037
Var. conc. 3x3 m	-0.206*	0.043	0.027	0.793	0.028	0.780	**0.301****	**0.003**
Abs. sum conc. 3x3 m	-0.129	0.215	0.058	0.575	-0.065	0.529	**0.321****	**0.002**
Rel. deciduos trees	-0.041	0.715	0.011	0.919	0.000	1.000	-0.023	0.839
Rel. conifer trees	0.228*	0.024	0.142	0.161	**-0.321****	**0.002**	**0.291****	**0.004**
Rel. total	0.219*	0.028	0.194	0.052	**-0.313****	**0.002**	0.241*	0.016
Crovn cover index	-0.025	0.795	-0.078	0.427	-0.019	0.847	0.337**	0.001
Litter index sum	0.110	0.284	**0.326****	**0.002**	-0.080	0.438	0.089	0.389
Average grass height	0.199	0.052	0.056	0.581	-0.039	0.703	-0.202*	0.048
Average shrub height	0.004	0.967	-0.034	0.731	. 0.128	0.199	-0.033	0.743
Max. soil depth	-0.124	0.209	-0.215*	0.029	-0.094	0.340	-0.112	0.255
Min. soil depth	0.058	0.561	-0.116	0.248	0.080	0.423	-0.077	0.443
Med. soil depth	-0.046	0.639	-0.201*	0.040	-0.044	0.651	-0.079	0.422
Max. org. layer	-0.166	0.095	**-0.282****	**0.005**	-0.125	0.211	-0.034	0.731
Min. org. layer	-0.109	0.278	**-0.309****	**0.002**	0.030	0.768	-0.151	0.132
Med. org. layer	-0.089	0.366	**-0.334****	**0.001**	-0.030	0.763	-0.018	0.854
Max. litter depth	0.101	0.330	0.146	0.162	**-0.263***	0.012	0.196	0.060
Min. itter depth	0.114	0.309	0.217	0.054	0.003	0.977	0.088	0.432
Med. litter depth	0.133	0.207	**0.307****	**0.004**	-0.153	0.147	0.182	0.085

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

Variable	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
Altitude	**0.594****	**0.000**	-0.163	0.108	-0.118	0.242	0.062	0.539
pH	-0.219*	0.025	0.155	0.114	**-0.254****	**0.010**	-0.101	0.303
H+	0.219*	0.025	-0.155	0.114	**0.254****	**0.010**	0.101	0.303
Dry matter%	0.019	0.847	**-0.288****	**0.003**	0.247*	0.011	0.006	0.953
Ctotal%	0.008	0.933	0.103	0.292	0.219*	0.025	0.041	0.676
Ca	0.058	0.606	-0.155	0.171	0.013	0.910	0.098	0.386
Mg	**-0.454****	**0.000**	0.050	0.660	0.121	0.285	0.007	0.950
K	0.144	0.204	0.061	0.589	0.121	0.285	0.070	0.538
CEC	0.007	0.950	-0.030	0.792	-0.078	0.489	0.138	0.223
Total N, mkg/g	0.156	0.110	0.161	0.099	0.079	0.417	-0.159	0.103
PO4 mg/kg	**0.260****	**0.008**	-0.056	0.569	0.213*	0.030	0.159	0.105
Ca, ppm	**-0.347****	**0.000**	0.118	0.230	0.021	0.834	0.082	0.406
Mg, ppm	-0.163	0.096	-0.025	0.795	-0.166	0.089	-0.032	0.744
K, ppm	0.205*	0.036	-0.007	0.940	-0.223*	0.022	-0.066	0.498
Al, ppm	0.195*	0.046	-0.203*	0.037	-0.213*	0.029	-0.024	0.808
Fe, ppm	0.193*	0.047	-0.189	0.053	-0.205*	0.036	-0.058	0.553
P, ppm	**-0.327****	**0.001**	0.097	0.320	0.055	0.575	-0.151	0.122
Zn, ppm	0.107	0.273	0.045	0.645	0.251*	0.010	0.143	0.143
Ca/CTot*100	-0.075	0.505	**-0.317****	**0.005**	-0.144	0.204	-0.013	0.910
Mg/Ctot*100	**-0.320****	0.005	-0.016	0.890	-0.001	0.990	0.061	0.589
K/Ctot*100	0.084	0.458	0.064	0.572	0.004	0.970	0.095	0.400
CEC/Ctot*100	0.001	0.990	-0.024	0.831	-0.152	0.179	0.104	0.359
Total N, mkg/g/Ctot*100	0.177	0.069	0.102	0.296	-0.045	0.645	-0.156	0.110
PO4 mg/kg/Ctot*100	0.249*	0.011	-0.097	0.320	0.223*	0.022	0.112	0.252
Ca, ppm/Ctot*100	**-0.300****	**0.002**	-0.025	0.795	-0.179	0.067	0.076	0.437
Mg, ppm/Ctot*100	-0.148	0.130	-0.020	0.834	-0.220*	0.024	-0.073	0.457
Na, ppm/Ctot*100	-0.058	0.558	-0.197*	0.046	-0.153	0.121	-0.049	0.617
K, ppm/Ctot*100	0.086	0.380	-0.032	0.744	-0.238*	0.015	-0.045	0.645
Al, ppm/Ctot*100	0.100	0.304	-0.138	0.157	-0.229*	0.019	-0.040	0.682
Fe, ppm/Ctot*100	0.113	0.245	-0.151	0.122	-0.236*	0.016	-0.037	0.707
P, ppm/Ctot*100	-0.205*	0.036	-0.051	0.598	-0.202*	0.039	-0.071	0.467
Zn, ppm/Ctot*100	0.048	0.622	0.025	0.795	-0.017	0.861	0.029	0.770

