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

Establishment of monitoring reference area in Sary-Chelek, Jalal-Abad oblast, the Kyrgyz Republic, 2007. TEMP-CAmonitoring site No.5.

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 Sary-Chelek monitoring site in Jalal-Abad oblast in Kyrgyzstan was the fifth 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.
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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 five plots of 1-m^2 were randomly placed.

All trees within the ten 30x30 m plots were marked on a sketch map and a number of tree growth and tree vitality measurements were recorded. The Sary-Chelek site consists of both coniferous and deciduous species. *Betula pendula* and *Picea schrenkiana*, both planted, are the most common forest forming species, followed by *Crataegus turkestanica*. Defoliation is modest for most species, but *Juniperus semiglobosa* was in the warning stage. The proportion of trees with discoloration was low, not exceeding 3.5%. The forest vitality at the site is acceptable, but future monitoring is strongly encouraged. The *size distributions* of the main forest-forming species suggest a similar *age class distribution*. In *Crataegus* the low proportion of small individuals indicates that regeneration is limiting. At this site it is uncertain whether there is any relationship between the current forest management and the forest condition, but it is important to be aware of the effect a management regime may have.

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. Fifty vascular plant species, of which 39 herbs, and seven bryophytes were recorded in the fifty 1-m^2 plots. The average number of plant species (vascular plants + bryophytes) recorded in the fifty 1-m^2 was 10.9. Vascular plants present in the 10x10 m macro plots and the 30x30 m extended macro plots were listed; altogether 63 species of vascular plants have been recorded, including the 50 species in the 50 1-m^2 plots. Of these 63 species of vascular plants, eleven are endemic to Central Asia (*Abies semenovii*, *Acer turkestanica*, *Allium semenovii*, *Astragalus sieversianus*, *Codonopsis clematidea*, *Crataegus songorica*, *Iris alberti*, *Juniperus semiglobosa*, *Lamium turkestanicum*, *Malus kirghisorum* and *Nepeta alatavica*), and one is endemic to the Kyrgyz Rebublic (*Exochorda tianschanica*). *Abies semenovii* is on the Red list of the Kyrgyz Republic. 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. Difference in altitude, influence of deciduous trees as well as crown cover, aspect and nutrient condition are some of the most important environmental conditions influencing the species composition according to these results. The variation in species composition in ground vegetation is thus strongly influenced by the mix of tree layer and variation in tree density between plots (affecting light and litter conditions), and by soil depth, aspect and nutrient conditions.

The mountains in the region are from dolomite origin and calcareous. The watershed in which the plots are set out does not contain any streams. The surplus of water goes directly via the underground to the nearby lake. The soils are relatively homogenous. The parent material is a loess deposit in which Cambisols have developed. Leptosols could develop on the few places with scree. The soil texture varied from loamy to clay soils. The area is generally well drained and no signs of gleyic/stagnic properties were found. No humus layer was found. The homogenous soil conditions in this area make it well suited to study also long term effects of land abandonment on vegetation and soil development

The soils at Sary-Chelek had circum neutral pH conditions at all sampling plots, though the pH is the lowest among the studied TEMP sites with a low base saturation on the cation exchanger. Base cations constitute only 36 and 31% of the oxide composition in the A and B horizons, respectively. Contrary to what is commonly found the pH decreases with depth. This is likely related to a slight increase in organic content, based on loss on Ignition (LOI). The amount of adsorbed phosphate (Ads. PO_4^{3-}) and total phosphorous (P) are the highest among the TEMP sites (256 and 904 mg/kg, respectively, in the A horizon). As also found elsewhere the values of Ads. PO_4^{3-} are negatively correlated to soil pH_{H2O} (r = -0.835). The content of iron (Fe) and aluminium (Al) are strongly correlated (r = 0.948). Deviations from this correlation are typically associated with elevated levels of trace elements. The content of a majority of the 16 measured trace elements were strongly correlated to the Fe and Al content. Important exceptions are the typically soft (or type B) elements 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 practically half of the variation in the dataset. The PCA 1 axis was mainly explained by the Al and Fe content relative to calcium (Ca) and total carbon content, reflecting variations in the 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 = 0.336 and 0.436 in the A and B horizons, respectively).

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

Adm.dir./Avdelingsdirektør

Oppdragsrapport fra Skog og landskap 08/2011

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

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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.

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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.:

Abdunaman Maksutov, Aitkul M. Burhanov, Ajar K. Madieva, Ajar K. Madieva, Almaz B. Kurmankulov, Asel Orokbaeva, Bakmurat Arabek uluu, Bakyt A. Mamytova, Beishekan Sultanova, C. Kysanov, Emma G. Beletskaya, Margarita Y. Kuznesova, Mirdin A. Mursaliev, Muhitdin Hamraliev, N. Mairykova, N. Polyanskaya, Nicholas Clarke, Nurgul K. Kuldanbaeva, Nuriya S. Isakunova, Oktyabrin A. Sadyrov, Oleg R. Mujdabaev, Omurbek Smat uluu, Salamat B. Imanakunov, Saltanat R. Narynbaeva, Sovetbek S. Murzakulov, Svetlana G. Nesterova, Taalai K. Mekishev, Turatbek S. Musuraliev, Umar Temirbaev, Venera M. Surappaeva.and Vladimir K. Schudro.

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, 22 November 2010

Tonje Økland

Project leader

CONTENT

INTRODUCTION

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

1: The Public Foundation Relascope
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 broadly similar to that observed in Western Europe: The over-exploitation of the timber resources in the first half of the 20th century resulted in a dramatic decline in forest cover, and led to the establishment of institutions with a mandate to improve forest management and restore depleted mountain forests.

In contrast to Western Europe, the period of timber exploitation was followed by a period of severe overgrazing, which further degraded the forest cover and interrupted natural regeneration. Today, large areas are affected by soil erosion and land degradation. More than 50% of the 10.6 million ha of arable land in the Kyrgyz Republic are affected.

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 TEMP-CA project. This output cannot be fully expressed in a report.

Recording of ground vegetation, tree variables, soil variables and other environmental conditions in the same permanent plots enables identification of the main complex gradients in vegetation and the environmental conditions. Identifying these gradients is necessary as a basis for interpretation of changes in the forest ecosystem due to both anthropogenic and natural stress factors. Regular re-analyses of these plots may reveal changes in tree vitality, species composition in ground vegetation, biodiversity changes and changes in soil chemistry, as well as relationships between changes in these components of the forest ecosystem. Thus, integrated monitoring in permanent plots provides: 1) a better understanding of relationships between the different components of the forest ecosystems, 2) basic knowledge and data from the forest ecosystem necessary for identifying effects of anthropogenic as well as natural stress factors and 3) a contribution to different aspects of relevance for forestry policy at national, regional and global levels, such as effects of climate change on the forests, sustainable forest management and biodiversity in forests.

In this report we present the main results from the fifth monitoring site established in the TEMP-CA project, Sary-Chelek in Jalal-Abad oblast in the Kyrgyz Republic. This monitoring site was established and analysed in 2007. Measurements of a lot of variables for forest tree condition, forest growth, soil chemistry, and soil classification, ground vegetation, and environmental factors were performed in 2007 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 SARY-CHELEK REFERENCE MONITORING AREA

Nurlan I. Kasymbaev[1], Adilet Usupbaev[2], Kuvanychbek S. Kasiev[2], Nurbek Kuldanbaev[1] and Farhat S. Asanov[2]

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

1.1 Geographical position of the reference monitoring area

The Sary-Chelek monitoring site is positioned within the Sary-Chelek State Biosphere Reserve, which is located in the north-eastern part of the Chatkal mountain range, in the Tien-Shan mountain province in the Central Asian Mountain region (Zinkova & Pushkareva 1987). Administratively the investigations area belongs to Aksy district of Jalal-Abad oblast, the Kyrgyz Republic.

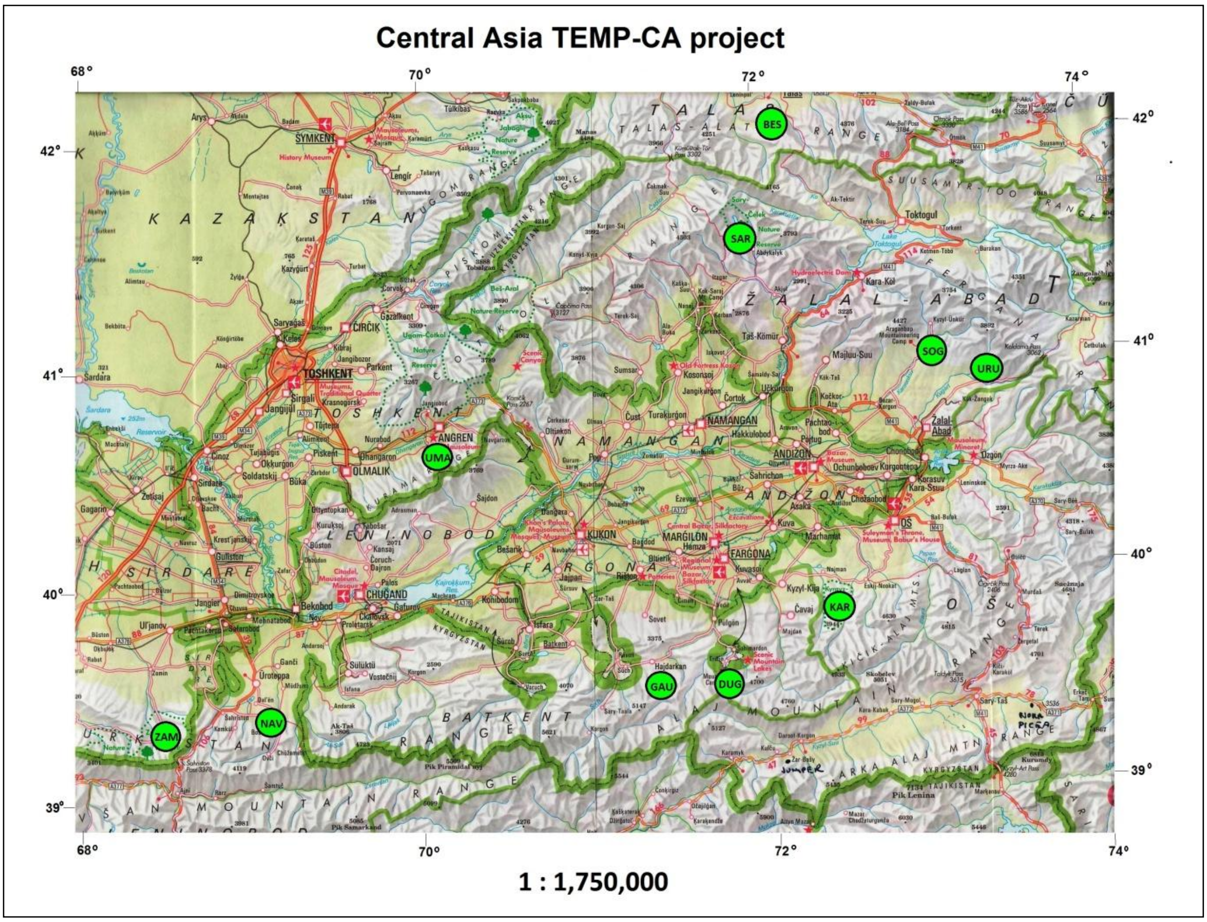

Fig. 1.1. Map of the Sary-Chelek (SAR) and the nine other TEMP-CA monitoring reference areas

