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

Establishment of monitoring reference area in Kara-Koi, Osh oblast, the Kyrgyz Republic, 2005. TEMP-CA monitoring site No.1.

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

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Tittel: Report from the Terrestrial Environmental Monitoring Project in Central Asia [TEMP-CA]. Establishment of monitoring reference area in Kara-Koi, Osh oblast, the Kyrgyz Republic, 2005. TEMP-CA monitoring site No. 1.	**Nr. i serien:**	**Dato godkjent av oppdragsgiver:** 14.02.2011
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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 Kara-Koi monitoring site in Osh oblast in the Kyrgyz Republic was the first of ten monitoring sites established in forests in Central Asia:

1: "Kara-Koi" in the Osch oblast, the Kyrgyz Republic.
2: "Sogot in the Jalal-Abad oblast, the Kyrgyz Republic.
3: "Dugoba" in Batken oblast, the Kyrgyz Republic.
4: "Besh-Tash" Talass oblast, the Kyrgyz Republic.
5: "Sary-Chelek", in Jalal-Abad oblast, the Kyrgyz Republic.
6: "Navobod" in Sogdi oblast, the Republic of Tajikistan.
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9: "Urumbash" in Jalal-Abad oblast, the Kyrgyz Republic.
10: "Umalak Teppa", Tashkent region, the Republic of Uzbekistan.

Ten plots of 30x30 m were placed subjectively in the area in order to represent the variation in the presumed most important environmental gradients. A 10x10 m plot was placed in the centre of the 30x30 m plots. Within each 10x10 m plot (macro plot) five plots of 1-m^2 were randomly placed.

All trees within the ten 30x30 m plots were marked on a sketch map and a number of tree growth and tree vitality measurements were recorded. At this site *Juniperus turkestanica* and *Juniperus semiglobosa* were the dominant tree species; however, most of them were relatively small with trunk diameters of 5-15 cm. Defoliation of juniper trees was on average 35-38%. Discoloration was almost insignificant. *Juniperus* species may be attacked by fungi, and the frequent cutting of branches for firewood in combination with climatic stress may increase the possibility for fungal attack.

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. Sixty vascular plant species were recorded in the fifty 1-m^2 plots and 49 of these were herbs. Vascular plants present in the 10x10 m plots and the 30x30 m plots were listed. Altogether 71 species have been recorded in the plots, included the sixty species recorded in the 50 1-m^2 plots. Of these, six are endemic for central Asia: *Astragalus aksuensis, Carex turcestanica, Iris sogdiana, Betula turkestanica, Juniperus turkestanica* and *Phlomis olgae.* Though the species diversity in the area is known to be rich, the species number recorded per plot was relatively low. 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 and nutrient condition are of the most important environmental conditions influencing the species composition according to these results.

All the plots are situated in a steep valley. Down in the valley the soils are generally characterized by Umbrisols. On the lower part of the slopes with a southern exposition the soils are dominantly Cambisols. The wetter north facing slopes have deep organic profiles with A horizons sometimes 100 cm thick, classified as Umbrisols. Higher on the south facing slopes the soils are stony and can be classified as Leptosols. Overgrazing induces downslope transport of soil, a quite common phenomenon throughout the whole area.

The whole region has a limestone origin, so all soils are calcaric.The pH circumneutral with a relatively high base saturation on the cation exchanger. Spatial variation in soil chemistry was mainly governed by the soil organic content. The soil contents of titanium (Ti) and zinc (Zn) were relatively high (913 and 108 mg/kg, respectively, in the B horizon). The contents of a majority of the 16 measured trace elements were strongly correlated to the iron (Fe) content, which again was strongly correlated to the aluminium (Al) content. A Principal Component Analysis (PCA) of the metal content and chemical characteristics of the A- and B horizons gave a main principal component (PCA 1), explaining more than half of the variation in the dataset, that was mainly explained by the Al and Fe content relative to calsium (Ca) and total carbon (C) content. The parameter loadings along the PCA 2 were to a certain extent correlated to the Covalent index (CI = X2r) of the elements (r = -0.437 and -0.598 in the A and B horizons, respectively).

Ansvarlig signatur

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

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Oppdragsrapport fra Skog og landskap 04/2011

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Cover Photo: Adilet Usupbaev Photo: Anders Bryn

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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.

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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.:

Aitkul M. Burhanov, Emma G. Beletskaya, Nicholas Clarke, Muhitdin Hamraliev, Nuriya S. Isakunova, Salamat B. Imanakunov, Nurgul K. Kuldanbaeva, Abdunaman Maksutov, Ajar K. Madieva, Bakyt A. Mamytova, Mirdin A. Mursaliev, Oleg R. Mujdabaev, Sovetbek S. Murzakulov, Turatbek S. Musuraliev, Taalai K. Mekishev, Saltanat R. Narynbaeva, Oktyabrin A. Sadyrov, Beishekan Sultanova, Vladimir K. Schudro, Kubanych T. Turgunbaev, Umar Temirbaev and Venera M. Surappaeva.