3.3 Discussion

3.3.1 GENERAL DESCRIPTION OF VEGETATION AND GROUND VEGETATION BIODIVERSITY

Picea schrenkiana was the dominating tree species in the spruce forest in the Besh – Tash monitoring site. The relict endemic species *Abies semenovii*, which is in the Red Data Book of Kyrgyz Republic (2006), is a typical component of the spruce forests of the northern macro slope of the Talas Range. It usually occupies steep slopes with northern, north-western and north-eastern expositions.

A low number of species (i.e. low α-diversity), both in total and per plot, is typical for the *Picea schrenkiana* forests. Common shrub species include *Clematis orientalis, Cotoneaster multiflorus, Evonymus semenovii* and *Lonicera karelini.* The grass and herb layer is mainly dominated by *Aegopodium alpestre*, with *Ligularia thompsonii* and *Poa pratensis* dominating on some sites. Other typical species are *Alchimilla retropilosa, Astragalus aksuensis, Carex turkestanica, Convolvulus lineatus, Erysimum croceum, Galium turkestanicum, Lathyrus gmelini* and *Hedysarum semenovii*.

Of the 55 species recorded in the 50 1-m^2 plots, 26 were herbs. Many of the meadow species in the area are herbs. Most of the herbs, however, are shade tolerant species with a low cover. In contrast to many of the other TEMP-CA monitoring sites, the spruce forest at Besh Tash has a well developed bryophyte layer. The average sum of % cover of the 14 bryophytes species in the for the 50 1-m^2 plots is 54%. *Hypnum cupressiforme* is the most abundant species.

3.3.2 INTERPRETATION OF GROUND VEGETATION GRADIENTS

The variable *altitude* showed a strong (positive) correlation with DCA 1, indicating variation in species compositions when going from lower to higher *altitudes*. The difference in *altitude* is c. 270 m, with the highest altitudes at 2324 m.a.s.l. *Aspect* and *aspect favourability* also showed positive correlations with DCA 1. The content *exchangeable Mg* and total amounts of *Ca* and *P* in soil were negatively correlated with DCA 1. Thus the species composition along this ordination gradient represents variation from relatively nutrient rich low altitude sites to more nutrient poor high altitude sites, and variation in aspects between sites.

The *litter index* and the *median litter depth* both showed strong positive correlations with DCA 2, indicating that variation in species composition along this gradient is partly due to differences in litter and light conditions. The *median depth of the organic layer* was the variable with strongest negative correlation with DCA 2.

The *soil depth* and the *relascope sum of coniferous trees* was negatively correlated with DCA 3, indicating a gradient from sites with a high density of trees on deep soil to more open sites with fewer trees on shallower soil.

The variation in species composition of ground vegetation in Besh Tash is thus mainly due to variation in *altitude*, *aspect*, influence of the tree layer on light and litter conditions, as well as nutrient conditions.