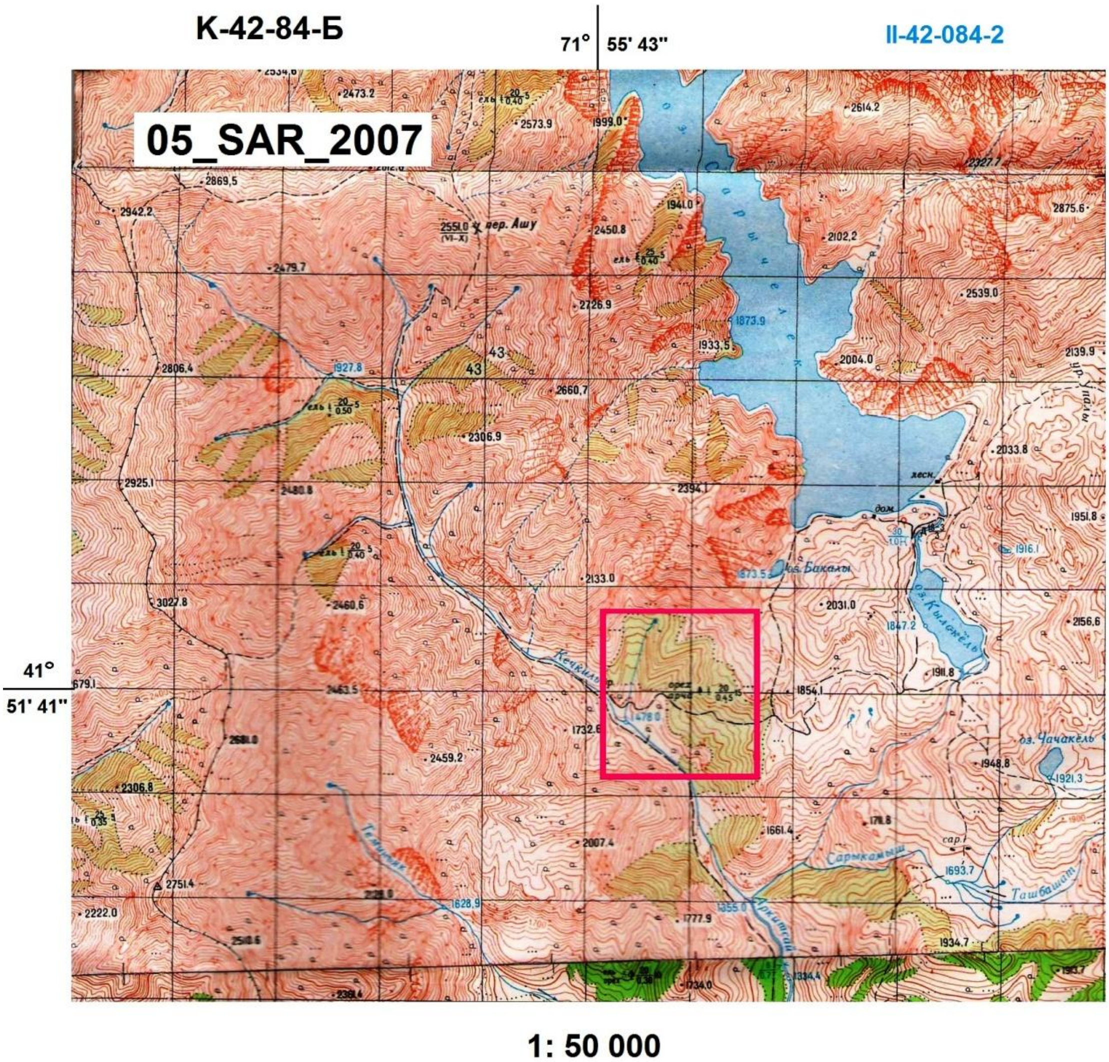

Fig. 1.2. Geographical position of the Sary-Chelek (SAR) monitoring reference area.

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	SAR 1	1879 m	41°52.115′
2	SAR 2	1918 m	41°52.047′
3	SAR 3	1881 m	41°51.986′
4	SAR 4	1923 m	41°51.967′
5	SAR 5	1901 m	41°51.940′
6	SAR 6	1904 m	41°51.929′
7	SAR 7	1903 m	41°51.938′
8	SAR 8	1929 m	41°51.873′
9	SAR 9	1957 m	41°51.866′
10	SAR 10	1948 m	41°52.034′

1.2 Forest type, ownership, and conservation status

Sary-Chelek State Biosphere Reserve is a regional, scientific, research and nature conserve institute established in accordance with the Resolution of Council of Ministers of the Kirgiz SSR dated May 5, 1959. This institute is an independent subdivision of the State Committee on Nature Protection of the Kyrgyz republic. The Reserve was established for the purpose of conservation, regeneration and development of vegetation and fauna on an area with great economic and scientific value. The Sary-Chelek biosphere reserve is included in the world network of UNESCO biosphere reserves.

Sary-Chelek Biosphere Reserve, which is one of western Tien Shan flora centers, has a high diversity of vegetation and fauna. The reserve's flora includes about 1200 plant species, of which about 130 are woody species. The mixed forest type consists of coniferous and deciduous species; among them are *Picea shrenkiana*, *Abies semenovii*, *Juniperus semiglobosa* (rare), *Juglans regia*, *Malus* spp., *Acer* spp., *Pyrus* spp., *Cerasus mahaleb* and *Betula turkestanica*. The diversity of bushes is also high, including among others species of the genra *Exochorda*, *Abelia*, *Prunus*, *Rosa*, *Lonicera*, *Berberis*, *Aflatunia*, *Evonimus*, *Ribes*, and *Spiraea*.

1.3 Geology, topography, and quaternary deposits

The Sary-Chelek site belongs to the western Tien Shan mountain group (Fergana, Chatkal, Pskem, and Kuramin mountain ranges), a part of the tectonic region of South Tien Shan. According to the geomorphologic zones this area is situated in the Chatkal-Fergana province and occupies the right bank of Syrdar'ya River.

The main features of the area are geosynclinal formations of various compositions dating from the medium and upper Paleozoic. The main linear folding is middle-Hercynian, with widely developed faults. The concluding folding is late Hercynian developed in the upper Paleozoic; with red-colored continental molass of the Permian fills in “residual red troughs”. The occurrences of upper-Paleozoic granitoid intrusions are limited, while alkaline magma intrusions are typical. The Paleozoic folded base with regional unconformity is overlain with Mesozoic and Cenozoic deposits that fill intermountain and sub-mountain troughs. The age for the formation of the mountain ranges and mountains is predominantly Pliocene and rare early Quaternary.

The mountain complex dominates together with developed sub-mountain, sub-mountain-valley and partly down-mountain-plain reliefs. The relief is made primarily by Paleozoic and Proterozoic bedrock; rarely by Mesozoic-Cenozoic rocks. The type of relief is tectonic-denudation and mainly erosion. The characteristic feature are deep and thick partitions (from 500 m up to 1000-1500 m and even up to 2000 m). Deep V-formed canyons with large amounts of debris and landslides at the bottom are typical. Relics of the ancient surface can often be found on slopes and in watersheds of the mountain ranges. The presence of water along the slopes, combined with a continental climate, causes fragmentation of the rocks due to frost.

1.4 Climate

The climate in the Sary-Chelek monitoring site is continental, characterized by considerable seasonal variation. The main wind directions are west and south-west (Ryazantseva 1965).

1.4.1 TEMPERATURE

The average annual temperature of the forest zone depends on the altitude and fluctuates from 15 to 25 °C (Tab. 1.2). The summer average monthly temperature is 19.3 °C. July is the warmest month (the absolute maximum is 29.3 °C) and January is the coldest month (the absolute minimum is -22.6 °C).

Tab. 1.2. The average temperature (°C) and precipitation (mm) at the nearest weather station, Ak-Terek.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des	Year
Temperature (°C)	-2.2	-1.7	2.6	9.5	13.2	17.7	20.5	19.9	15.9	9.7	4.6	0.6	9.2
Precipitation (mm)	78	81	111	157	142	87	47	25	33	92	96	81	1030

1.4.2 PRECIPITATION

The annual amount of precipitation on the territory slopes is 900-1050 mm. The maximum precipitation usually falls in spring (March-May). The minimum precipitation period is the end of summer and the beginning of autumn (Tab. 1.2).

1.5 Vegetation zones and sections

The Sary-Chelek monitoring site belongs to the ancient Mediterranean sub-kingdom of the Holarctic, Western Asian province, in the Fergana Valley region of the Central Asian Mountain area (Kamelin 2002). The vegetation cover of the Sary-Chelek investigation area is included in the unique western-Tien-Shan type of landscape zone structure. In the mountains six altitudinal belts follow in succession from a valley-sub-montane-desert to a glacier belt into highland. The high altitude zone structure is typical on the south-eastern slope of Chatkal Range (Zinkova & Pushkareva 1987).

1.6 Forest history, forest structure, and external influence

1.6.1 HUMAN IMPACT

Within the reserve economic activity not in accordance with the purpose of the reserve is prohibited. However, according to information from local foresters, about 40% of the reserve’s territory is exposed to human impact. Almost 20% of the reserve’s territory, or 28% of the vegetation cover, is in different degrees of degradation. Grazing, haymaking and wood harvesting have the largest impact on the reserve’s condition. About 1000 tones of hay are harvested every year along the road to the Sary-Chelek Lake and around the small lakes. Walnut and fruit forests located near the Arkyt village, and stretching up to the lake and partly around small lakes, are intensively used by the local people (haymaking, grazing, fruit and wood harvesting).

1.6.2 FOREST HISTORY

In the period from 1910 up to 1918 the Migratory Department Expedition of Russia had economic interests in the walnut-fruit forests of the Kyrgyz Republic. From 1930 to 1940 the forest departments went through a number of organizational reconstructions. The main economic interests of walnut sovkhozs in that time period were harvesting of wild fruits and improvement of growing conditions for wild trees.

From 1933 up to 1947 walnut and fruit sectors were under the authority of different ministries and departments. Repeatedly being turned from one ministry to another affected the conditions of the walnut forests. Then, following a 1944 USSR Governmental Order to investigate the production forces of the USSR, the Academy of Sciences sent an expedition under the direction of Vladimir N. Sukachev to the forests of South Kirgizia. After inspecting data from this expedition, especially with regards to the importance of walnut and fruit forests, the SNK of the USSR by its Resolution of April 30. 1945, declared special use conditions for the walnut and fruit forests of southern part of Kyrgyzstan. In 1948 all leskhozs of the southern part of Kyrgyzstan were passed to the Ministry of Forestry of Kirgiz SSR.

The Sary-Chelek Biosphere Reserve was included in the world wide net of biosphere reserves by the UNESCO Resolution of February 19, 1979 in consideration of flora and fauna diversity, original climatic conditions, and its importance for the science.

1.6.3 GRAZING

All monitoring plots were established in the middle of the protected area, where there are no marks of grazing. However, in the lower parts of the reserve, and around the small lakes, local people have grazing animals. There is a limit for stock keeping in the settlements close to the reserve (keeping of 2 cows with calf, 5 sheep with yeanlings, and 1 horse is permitted; while keeping dogs and goats is forbidden). According to information from workers at the reserve, the actual livestock is too large. This may explain overgrazing and degradation of pastures in parts of the reserve, as well as reductions of important fodder grass from the forest and its replacement by non-fodder and poisonous species.

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.

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 Sary-Chelek site consisted of both coniferous and deciduous species. The most common species were *Betula pendula* (24.4%), *Picea schrenkiana* (23.1%) and *Crataegus turkestanica* (20.3%) (Fig. 2.1). Less abundant species were *Juniperus semiglobosa* (10.8%), *Abies semenovee* (8%), *Malus kirghisorum* (7.8%) and *Cerasus mahaleb* (4.4%). In addition there were small amounts of *Acer turkestanica* (0.6%) and *Abelia corumbosa* (0.6%). *Picea schrenkiana* and *B. pendula* are planted.

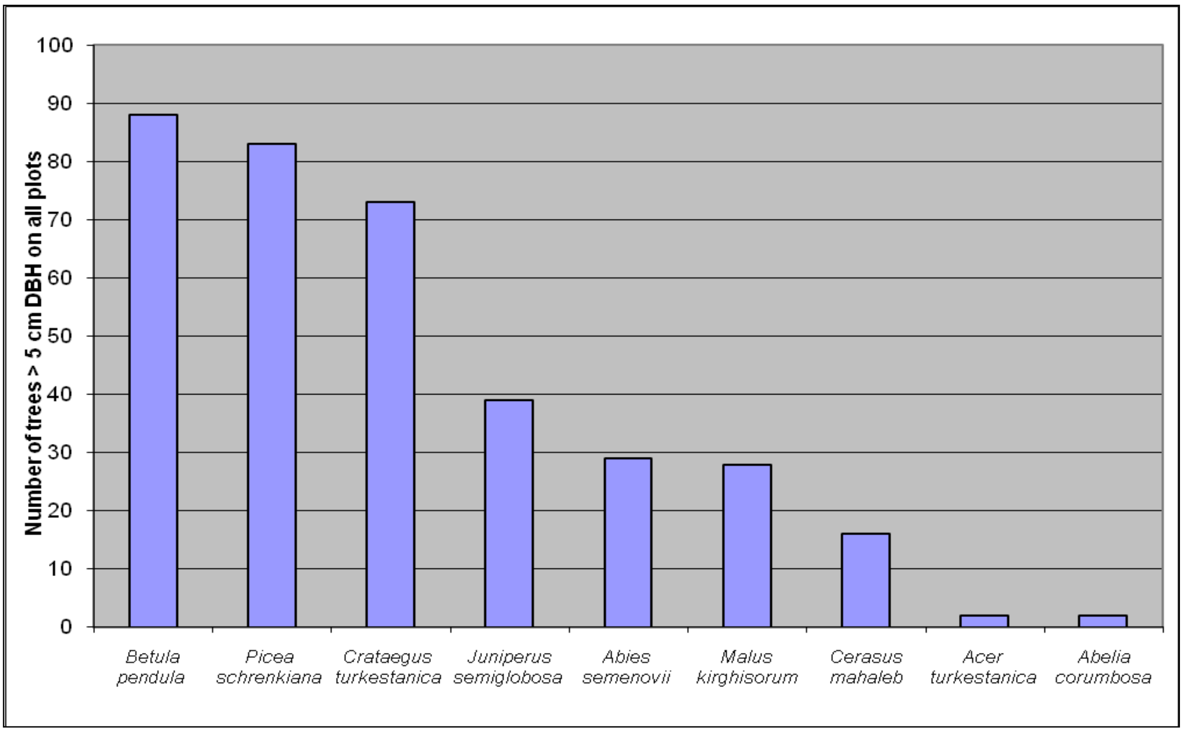

Fig. 2.1. Total number of trees of the different species > 5 cm DBH in all plots.

2.2.2 TREE CONDITION

Tree condition is only reported for abundant species with enough data to draw reasonable conclusions. According to Fig. 2.2 defoliation of all species at this site is relatively modest. Even *J. semiglobosa* with a defoliation of 20.6% belongs to the "warning stage" rather than being classified as “damaged”. The frequency of discolorated trees was limited, being 3.5% for *J. semiglobosa*, 2.8% for *C. turkestanica*, 1.2% for *P. shrenkiana* and 1.1% for *B. pendula*.

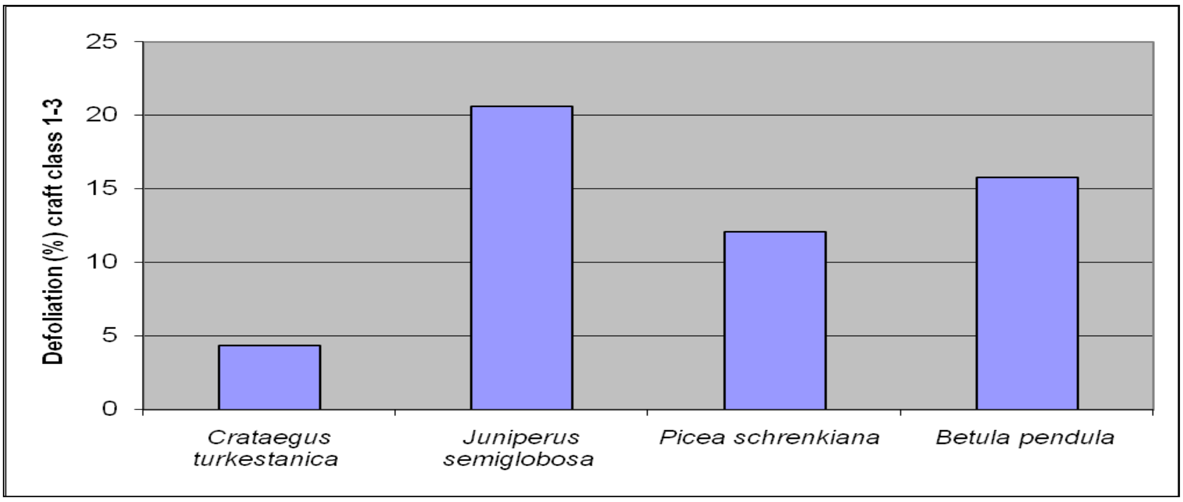

Fig. 2.2. Defoliation for the main species.

2.2.3 DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

The demography is presented only for two naturally growing forest-forming species.

The greatest number of *C. turkestanica* individuals was found in the intermediate size class with DBH 15-20 cm (39.7%) (Fig.2.3). The smallest size classes (DBH < 15 cm) constituted only about 33%, while individuals with DBH > 20 cm made up 27.3% of the individuals of this species.

Only 38 trees (> 5 cm DBH) of *J. semiglobosa* were found at the site (Fig.2.4). It is rather difficult to draw conclusions about the size distribution with such a small number of trees. Nevertheless, the two smallest size classes (DBH 5-15 cm and 15-25) were similar, and combined they constituted 36.8% of the juniper trees at the site. There were only 10 trees with DBH > 25 cm, which represents a proportion of 26.3%.

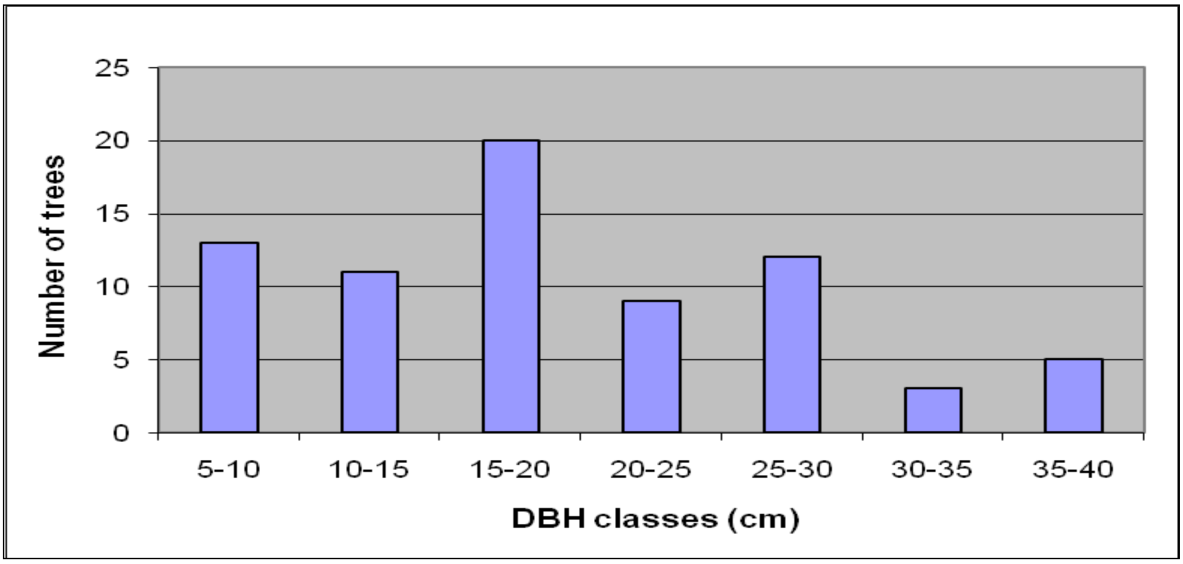

Fig. 2.3. Size distribution (DBH) of *Crataegus turkestanica* (all plots).