3.4 Appendix

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

Latin names of species	Kyrgyz names of species	Russian names of specie
Abies semenovii	Семенов көк карагайы	Пихта Семенова
Aegopodium alpestre	Тоо элик балтырканы	Сныть горная
Alchimilla retropilosa	Кайрылган түктүү тогуз төбөлү	Манжетка отклоненно-волосистая
Astragalus aksuensis	Ак-Суу астрагалы	Астрагал аксууйский
Barbarea stricta	Түз кычы	Сурепка прямая
Carex turkestanica	Түркстан ыраңы	Осока туркестанская
Carum carvi	Кадимки карум	Тмин обыкновенный
Cerastium tianschanicum	Тянь-Шань серастиуму	Ясколка тяньшанская
Clematis orientalis	Чыгыш жебелгеси	Ломонос восточный
Clematis songorica	Жунгар жебелгеси	Ломонос джунгарский
Convolvulus lineatus	Ичке жалбырактуу чырмоок	Вьюнок узколистный
Cotoneaster multiflorus	Көп гүлдүү ыргай	Кизильник многоцветковый
Erysimum croceum	Шафран даргыны	Желтушник шафранный
Evonymus semenovii	Семенов бересклети	Бересклет Семенова
Fritillaria walujewii	Валуев чаар гүлү	Рябчик Валуева
Galium turkestanicum	Түркстан галиуму	Подмаренник туркестанский
Geranium rectum	Түз каз таманы	Герань прямая
Hedysarum semenovii	Семенов тыйынчанак	Копеечник Семенова
Helictotrichon desertorum	Чымдак тоо сулусу	Овсец дернистый
Lathyrus gmelini	Гмелин шалбаа бурчагы	Чина Гмелина
Ligularia thomsonii	Томсон кой жалбырагы	Бузульник Томсона
Lonicera karelinii	Карелин шилбиси	Жимолость Карелина
Picea tianschanica	Шренк карагайы	Ель Шренка
Poa pratensis	Шалбаа жылганы	Мятлик луговой
Potentilla asiatica	Азия каз таманы	Лапчатка азиатская
Kortusa brotheri	Бротерус кортузасы	Кортуза Бротеруса
Ranunculus polyanthemus	Көп гүлдүү байчечекей	Лютик многоцветковый
Rosa beggeriana	Беггер ит муруну	Роза Беггера
Sagitaria trifolia	Үч жалбырактуу жебе жалбырак	Стрелолист трехлистный
Saxifraga sibirica	Сибирь саксифрагасы	Камнеломка сибирская
Solidago dahurica	Даурия алтынчыгы	Золотарник даурский
Sorbus tianschanica	Тянь-Шань четини	Рябина тяншанская
Taraxacum maracandicum	Мараканд сымал какым	Одуванчик маракандийский
Thalictrum foetidum	Сасык тармал чөп	Василистник вонючий
Thalictrum minus	Кичинекей тармал чөп	Василистник малый
Thalictrum sultanabadense	Султанабад тармал чөбү	Василистник султанабадский
Thymus marschallianus	Маршалдар кийик оту	Тимьян Маршаллов
Vicia tenuifolia	Жука жалбырактуу жер буурчак	Вика тонколистная
Viola acutifolia	Учтуу жалбырактуу ала гүл	Фиалка остролистная

Appendix 3.1. continues: Scientific (Latin), Kyrgyz and Russian names of plant species		
Latin names of species	**Kyrgyz names of species**	**Russian names of specie**
Abietinella abietina	--	--
Brachythecium campestre	--	--
Bryum bryoides	--	--
Dicranum scoparium	--	--
Distichium inclinatum	--	--
Drepanocladus uncinatus	--	--
Hypnum bambergeri	--	--
Hypnum cupressiforme	--	--
Mnium affine	--	--
Plagiothecium denticulatum	--	--
Pleurozium schreberi	--	--
Timmia bavarica	--	--
Tortula ruralis	--	--
Tortula starkei	--	--
Cladonia sp.	--	--
Peltigera sp.	--	--

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 Besh-Tash area the following soil data are gathered:

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

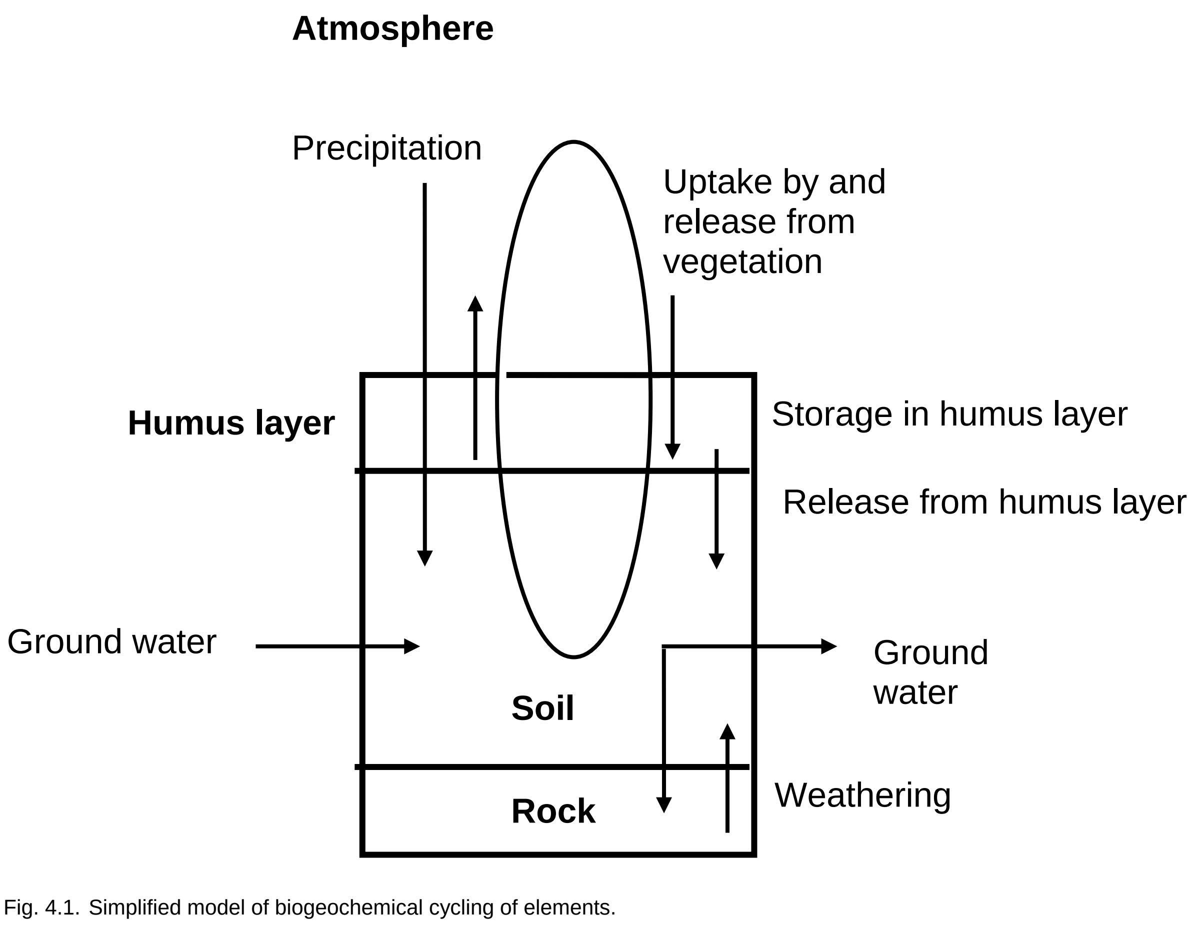

Fig. 4.1. Simplified model of biogeochemical cycling of elements.

The methodology for placing the macro plots and 1-m^2 vegetation plots is described in 3.1.1. From the 7th – 10th of June 2006 soil samples were taken from each 1-m^2 plot. Field work was done under varying weather conditions. Daily there were showers, sometimes with thunder and hail. Soil moisture samples were taken in June 2006. For long term monitoring it is important to get information from all the soil horizons. Accordingly, 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 1M 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 sampled watershed is lying in a steep to very steep valley. The surrounding mountains were made of dolomite, and the soil was calcareous. The slopes were mainly built up from scree and weathered material. In Macro plot 10 a massive iron ore was found.

All macro plots were placed in coniferous forest with a dominance of *Picea tianschanica* and *Abies semenovii.* Some macro plots were situated in the old river bed (macro plot 1, 8, 9, 10), while the others were situated on (very) steep slopes.