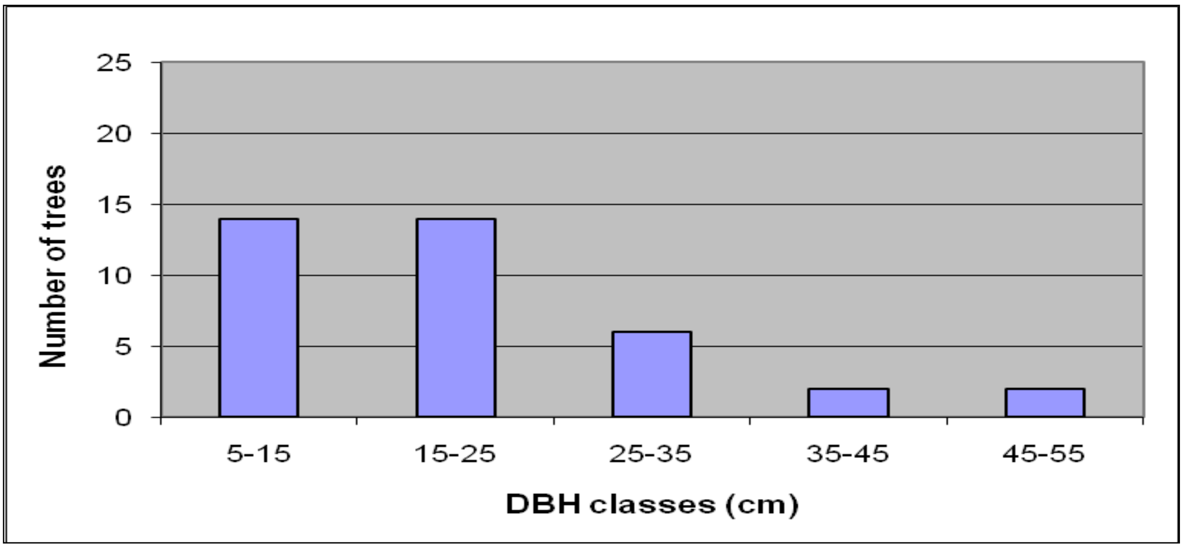

Fig. 2.4. Size distribution (DBH) of *Juniperus semiglobosa* (all plots).

2.3 Discussion

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

At this site the defoliation was limited. A maximum defoliation level of 20.6% was found for *Juniperus semiglobosa* (Fig. 2.2), which according to the ICP Forest classification is a warning level. In addition, the proportion of trees with discoloration was low, not exceeding 3.5%. Thus, the forest vitality at the site is acceptable, but future monitoring is strongly encouraged. Whenever symptoms of pathogens are observed samples of wood and needles should be collected for plant pathological and entomological investigations, particularly when the cause of injury cannot be assessed in the field.

Sufficient regeneration is fundamental for sustainable forests. The low proportion of small *Crataegus* individuals (DBH 5-15 cm) suggests that that its regeneration is limited, while the low number of *J. semiglobosa* individuals makes inferences about regeneration of this species uncertain. However, this project did not monitor natural regeneration as such, and we have limited information about individuals < 5 cm DBH: More specific investigations of abundance at the sapling stage is therefore required in order to conclude about natural regeneration.

At this site it is uncertain whether there is any relationship between the current forest management and the forest condition, but it is important to be aware of the effect a management regime may have. Heavy grazing can for instance hinder regeneration, while cutting of firewood may represent entries for pathogens that can affect forest health. Thus, in order to better monitor possible effects of management on forest condition we will propose some additions to the assessment method.

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. Recording species abundance in a 1-m^2 plot.

3.1.3 EXPLANATORY VARIABLES

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

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

(1) Topographical variables include:

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

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

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

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

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

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

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

(2) Tree influence variables include:

- Crown cover index
- Litter index
- Basal area

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

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

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

Litter index was 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:

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

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

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

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

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

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

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

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

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

3.1.4 ORDINATION METHODS

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

Ordination methods are used to summarize the main gradients in the vegetation of the sample plots. DCA (Detrended Correspondence Analysis; Hill 1979, Hill & Gauch 1980), one of the most common used multivariate statistical methods, was performed on subplot frequency data on 50 plots by means of CANOCO Version 4.54 (ter Braak & Šmilauer 1998), which are debugged according to Oksanen & Minchin (1997). Standard options were used (i.e. no down-weighting of species, nonlinear rescaling of axes and de-trending 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 the 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 for species recorded in the fifty 1-m^2 plots is given in Appendix 3.4. The number of vascular plant species within plots was calculated as: (a) the sum of species recorded within the five 1-m^2 plots in each 10x10 m macro plot, (b) the total number of species recorded in each 10x10 m macro plot included the species in the 1-m^2 plots, and (c) the total number of species in each 30x30 m extended macro plot included the species recorded in the 1-m^2 plots (c), Tab. 3.1. The ratio a/b and a/c was calculated for each macro plot.

All together 57 species of vascular plants and bryophytes were recorded in the 50 1-m^2 plots, of which six vascular plants are endemic to Central Asia (*Allium semenovii, Astragalus sieversianus, Codonopsis clematidea, Iris alberti, Lamium turkestanicum* and *Nepeta alatavica*), and one is endemic to Kyrgyzstan (*Exochorda tianschanica*). The average number of plant species recorded in the five 1-m^2 plots within the macro plots was 21.4.

The maximum number of vascular plant species recorded in five 1-m^2 plots within a macro plot was 29, while the minimum number was 10. The average number of vascular plant species recorded in five 1-m^2 plots within a macro plot was 19.1 (Tab. 3.1). The total number of vascular plant species recorded within the 50 1-m^2 plots + ten 10x10m^2 macro plots was 59, while the total number of vascular plant species in the 50 1-m^2 plots + ten 30x30m^2 extended macro plots was 63.

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	c Five 1-m^2 plots + 10x10 m + 30x30 m	Ratio a/b	Ratio a/c
1	29	32	34	0.91	0.85
2	15	21	25	0.71	0.60
3	17	22	25	0.77	0.68
4	22	27	32	0.81	0.69
5	22	27	30	0.81	0.73
6	13	20	25	0.65	0.52
7	25	29	32	0.86	0.78
8	20	24	27	0.83	0.74
9	10	15	20	0.67	0.50
10	18	23	28	0.78	0.64
Total number	50	59	63	0.85	0.79

When considering the 30x30 m extended macro plots, there were, in addition to the species mentioned for the 50 1-m^2 plots above, five more species endemic to Central Asia (*Abies semenovii, Acer turkestanica, Crataegus songorica, Juniperus semiglobosa* and *Malus kirghisorum*). Of these one species, *Abies semenovii*, is listed in the Red Data Book of Kyrgyz Republic (2006). The maximum number of species recorded in any of the 10x10 m macro plots (the five 1-m^2 plots included) was 32 and the minimum number was 15. The average number of species in the 10x10 m macro plots (the five 1-m^2 plots included) was 24. The ratio a/b varied between 0.65 and 0.91 (Tab. 3.1). The ratio a/c varied between 0.50 and 0.85 in the extended macro plots.

The plant species were divided into species groups, tree species, shrubs, herbs, ferns, graminoids, bryophytes and lichens (Tab. 3.2).

Tab. 3.2. Number of species in different species groups within each macro plot and in total.

Plot number	Tree species	Shrubs	Herbs	Ferns	Graminoids	Bryophytes	Lichens
1	0	2	22	0	5	2	0
2	1	0	11	0	3	0	0
3	0	0	14	0	3	0	0
4	0	0	19	0	3	6	0
5	0	0	19	0	3	6	0
6	0	0	10	0	2	5	0
7	2	2	18	0	3	4	0
8	0	1	17	0	2	0	0
9	0	0	9	0	2	0	0
10	0	0	15	0	3	0	0
Total number	**2**	**4**	**39**	**0**	**5**	**7**	**0**

3.2.2 MAIN GROUND VEGETATION GRADIENTS

DCA ordination of 50 plots is shown in Figs. 3.2-3.3. Gradient lengths; β-diversity, and eigenvalues for DCA 1-4 are given in Tab. 3.3.

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

	DCA 1	DCA 2	DCA 3	DCA 4
Eigenvalues	0.463	0.265	0.162	0.110
Gradient lengths	2.631	2.280	2.681	1.846

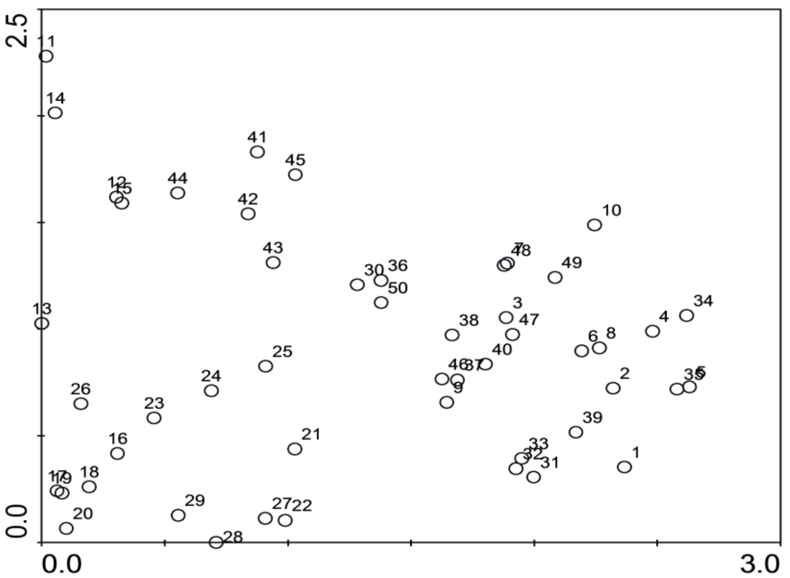

Fig. 3.2. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 2 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

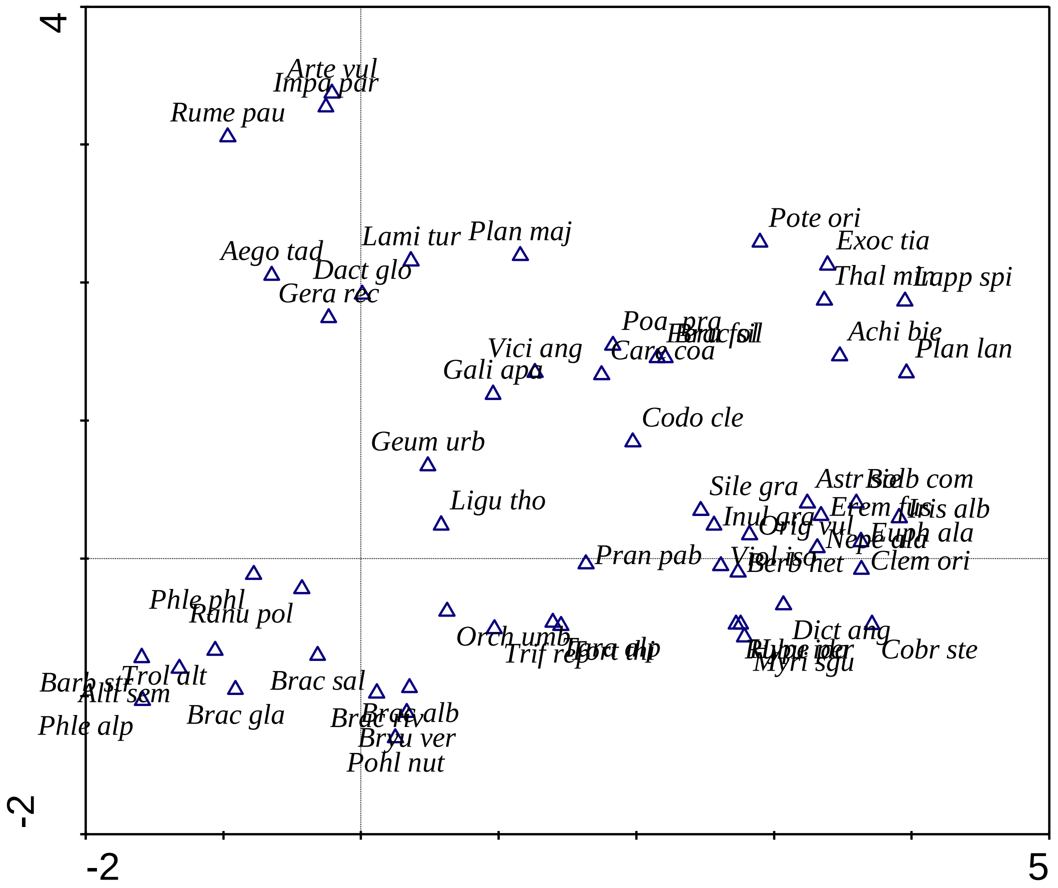

Fig. 3.4. DCA ordination of species in the 50 1-m^2 plots.

3.2.3 CORRELATION 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.

	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
DCA 1	*	*	-0.004	0.967	-0.086	0.380	0.097	0.320
DCA 2	-0.004	0.967	*	*	0.086	0.380	-0.074	0.447
DCA 3	-0.086	0.380	0.086	0.380	*	*	-0.029	0.770
DCA 4	0.097	0.320	-0.074	0.447	-0.029	0.770	*	*
Soil moisture	0.081	0.408	0.125	0.201	0.099	0.311	**-0.280****	0.004
Inclination	0.164	0.099	0.079	0.426	**0.370****	0.000	0.091	0.361
Aspect	**-0.412****	0.000	-0.023	0.815	0.043	0.663	0.140	0.155
Aspectfav	**0.202***	0.042	**0.200***	0.043	0.114	0.251	-0.061	0.541
Heat index	-0.024	0.808	0.081	0.408	-0.128	0.189	-0.141	0.148
Max. incl.	0.052	0.597	-0.014	0.887	0.069	0.486	0.054	0.586
Sum conc 1x1 m	**-0.281****	0.006	-0.103	0.311	-0.003	0.973	-0.029	0.774
Var. conc 1x1 m	-0.171	0.087	-0.166	0.097	**-0.428****	0.000	-0.054	0.591
Abs. sum conc 1x1 m	**-0.199***	0.048	-0.166	0.098	**-0.432****	0.000	-0.035	0.730

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

	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
Sum conc. 3x3 m	**-0.263***	0.011	-0.199	0.055	**-0.274****	0.008	-0.119	0.252
Var. conc. 3x3 m	**-0.284****	0.005	-0.150	0.141	-0.152	0.136	-0.021	0.839
Abs. sum conc. 3x3 m	**-0.278****	0.007	-0.166	0.107	**-0.210***	0.042	0.035	0.734
Rel. deciduos trees	-0.169	0.110	**0.499****	0.000	0.059	0.574	**-0.412****	0.000
Rel.conifer trees	-0.140	0.165	**-0.487****	0.000	0.013	0.900	**0.286****	0.005
Rel. total	**-0.584****	0.000	-0.037	0.711	0.031	0.761	0.002	0.987
Crown cover index	**-0.373****	0.000	0.083	0.429	0.144	0.166	-0.144	0.166
Litter index	**-0.267***	0.016	**0.340****	0.002	0.016	0.888	-0.103	0.355
Average grass height	-0.161	0.104	0.078	0.431	-0.106	0.283	-0.178	0.073
Average shrub height	**0.300***	0.010	0.100	0.391	-0.067	0.568	**0.286***	0.014
% cover animal dung	**-0.249***	0.032	-0.008	0.943	0.166	0.153	-0.124	0.284
Max. soil depth	**-0.323****	0.001	0.019	0.847	0.157	0.113	-0.132	0.182
Min. soil depth	**-0.364****	0.000	0.057	0.563	-0.012	0.900	-0.124	0.211
Med. soil depth	**-0.295****	0.003	0.042	0.669	0.114	0.245	-0.142	0.148
Max. org. layer depth	**0.454****	0.000	-0.039	0.704	0.168	0.099	0.125	0.221
Min. org. layer depth	**0.376****	0.000	0.021	0.847	**0.271***	0.012	0.197	0.066
Med org. layer depth	**0.447****	0.000	-0.015	0.886	0.184	0.069	0.145	0.154
Max. litter depth	**0.413****	0.000	0.087	0.407	0.078	0.458	0.133	0.208
Min. litter depth	**0.244***	0.025	**0.229***	0.035	**0.213***	0.050	0.176	0.104
Med. litter depth	**0.375****	0.000	0.125	0.208	0.144	0.149	0.181	0.070
Altitude	-0.045	0.656	0.152	0.132	**0.384****	0.000	0.120	0.235
pH	**0.330****	0.001	0.143	0.143	0.057	0.564	-0.140	0.152
H+	**-0.330****	0.001	-0.143	0.143	-0.057	0.564	0.140	0.152
Dry matter	**0.312****	0.001	0.147	0.132	0.029	0.763	0.011	0.907
LOI	**0.236***	0.016	-0.046	0.639	-0.039	0.688	-0.008	0.933
Ctot	**0.496****	0.000	-0.084	0.389	0.020	0.834	-0.087	0.371
Ca	**0.321****	0.001	0.127	0.195	0.113	0.245	-0.076	0.437
Mg	0.115	0.238	-0.151	0.122	**-0.203***	0.037	-0.053	0.587
K	**0.227***	0.022	0.109	0.274	-0.052	0.602	0.005	0.960
CEC c mol+/kg	-0.140	0.153	0.149	0.126	-0.069	0.477	-0.174	0.075
Total N	**0.345****	0.000	-0.075	0.442	0.010	0.920	-0.134	0.170
Ca, ppm	**0.433****	0.000	-0.071	0.467	0.004	0.967	**-0.195***	0.046
Mg, ppm	**0.254****	0.009	**-0.221***	0.023	-0.172	0.078	-0.179	0.067
Na, ppm	0.077	0.435	-0.152	0.125	-0.031	0.756	**-0.266****	0.007
K, ppm	**-0.308****	0.002	-0.169	0.083	-0.009	0.927	-0.189	0.053
Al, ppm	**-0.303****	0.002	-0.115	0.238	0.143	0.143	-0.099	0.311
Fe, ppm	**-0.231***	0.018	-0.187	0.055	0.032	0.744	-0.092	0.345
Mn, ppm	-0.030	0.757	**-0.224***	0.021	**-0.238***	0.015	-0.097	0.320
P, ppm	-0.112	0.252	**-0.267****	0.006	**-0.215***	0.028	-0.117	0.232
Ca/LOI*100	-0.006	0.953	0.117	0.232	0.061	0.530	-0.014	0.887
Mg/LOI*100	-0.025	0.795	-0.131	0.178	**-0.216***	0.027	-0.033	0.732
K/LOI*100	0.135	0.168	0.094	0.336	0.019	0.847	-0.027	0.783
CEC/LOI*100	-0.154	0.114	0.066	0.498	-0.032	0.744	-0.104	0.288
Total N/LOI*100	0.009	0.927	-0.002	0.980	0.053	0.587	-0.074	0.447
Ca, ppm/LOI*100	0.144	0.139	-0.007	0.940	-0.096	0.328	-0.027	0.783
Mg, ppm/LOI*100	0.001	0.993	-0.033	0.732	-0.118	0.225	0.002	0.980
Na, ppm/LOI*100	**-0.218***	0.026	0.019	0.847	0.025	0.795	-0.047	0.634
K, ppm/LOI*100	**-0.280****	0.004	0.025	0.795	0.029	0.770	-0.024	0.808

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

	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
Al, ppm/LOI*100	**-0.252****	0.010	0.030	0.757	0.040	0.682	0.007	0.940
Fe, ppm/LOI*100	**-0.246***	0.012	0.020	0.834	0.027	0.783	0.011	0.913
Mn, ppm/LOI*100	**-0.210***	0.032	0.020	0.834	0.001	0.993	-0.029	0.770
Zn, ppm/LOI*100	**-0.228***	0.020	0.032	0.744	0.022	0.821	0.012	0.900

3.3 Discussion

3.3.1 GENERAL DESCRIPTION OF VEGETATION AND GROUND VEGETATION BIODIVERSITY

The vegetation of the Sary-Chelek monitoring site is unique and of special interest. It lacks species typical for the sagebrush deserts and bluegrass steppes of central Tien Shan. The tree layer of the monitoring site was mixed and consisted of species like *Abies semenivii*, *Acer turkestanic*, *Crataegus songorica*, *Juglans regia*, *Malus sieversiana*, *Picea schrenkiana*, *Prunus sogdiana* and *Pyrus communis*.

The species composition of shrubs included *Euonymus semjenovii*, *Exochorda tianschanica, Lonicera lanata* and *Rosa kokanica.* The grass and herb layer was mainly dominated by *Brachypodium silvaticum* and *Phleum phleoides*, but *Aegopodium tadshikorum*, *Carex divisa* and *Lamium turkestanicum* was occasionally dominating. Examples of other species occurring were *Cobresia stenocarpa, Euphorbia alatavica, Galium aparine, Hypericum perforatum, Inula macrophylla, Phleum phleoides, Vicia angustifolia* and *Viola isopetala.*

As many as 39 of the 50 (i.e. 78%) vascular plant species recorded in the 50 1-m^2 plots were herbs; many of them meadow species. Only seven bryophyte species were recorded.

3.3.2 INTERPRETATION OF GROUND VEGETATION GRADIENTS

The vegetation gradients in the Sary-Chelek monitoring area, as expressed by the DCA ordination axes, are strongly influenced by the mix of tree layer and variation in tree density between plots. Most frequent dominating trees were *Betula pendula*, *Crataegus turkestanica* and *Picea schrenkiana* (see chapter 2). Accordingly, the variable with the strongest (negative) correlation with DCA 1 axis was *relascope sum total*, expressing tree density. Variables with a significant negative correlation with DCA 1 were *minimum soil depth* and *aspect*, indicating that sites with the highest tree density also have the deepest soil layer, and that plots differ in aspect along DCA 1. *Depth of organic soil layer*, *litter depth*, *pH*, and several other variables representing a nutrient gradient, were positively correlated with DCA 1. These correlations indicate a gradient from nutrient poor, low pH sites in a relatively dense forest, to more nutrient rich, high pH sites in a more open forest.