The soils were usually well developed and often contained deep organic layers. According to WRB they were Eutrisols (“Mountain Forest Humic dry“ soils in the Russian system), while soils in the old riverbed were characterised as Leptosols due to the many stones (macro plot 8, 9, 10). The altitude of the macro plots varied from 2116 m. to 2324 m.

The altitude influenced the humus types. Mull humus was often found at lower altitudes, while moder was found at higher altitudes (Macro plot 5), and moder–mor humus was found in the most elevated macro plot (7). Due to the stones in the stream bed, macro plot 10 also had a moder – mor humus.

The soil moisture in the underground varied from wet to dry. Signs of gleyic/stagnic properties, however, were not found. It is uncertain whether the wetter conditions were caused by the actual weather conditions or by oxygen rich ground water streams. Due to the many stones macro plot 9 and 10 were very dry.

The texture of the soil varied from sandy loam – silt loam – loam.

Contrary to the other monitoring sites, the litter/fermentation/humus layer was intact in many places, making it possible to take samples of this layer. Due to logistic reasons this layer was marked A1, and the normal mineral A horizon was marked A2.

The soil moisture varied, but corresponded with exposition, vegetation, and position of the macro plots. Moisture values varied from 19.3 to 65%.

The pH was in general around and above 7. Some macro plots (6, 7, 8), however, were more acid. This was reflected in the humus, which were more moder and mor in the higher altitude plots (6, 7).

4.3 Discussion

In the present watershed, the impact of man is much lower than e.g. in the Batken area. Due to the calcareous parent material effects of acid precipitation will only show up after a very long time. Due to the presence of local weathered material it is important to include the effects on biogeochemical cycling in cases where changes in nutrient/heavy metal content are found.

The site in Besh Tash is very interesting due to the fact that relatively strong differences in altitudes are present and that these differences are clearly reflected in vegetation growth and soil conditions.

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. At Besh-Tash the A horizon is split into two sub-horizons (A1 and A2), which were both sampled. 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 Edelman 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 Besh-Tash 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 ISO1039 0.

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 exicator before weighing (m_4).

Be aware that soils containing high amounts of organic matter easily get “blown away” when opening the exicator.

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:

<u>Mehlich's</u>
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 2   0.0 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.

<u>Olsen's</u>
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 10   0.0 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 (2 0.0 or 10 0.0 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 <u>100 ppm of P</u> (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 5 0.00 mL of 100 ppm P, and the soluble inorganic sulphate by shaking 5 g of air-dried soil (< 2mm) with 5 0.00 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 (5 0.0 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

5.2.1 SOIL CHEMISTRY DATA

Average soil chemical data for each horizon are presented in Tab. 5.2. Circum neutral pH conditions prevail at all the sampling plots and all horizons at Besh-Tash. As commonly found, the pH increases with depth along with decreasing organic content. The aluminium (Al) and iron (Fe) content at this site was negatively correlated to the % total carbon (C) content (%C_{tot}; r = -0.754 and -0.755, respectively). The total nitrogen (N) content is the highest among the studied sites. This may be due to the relatively high organic content, as we also find that the total N is in fact strongest related to the % C_{tot} (r = 0.565). No strong correlations (i.e. r > 0.7) were found between % C_{tot}, adsorbed phosphate (ads. PO_4^{3-}) and sulphate (SO_4^{2-}), and base cations. %C_{tot} was negatively correlated to the acid cations Al (r = -0.754) and Fe (r = -0.755) and several trace elements (Co, La, Be, Sc and Y; -0.733 < r < -0.823). Across the site the values of Ads. PO_4^{3-} (Table 5.2) are negatively correlated to average soil pH_{H2O} (r = -0.556). Adsorbed sulphate (Ads. SO_4^{2-}) were in practically all the samples below the detection limit (0.01 g/kg).

Tab. 5.2. Average and quartiles of soil chemical characteristics. LOI is loss on Ignition.