For DCA 2 the variable with strongest (positive) correlation was *relascope sum of deciduous trees*, while *relascope sum of conifer trees* showed a strong negative correlation with this axis. Thus, several plots with low DCA 2 scores are from sites dominated by coniferous trees, while some plots with high DCA 2 scores are from sites dominated by deciduous trees. Also the *litter index* was positively correlated with DCA 2, meaning that plots with high scores along this axis contain more litter, i.e. are from sites more influenced by deciduous trees.

Some variables were strongly correlated with DCA 3 and DCA 4, but except for *inclination* and *altitude* (both positively correlated with DCA 3) and some of the variables expressing micro-topography (negatively correlated with DCA 3), most variables were more strongly correlated with DCA 1 or DCA 2 than with DCA 3 and DCA 4.

The variation in species composition in ground vegetation in Sary-Chelek is thus mainly due to influence by different tree species affecting light and litter conditions and to some degree to differences in soil depth, nutrient conditions and aspect

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 species
Achillea bieberschteinii	Биберштейн каз таңдайы	Тысячелистник Биберштейна
Aegopodium tadshikorum	Тажик элик балтырканы	Сныть таджикская
Allium semenovii	Семенов пиязы	Лук Семенова
Artemisia vulgaris	Кадимки шыбак	Полынь обыкновенная
Astragalus sieversianus	Сиверс астрагалы	Астрагал Сиверса
Barbarea stricta	Түз кычы	Сурепка прямая
Berberis sphaerocarpa	Бөрү карагат	Барбарис разноножковый
Bolboschoenus compactus	Суучул түймөк камыш	Клубнекамыш морской
Brachypodium silvaticum	Токой брахиподиуму	Коротконожка лесная
Carex divisa	Топтолгон ыраң	Осока скученная
Clematis orientalis	Чыгыш жебелгеси	Ломонос восточный
Cobresia stenocarpa	Ичке мөмөлүү доңуз сырты	Кобрезия узкоплодная
Codonopsis clematidea	Коңгуроодой сасык гүл	Кодонопсис ломоносовидный
Dactylis glomerata	Топтолушкан ак сокто	Ежа сборная
Dictamnus angustifolius	Ичке жалбырактуу диктамнус	Ясенец узколистный
Eremurus fuscus	Күрөң чыраш	Еремурус загорелый
Euphorbia alatavica	Ала-Тоо сүттүү чөбү	Молочай алатавский
Exochorda tianschanica	Тянь-Шань жыттуу ак гүлү	Экзохорда тяньшанская
Ferula foliosa	Жалбырактуу чайыр	Ферула лиственная
Galium aparine	Жабышчак галиуму	Подмаренник цепкий
Geranium rectum	Түз каз таманы	Герань прямая
Geum urbanum	Шаар геуму	Гравилат городской
Hypericum perforatum	Көзөнөкчөлүү сары чай чөп	Зверобой продырявленный
Impatiens parviflora	Майда гүлдүү кына	Недотрога мелкоцветковая
Inula macrophylla	Чон карындыз	Девясил большой
Iris alberti	Альберт чекилдеги	Ирис Альберта
Lamium turkestanicum	Түркстан дүлөй чалканы	Яснотка туркестанская

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

Latin names of species	Kyrgyz names of species	Russian names of species
Lappula spinocarpos	Майда мөмөлүү кара кыз	Липучка мелкоплодная
Ligularia thomsonii	Томсон кой жалбырагы	Бузульник Томсона
Myricaria sguamosa	Түпүчөлүү жылгын	Мирикария чешуйчатая
Nepeta alatavica	Ала-Тоо непетасы	Котовник алатавский
Dactylorhiza umbrosa	Көлөкөлүү арала	Ятрышник тенистый
Origanum vulgare	Кадимки көк чай чөп	Душица обыкновенная
Phleum alpinum	Альпы кыягы	Тимофеевка альпийская
Phleum phleoides	Кара кыяк	Тимофеевка степная
Plantago lanceolata	Ичке бака жалбырак	Подорожник ланцетолистный
Plantago major	Чоң бака жалбырак	Подорожник большой
Poa pratensis	Шалбаа жылганы	Мятлик луговой
Potentilla orientalis	Чыгыш каз таманы	Лапчатка восточная
Prangos pabularia	Тою аюу чачы	Прангос кормовой
Ranunculus polyanthemus	Көп гүлдүү байчечекей	Лютик многоцветковый
Rubus caesius	Көгүлтүр кара бүлдүркөн	Ежевика сизая
Rumex paulsenianus	Паульсен ат кулагы	Щавель Паульсена
Silene graminifolia	Кара кыяк жалбырактуу чайыр гүлү	Смолевка злаколистная
Taraxacum alpigenum	Бийик тоо какымы	Одуванчик высокогорный
Thalictrum minus	Кичинекей тармал чөп	Василистник малый
Trifolium repens	Сойломо уй беде	Клевер ползучий
Trollius altaicus	Алтай троллиусу	Купальница алтайская
Vicia angustifolia	Ичке жалбырактуу жер буурчак	Вика узколистная
Viola isopetala	Тең желекчелүү ала гүл	Фиалка равнолепестная
Brachythecium albicans	--	--
Brachythecium glaciale	--	--
Brachythecium rivulare	--	--
Brachythecium salebrosum	--	--
Bryum vernum	--	--
Pohlia nutans	--	--
Tortulla thianschanica	--	--

4 SOIL CLASSIFICATION AND SOIL DESCRIPTION

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

4.1 Methods

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

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

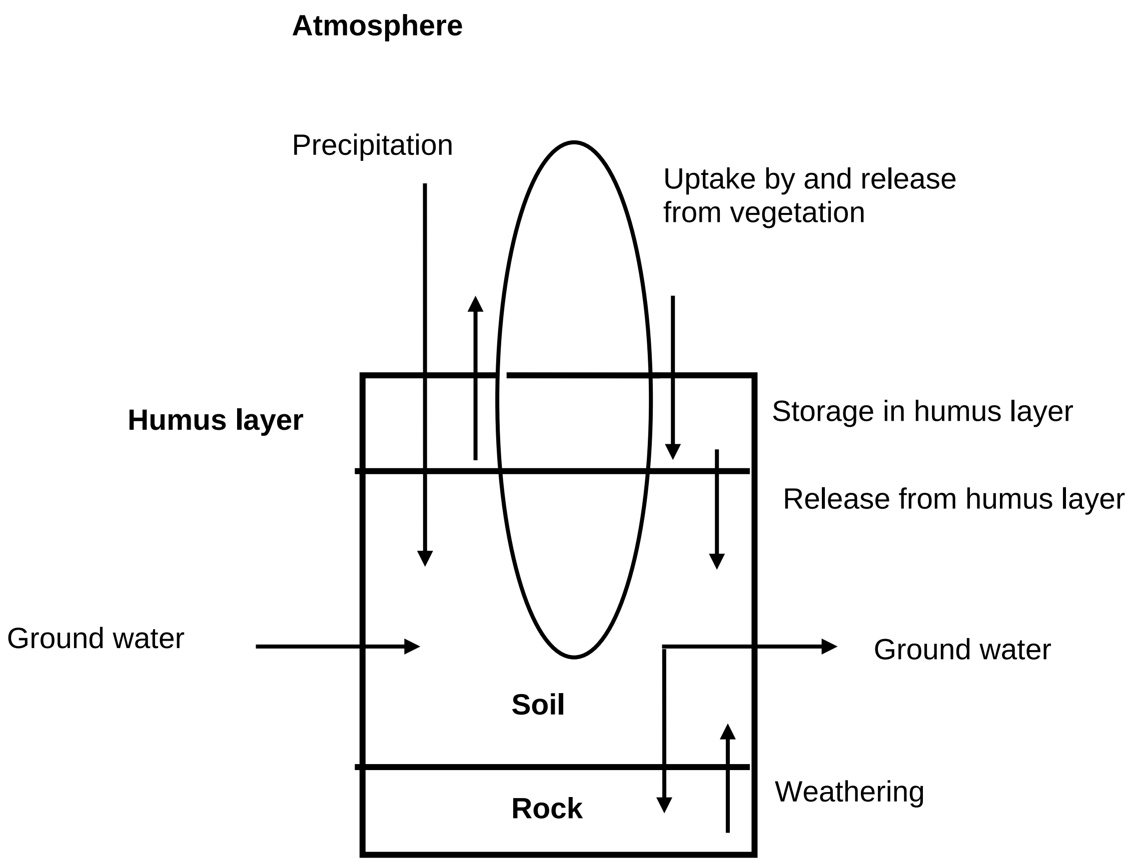

Fig. 4.1. Simplified model of biogeochemical cycling of elements.

The methodology for placing the macro plots and 1-m^2 vegetation plots is described in 3.1.1. The altitude of the macro plots varied from 1885 to 1960 m a.s.l. During the 2nd – 3rd of June 2007 soil samples were taking from each 1x1-m^2 plot. Field work was done under sunny circumstances. Some days before there were a few thunderstorms. 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

Grazing by cattle has not been allowed in the area since 1959. The land abandonment has resulted in an increased forest/shrub growth and in the development of ruderal vegetation.

The mountains in the region were of dolomite and calcareous origin. The soils were relatively homogenous. The soil texture varied from loamy to clay soils. In general, the soil was well drained and no signs of gleyic/stagnic properties were found. Soil moisture varied within and between the macro plots from 14% to 38%. Macro plot 2 was generally drier. The watershed in which the plots were positioned did not contain any streams. Surplus water goes directly via the underground to the nearby lake.

The parent material was a loess deposit in which Cambisols had developed, and on a few places with scree Leptosols had developed. No humus layer was found; and 1 – 2 horizons were usually sampled for each 1x1-m^2 plot. On the leptosols (macro plot 1, 2, 7, 10) only the A horizon could be sampled. In the other macro plots both the A and B horizon were present. The sampling depth was in most cases 3 – 7 cm for the A horizon and 40 – 45 cm for the B horizon.

On the Cambisols the A horizon was coloured light brown and the texture varied from loam to clay. The B horizon was characterised by increasing clay content with increasing soil depth. Sometimes stones in the soil matrix reacted with HCl, indicating the presence of free chalk. The soil material itself, however, never reacted with HCl. On the Leptosols the A horizon was dark coloured by humus. Stones in the underground reacted in many cases with HCl.

The soil pH was often just below pH 7, except for macro plots 7, 8, and 9, which showed high to very high pH levels. Especially macro plots 7 and 8, which originated from scree material of limestone. The levels of total carbon varied from about 1% (in macro plots 2 and 9) to 17.2% (in macro plot 7).

The heavy metal content varied. The levels of Arsenic (As) were variable but low; highest in macro plot 1, 2, 6 and 7. Cadmium (Cd), mercury (Hg) and antimony (Sb) showed low to very low levels. Strontium (Sr) showed variable but higher levels; with remarkable high levels in macro plot 8. Zink (Zn) was variable, with highest levels in macro plots 1 and 6.