Horizon	Samples	pH_{H2O}	LOI	C total	Total N	Ads. PO_4^{3-}
	#		w/w %		µg/g	
A1	39	6.28	N/A	18.5	5325	115
		6.2 - 7 1	N/A	14 - 22	2958 – 6495	23 - 114
A2	35	6.48	N/A	9.1	3242	162
		6.5 – 7.5	N/A	7 - 11	2233 - 4200	9 - 134
B	23	6.58	N/A	4.1	1811	109
		6.5 – 8.2	N/A	2 - 6	1073 - 2498	4 - 104

The soil composition of main (avg. value > 3.5 mg/g) oxides at Besh-Tash, not considering SiO_2 (not measured), differ from the other TEMP study sites in that the content of calcium (Ca) is greater than Fe in the A horizons (Fig. 5.1). These elements are as usual followed by Al and magnesium (Mg). Base cations (Ca+Mg+Na+K) account for more than 50% of the oxide composition in the A horizon and 44% in the B horizon. The values are somewhat misleading as samples with an elemental content greater than a maximum analytical value, e.g. 50 mg/g for Ca and Mg, are set to this analytical maximum value; this was the case for 20 data for Ca. Nevertheless, the data indicate that the soil mineral base cation content in the A horizons is the greatest among the TEMP sites. The B horizon follows somewhat the same trend as found at the other sites with Fe>Ca>Al>Mg>K.

The content of Fe and Al are strongly correlated (r = 0.936). Deviations from this correlation are typically associated with elevated levels of trace elements. In Besh-Tash the relationship is not found in macro plot 3 where there is an elevated amount of Arsenic (As) (up to 153 ppm). The Fe content is also found to be negatively correlated to Ca (r = -0.704) and positively correlated to K (r = 0.817). Al is as usual negatively correlated to Ca, though this correlation is not strong (r = - 0.660).

The major oxide elements presented in Fig. 5.1 are followed in abundance by phosphorous (P) or manganese (Mn), and titanium (Ti) (Tab. 5.3). The amount of Ti was relatively high compared to e.g. Na. P is strongly correlated to Ca (r = 0.720) and negatively correlated to the acid cations Al (r = -0.778) and Fe (r = -0.766). It is also negatively correlated to several trace elements (Ni, V, Be, Sc and Ti). Ti is also correlated to Al (r = 0.874), Fe (r = 0.759) and several trace elements (Cr, Ni, Co, Sc). The variation in La is negatively correlated to the % C_{tot} (r = -0.780) and as always correlated to Al (r = 0.818), Fe (r = 0.742) and a number of trace elements (Cr, Co, Be, Sc, Y). As usual no strong correlations were found for Mn and Na. For Na this may partly be due to the fact that 11 samples had Na levels below detection limit, of which most were in the A1 horizon.

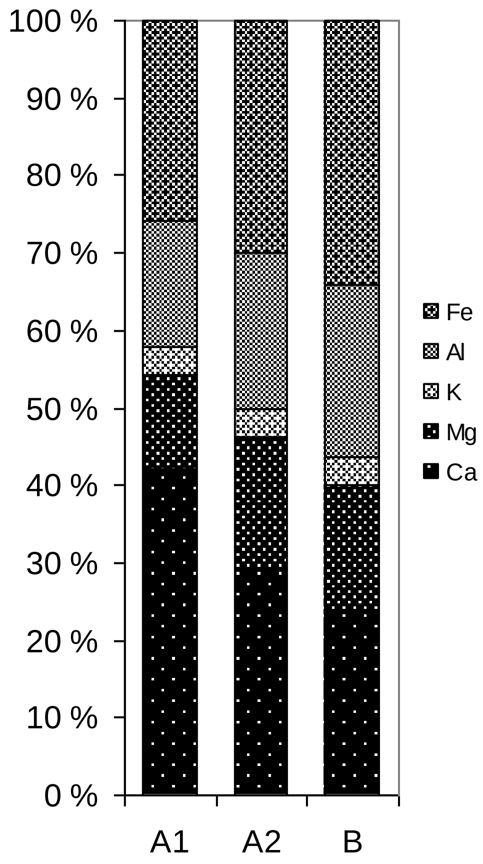

Fig. 5.1 Main (avg. value > 3.5 mg/g) oxide composition of the mineral soils.

Tab. 5.3. Soil average and quartile content of less abundant oxide elements in 50 A and 50 B horizon samples.

Horizon	P	Mn	Ti	Na	La
			mg/kg		
A1	884	711	242	152	9.6
	162 - 232	533 - 900	175 - 303	116 - 173	7 – 12
A2	758	958	358	157	16.2
	545 - 897	831 - 1109	235 - 498	138 - 179	14 – 19
B	529	838	463	156	19.6
	225 - 659	704 - 975	252 - 610	135 - 180	17 - 23

Soil composition of measured trace elements along with the composition of continental crust (Taylor & McLennan 1985) and selected heavy metal contamination norms (Lacatusu 1998) are presented in Tab. 5.4. The bedrocks in the studied sites are generally secondary minerals (sandstone, clay and limestone) that are apparently partly transformed to shale and marble by metamorphosis. The contents of trace elements are therefore generally depleted compared to continental crust, except for soft (type B) elements arsenic (As), lead (Pb) and cadmium (Cd) as commonly found in the TEMP sites. Nevertheless, the heavy metal contents are 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) (Tab.5.4).

Tab.5.4. Soil content of measured trace elements in 50 A and 50 B horizon samples 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. (Pl) [2]					100	3	100	100	300	100	50						
Besh-Tash	A1	9.4	195	54	34	1.4	21	23	69	21	8.0	27	2.4	5.3	3.0	0.7	0.9
	A2	15	195	46	31	0.7	25	32	63	30	12	39	3.7	8.0	3.5	1.1	0.6
	B	21	159	41	27	0.3	26	39	71	33	14	50	5.0	10	4.2	1.3	0.7

[1] Taylor & 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 (Allaway1968)

Fe content is strongly correlated to the majority of the 16 measured trace elements (Fig. 5.2). Important exceptions are the soft (or type B) metals Pb, molybdenum (Mo), and Cd and the hard (type A) elements barium (Ba) and strontium (Sr). Soft metals (high covalent index) were instead generally found to be correlated only to each other (Table 5.5) and negatively correlated to hard (Type A) metals. Similarly, the variation in Sr content followed closely the Ca levels (r = 0.707). Only at Besh-Tash strong negative regressions are in addition found between Be and % C_{tot} (r = -0.796), P (r = -0.706) and Sr (r = 0.729), between Fe and Sr (r = -0.721) and between Sr and Sc (r = - 0.734).

Most soil content of most of the trace elements co-varied in the soils; 33 strong correlations were found between the 16 measured trace elements (Table 5.5), implying that this site has the highest number of strong correlations. As usual the borderline elements cobalt (Co), nickel (Ni), vanadium (V) and chromium (Cr) showed the largest number of strong correlations. The type B elements (Pb, Mo and Cd) along with the type A elements (Ba and Sr) showed as usual the poorest positive correlations to the other trace elements. Instead strong negative correlations were found between Sr and Cr, V, Ni, and Co. As commonly found there were no strong correlations with zinc (Zn), though poor negative correlations were found between Zn and base cations and Sr.

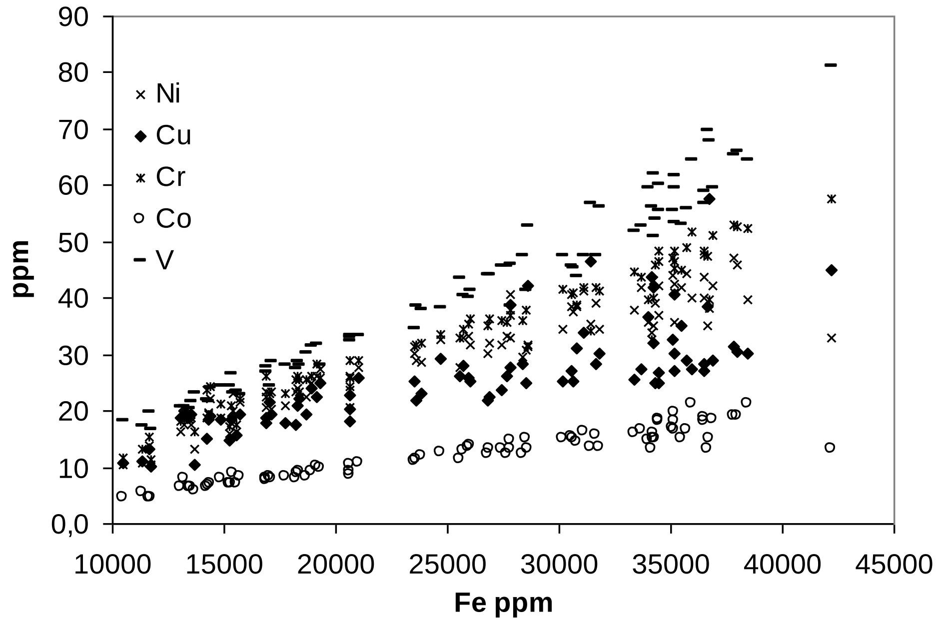

Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements nickel (Ni), copper (Cu), chrome (Cr) cobolt (Co) and vanadium (V).