4.3 Discussion

Soil conditions are relatively homogenous, so it should be possible to analyse the influences of minor changes in soil condition. pH in soil is low compared to many other TEMP-CA sites and soil mineral base cation (Ca+Mg+Na+K). is relatively low (see chapter 5). However, effects of acid precipitation on soil will probably appear after a (very) long time. It is most likely that the heavy metals in the area originate from the geological underground.

In this area also long term effect of land abandonment on vegetation and soil development can be studied.

5 SOIL CHEMISTRY

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5.1 Methods

5.1.1 SAMPLING DESIGN

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

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

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

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

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

5.1.2 SOIL CHEMISTRY PARAMETERS

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

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

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

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

5.1.3 SOIL CHEMISTRY ANALYSES

Samples from Sary-Chelek were analyzed at Alex Steward Laboratories, Kara Balta, the Kyrgyz Republic.

5.1.3.1 Dry matter

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

5.1.3.2 Soil pH

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

5.1.3.3. Total and organic carbon (C)

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

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

5.1.3.4 Total nitrogen (N)

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

5.1.3.5 Effective CEC

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

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

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

5.1.3.6 Loss on ignition (LOI)

Procedure from Krogstad (1992):

Weigh a porcelain crucible using an analytical balance (m_1). Approx. 3 to 5 g air-dried soil passed through a 2.00 mm aperture sieve is weighted accurately using an analytical balance in the crucible (m_2) and glowed in a furnace at 550 ± 25 °C using a Carbolyte Muffle furnace for more than 3 hours. The crucible with dried soil must cool down for more than 30 minutes in an 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:

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

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

Detection:

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

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

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

Calculation:

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

where:

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

5.1.3.8 Inorganic Sulphate adsorption

Principle:

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

Reagents:

Calcium phosphate monohydrate solution [$Ca(H_2PO_4)_2 \cdot H_2O$], 100 ppm of P:
Dissolve 0.41 g $Ca(H_2PO_4)_2 \cdot H_2O$ in about 700 mL ion exchanged water, and make to volume of 1.000L with ion exchanged water.
Calcium chloride dihydrate ($CaCl_2 \cdot 2H_2O$), 0.15%:
Dissolve 1.5 g of $CaCl_2 \cdot 2H_2O$ in about 700 mL ion exchanged water, and make to volume of 1.000 L with ion exchanged water.

Procedure:

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

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

Detection:

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

Calculation:

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

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

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

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

5.1.3.9. ICP-AES metal scan

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

5.1.3.10 Extractable sulphate

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

5.2 Results

Average soil chemical data for each horizon are presented in Tab. 5.2. Circum neutral pH conditions prevailed at all the sampling plots, though the pH was the lowest among the studied TEMP sites. Contrary to what is commonly found the pH decreased with depth. This is likely related to a slight increase in organic content, based on Loss on Ignition (LOI). No significant correlation was found between LOI and the carbon content (% C_{tot}), despite a low content of calcareous minerals (see below). Nevertheless, the % C_{tot} at this site was as commonly found correlated to the total nitrogen content (tot N; r = 0.837), magnesium (Mg; r = 0.713) and negatively correlated to iron (Fe; r = -0.782), lanthanum (La; r = -0.770) and beryllium (Be; r = -0.839). The amount of adsorbed phosphate (Ads. PO_4^{3-}) was the highest among the TEMP sites. As found elsewhere the values of Ads. PO_4^{3-} are negatively correlated to soil pH_{H2O} (r = -0.835). Adsorbed sulphate (Ads. SO_4^{2-}) were, with a few exceptions, below the detection limit (0.01 g/kg).

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

Horizon	Number of samples	pH_{H2O}	LOI	C total	Total N	Ads. SO_4^{2-}
			w/w%		µg/g	
A	50	6.47	10.0	5.7	3464	256
		6.3 – 7.5	5 - 15	4 - 7	2300 - 4333	28 - 423
B	32	6.26	11.8	2.1	1227	260
		6.3 – 7.8	7 - 16	1 - 2	408 - 1523	14 - 450

In addition to SiO_2 (not measured) the main (avg. value > 3.5 mg/g) oxide composition of the mineral soils (Fig. 5.1) is made up by iron (Fe) and calcium (Ca), followed by aluminium (Al) and magnesium (Mg). The data indicate that the soil mineral base cation (Ca+Mg+Na+K) content in the A and B horizons are relatively low. The base cations constitute 36 and 31% of the oxide composition in the A and B horizons, respectively. This fits well with the overall low soil pH found at this site. This is a site that may be sensitive to anthropogenic acidification due to acid rain.

The content of Fe and Al are strongly correlated (r = 0.948). Deviations from this correlation are typically associated with elevated levels of trace elements. Fe and Al are as always negatively correlated to Ca, though this correlation is poor; r = -0.524 and -0.370, respectively. The Fe content is also correlated with potassium (K; r = 0.707).

The major oxide elements presented in Fig. 5.1 are followed in abundance by phosphorous (P), manganese (Mn) and titanium (Ti) (Tab. 5.3). The high level of P reflects the highest amount of adsorbed phosphate (Ads. PO_4^{3-}) among the TEMP sites (see above). Ti and La are strongly correlated (r = 0.838) and both elements are negatively correlated to % Ctot (r = -0.512 and -0.770), and as usual positively correlated to Al (r = 0.818 and 0.916) and Fe (0.804 and 0.934), in addition to a number of trace elements (Cu, Cr, Ni, Co and V). The amount of Ti was relatively high compared to e.g. sodium (Na). Na, having 11 samples with below detection limit values, was only correlated with strontium (Sr; r = 0.721). No strong correlations were found for P and Mn.

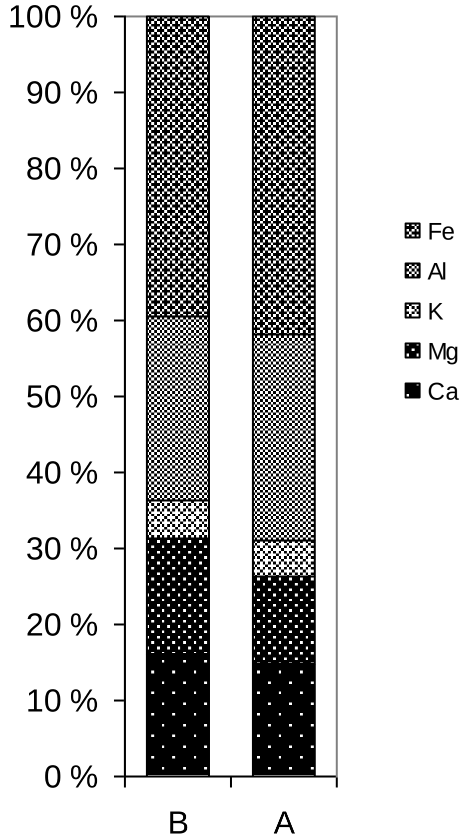

Fig. 5.1. Main (avg. value > 3.5 mg/g) oxide composition of the mineral soils.

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		
A	904	749	457	119	19,3
	834 – 981	719 - 787	422 – 524	107 - 131	19 - 21
B	737	757	550	126	22,5
	697 - 788	751 - 784	527 - 588	112 - 133	22 -23

Soil composition of measured trace elements along with the composition of continental crust (Taylor and McLennan, 1985) and selected heavy metal contamination norms (Lacatusu, 1998) are presented in 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), molybdenum (Mo), lead (Pb) and cadmium (Cd), as found in all 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						
Sary-Chelek	A	9.5	178	26	24	0.5	27	36	90	33	14	43	4.1	10	4.4	1.1	2.0
	B	8.8	178	30	20	0.4	28	41	85	39	16	49	5.0	11	5.0	1.2	1.9

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

Al and Fe content is strongly correlated to the abundance of a majority of the 16 measured trace elements (Fig. 5.2), as found at most of the TEMP sites. Important exceptions are as usual the soft (or type B) metals lead (Pb), cadmium (Cd) and arsenic (As) and the hard (type A) elements barium (Ba) and strontium (Sr). Molybdenum (Mo) gave no significant correlations due to a majority of samples below detection limit. Soft metals (high covalent index) were instead generally found to be correlated only to each other (see Tab. 5.5) and negatively correlated to hard (type A) metals (e.g. Ca, Mg, and Sr). The variation in the content of hard element strontium (Sr) follow the other type A elements, such as Ca levels (r = 0.892). This is also found in the other TEMP sites.

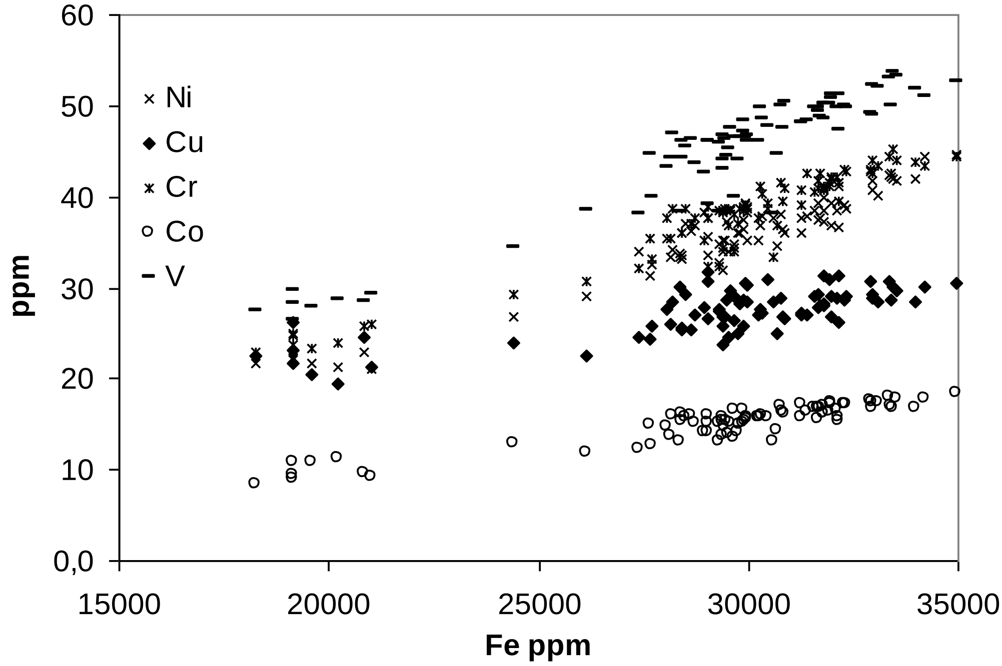

Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements nickel (Ni), copper (Cu), chrome (Cr) cobolt (Co) and vanadium (V).

A large number (25) of strong correlations were found between the 16 measured trace elements (Tab. 5.5). As usual the borderline elements Ni, Co and Vanadium (V) showed the largest number of strong correlations. The typical soft (or type B) elements (Pb, Mo, Cd and As) and the hard (or type A) elements (Ba, Sr) were the poorest correlated to the other trace elements.

The exception is that no strong (r > 0.7) correlations were found for zinc (Zn). Considering the lack of correlation, that the amount of Zn was high compared to earth crust, and that the Zn concentration was higher in the top horizon than deeper in the soil profile may indicate that there may be an anthropogenic deposition of zinc at this site.

Tab. 5.5. The strongest sets of correlations (i.e. r > 0.700) found for each of the measured 16 trace elements in 50 A and 50 B horizon samples from Sary-Chelek. 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	0	-	-
Cu	5	Ni	0.834
Co	7	Cr	0.956
Ni	8	Cr	0.938
Zn	0	-	-
V	8	Cr	0.984
Be	5	V	0.952
Cr	7	V	0.984
Sc	4	Ni	0.861
Y	2	Ni	0.773
Zr	4	Ni	0.849
Ba	0	-	-
Sr	0	-	-

5.3 Discussion

The role of Fe content as a governing factor for the soil chemical content of trace elements can be illustrated by a Principal Component Analysis (PCA) (Minitab®). In the plane of the first two principal components (PCA 1 and PCA 2), for both the A- and B horizons, the Fe is clustered together with Al and most trace elements (except Pb, Mo, Cd, As, Ba and Sr) (Fig. 5.3). Negatively loaded to this cluster along the PCA 1 axis we find a cluster of Ca and Sr, together with % Ctot, especially in the A horizon. In the B horizon the PCA 1 and PCA 2 axes explains 48 and 18% of the variation in the data set, respectively. The PCA 1 axis is mainly explained by a strong loading of Fe on the one side and Ca on the other. The PCA 2 axis at these sites may partly be explained by the Covalent index (CI = X2r) 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, Ba and Sr) have generally opposite loading to more type B elements (Pb, Mo, Cd, As). Borderline metals have generally low loading along PCA 2. Instead they are strongly clustered with Fe and Al. In the A and B horizons the PCA 2 axis is correlated with the Covalent index with an r = 0.336 and 0.436, respectively.

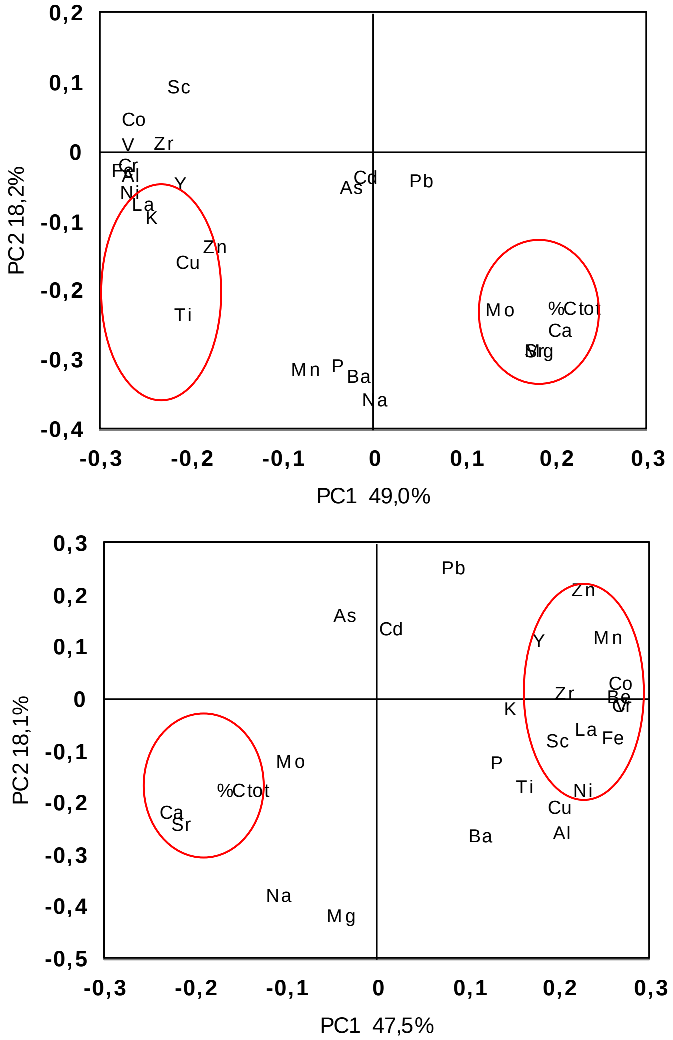

Figure 5.3. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 67.2 and 65.6% of the variation in soil elemental composition, respectively.

REFERENCES

Allaway W.H. 1968. Agronomic controls over the environmental cycling of trace elements. Advan. Agronomy 29: 235-74.

Eilertsen O., Økland R.H., Økland T. & Pedersen O. 1990. Data manipulation and gradient length estimation in DCA ordination. J. Veg. Sci. 1: 261-270.

Heikkinen R.K. 1991. Multivariate analysis of esker vegetation in southern Häme, S Finland. Ann. Bot. Fenn. 28: 201-224.

Hill M.O. & Gauch H.G.Jr. 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio 42: 47-58.

Hill M.O. 1979. DECORANA - A FORTRAN program for detrended correspondence analysis and reciprocal averaging. - Cornell University, Ithaca, New York, USA.

ICP Forests 2006. II. Crown condition assessments. Manual on methods and criteria for harmonised sampling, assessments, monitoring and analysis of the effect of air pollution on forests.
Part II. Visual assessment of crown condition. http://www.icp-forests.org/N8f/Chapt2_compl06.N8f.

ISO10390 1994. Soil quality - Determination of pH. International standard. 5pp.

ISO10694 1995. Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis). International standard. 7pp.

ISO11048 1995. Soil quality - Determination of water-soluble and acid-soluble sulphate. International standard. 18pp.

ISO11261 1995. Soil quality - Soil quality - Determination of total nitrogen - Modified Kjeldahl method. International standard. 4pp.

ISO11465 1993. Soil quality - Determination of dry matter and water content on a mass basis - Gravimetric method. International standard. 3pp.

ISO13536 1995. Soil quality - Determination of the potential cation exchange capacity and exchangeable cations using barium chloride solution buffered at pH = 8.1. International standard. 7pp.

Kamelin R.V. 2002. Short essay about vegetation of Kyrgyzstan. In: Pimenov M.G.& Kluikov E.V. (eds) Umbelliferae of Kyrgyzstan. Moscow, pp. 5-18.

Krogstad T. 1992. Methods for soil analysis (In Norwegian). NLH report no. 6. Institutt for Jordfag, Ås-NLH, ISSN 0803-1304. 32pp.

Lacatusu R. 1998. Appraising levels of soil contamination and pollution with heavy metals. In: Heineke H.J., Eckelmann W., Thomasson A.J., Jones R.J.A., Montanarella L. & Buckley B. (Eds). ESB Research Report no. 4: Land Information Systems: Developments for planning the sustainable use of land resources. EUR 17729 EN. 546pp. Office for Official Publications of the European Communities, Luxembourg. Pp. 393-402.

Lawesson J., Eilertsen O., Diekmann M., Reinikainen A., Gunnlaugsdóttir E., Fosaa A.M. Carøe, I. Skov, F. Groom G., Økland T., Økland R.H., Andersen P.N. & Bakkestuen V. 2000. A concept for vegetation studies and monitoring in the Nordic countries. In: Tema Nord 517: 1-125.

Liu H.Y., Økland T., Halvorsen R., Gao J.X., Liu Q.R., Eilertsen O. & Bratli H. 2008. Gradient analyses of forests ground vegetation and its relationships to environmental variables in five subtropical forest areas, S and SW China. Sommerfeltia 32: 1-196.

Naturvårdsverket 1997. Bakgrundshalter i mark. Rapport 4640. Stockholm.

Økland R.H. & Eilertsen O. 1993. Vegetation-environment relationships of boreal coniferous forests in the Solhomfjell area, Gjerstad, S Norway. Sommerfeltia 16: 1-254.

Økland T. 1990. Vegetational and ecological monitoring of boreal forests in Norway. I. Rausjømarka in Akershus county, SE Norway. Sommerfeltia 10: 1-52.

Økland T. 1996. Vegetation-environment relationships of boreal spruce forest in ten monitoring reference areas in Norway. Sommerfeltia 22: 1-349.

Oksanen J., & Minchin P.R. 1997. Instability of ordination results under changes in input data order: explanations and remedies. J. Veg. Sci. 8: 447-454.

Olsen S.R. & Sommers L.E. 1982. Phosphorus. In: Page A. L., Miller R. H. & Keeney D. R. (Eds.). Methods of Soil analysis, Part 2. Chemical and microbiological properties. Agronomy Monograph no. 9 (2nd edition) ASA-SSSA, S. Segoe., Madison, WI 53711, USA, pp. 403-430.

Olsen S.R. 1953. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U. S. Department of Agriculture. Circular 939.

Parker K.C. 1988. Environmental relationships and vegetation associates of columnar cacti in the northern Sonoran Desert. Vegetatio 78: 125-140.

Red Data Book of Kyrgyz Republic 2006. http://biombiodiversity.webatu.com/redbook.html. (2. ed.)

Ryazantseva Z.A. 1965. The Climate of the Kyrgyz SSR. - The Geography department of the Academy of Sciences of the Kyrgyz Republic. Frunze, Ilim, 291pp.

Tabatabai M. A. & Dick W. A. 1979. Ion chromatographic analysis of sulfate and nitrate in soils. In: Mulik J.D. & Sawicki E. (Eds). Ion Chromatographic Analysis of Environmental Pollutants, Vol. 2. Ann Arbor Science Publishers, Ann Arbor, Mich., pp. 361-370.

Tabatabai M. A. 1982. Sulfur. In: Page, A. L., Miller, R. H. & Keeney. D. R. (Eds.). Methods of Soil Analysis, Part 2, Chemical and microbiological properties. Agronomy Monograph no. 9 (2nd edition) ASA-SSSA, S. Segoe., Madison, WI 53711, USA., pp. 501-538.

Taylor St.R. & McLennan S.M. 1985. The Continental Crust: its Composition and Evolution. Blackwell Scientific Publications (Oxford). Geoscience texts. 312pp.

ter Braak C.J.F. & Šmilauer P. 1998. CANOCO reference manual and user's guide to Canoco for Windows: software for canonical community ordination (version 4). Microcomputer Power, Ithaca, N.Y.

Zinkova Z.A & Pushkareva M.I. 1987. The Atlas of the Kyrgyz SSR. - Nature conditions and Resources Main department of Geodesy and mapping under Ministry SSSR. Geography department of the Institution of the Geology by Adishev M.M. under Academy of the Sciences of the Kyrgyz Republic. Moscow, p.157.