Tab. 5.5. The strongest sets of correlations (i.e. r > 0.7) found for each of the measured 16 trace elements in 50 A and 50 B horizon samples from Besh-Tash. 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 (r < 0.7).

	# of corr.	Vs.	r
Pb	0	-	-
Mo	0	-	-
Cd	0	-	-
As	1	Cu	0.729
Cu	7	V	0.853
Co	10	Cr	0.969
Ni	10	Co	0.965
Zn	0	-	-
V	9	Sc	0.967
Be	5	V	0.941
Cr	10	Sc	0.973
Sc	6	Cr	0.973
Y	4	V	0.828
Zr	4	V	0.844
Ba	0	-	-
Sr	4	Cr	- 0.733

5.3 Discussion

The role of Fe content as a governing factor for the soil chemical content of trace elements can clearly be illustrated by a Principal Component Analysis (PCA) (Minitab®). The same pattern is found in all the studied TEMP sites. In the plane of the first two principal components (PCA 1 and PCA 2 axes) in both the A and B horizons the Fe is clustered together with Al and most trace elements (except Sr, Mo, As, Cd and Pb) (Fig. 5.3). Negatively loaded to this cluster along the PC1 we find a cluster of Ca and Sr, often together with % C_{tot}. The PCA 1 axis, explaining more than half of the variation in the dataset, is therefore mainly explained by the loading of Al and Fe relative to Ca. The PCA 2 axis at these sites 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 PCA 2 axis. Instead they are strongly clustered with Fe. This is clearly seen at this site where the PCA 2 axis in the A and B horizons is correlated to the Covalent index with an r = 0.579 and r = 0.481, respectively.

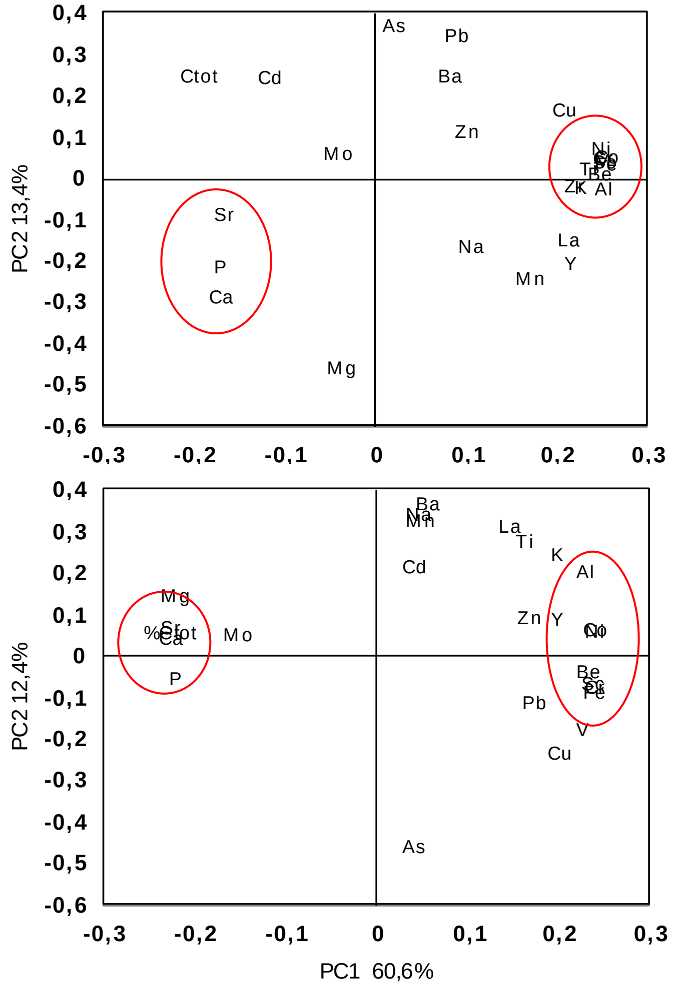

Fig. 5.5. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 69.1 and 73.0% of the variation in soil elemental composition, respectively.

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