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, Bishek
2: The Norwegian Forest and Landscape Institute/Norwegian Forestry Group

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

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

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

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

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

The project mandate was:

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

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

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

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

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

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

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

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

In contrast to Western Europe, the period of timber exploitation was followed by a period of severe overgrazing, which further degraded the forest cover and interrupted natural regeneration. Today, large areas are affected by soil erosion and land degradation. More than 50% of the 10.6 million ha of arable land in the Kyrgyz Republic are affected by soil erosion. The situation is more or less similar for the neighbouring countries around the Fergana Valley. Besides this, the main land degradation processes include salinization, swamping, chemical pollution, and destructive changes in vegetation cover.

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

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

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

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

In this report we present the main results from the first monitoring site established in the TEMP-CA project, Kara-Koi in Osh oblast in the Kyrgyz Republic. This monitoring site was established in 2004, but the first analyses of the plots were performed in 2005. 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 2005 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 KARA-KOI REFERENCE MONITORING AREA

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

1.1. Geographical position of the reference monitoring area

The ”Kyrgyz Ata” State National Nature Park is situated in the Nookat district of the Osh Forestry region and has a total area of 11172 ha, of which merely 4.2% (2975 ha) is forested. The study area, Kara-Koi (Figs. 1.1 -1.2), is centrally placed within the National Park and is composed of several adjacent catchments. Kara-Koi is located within a small part (540 ha) of the National Park which is under the jurisdiction of the Academy of Sciences. The State Agency on Environment Protection and Forestry under the Government of the Kyrgyz Republic is responsible for the management of the National Park.

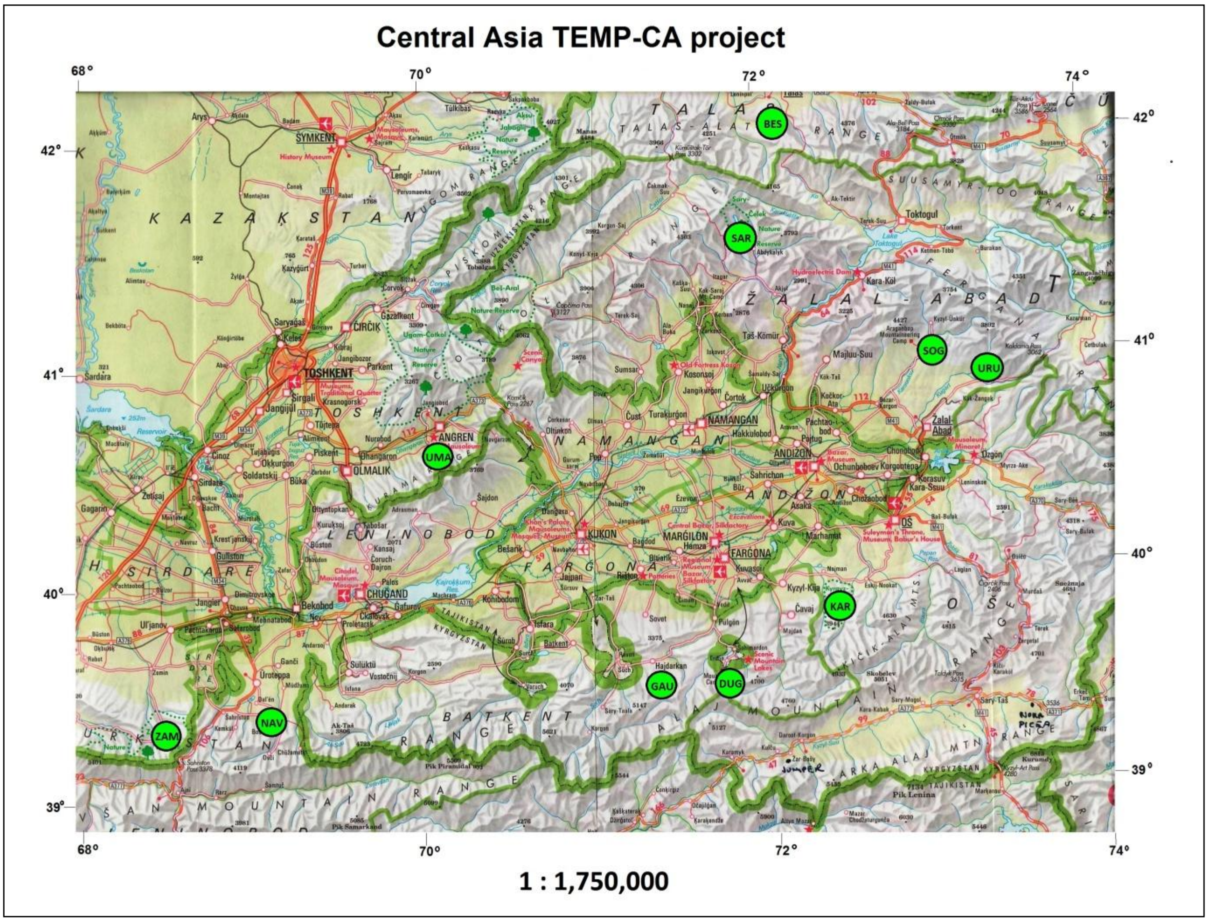

Fig. 1.1. Map of the Kara-Koi (KAR) and the nine other TEMP-CA monitoring reference areas.

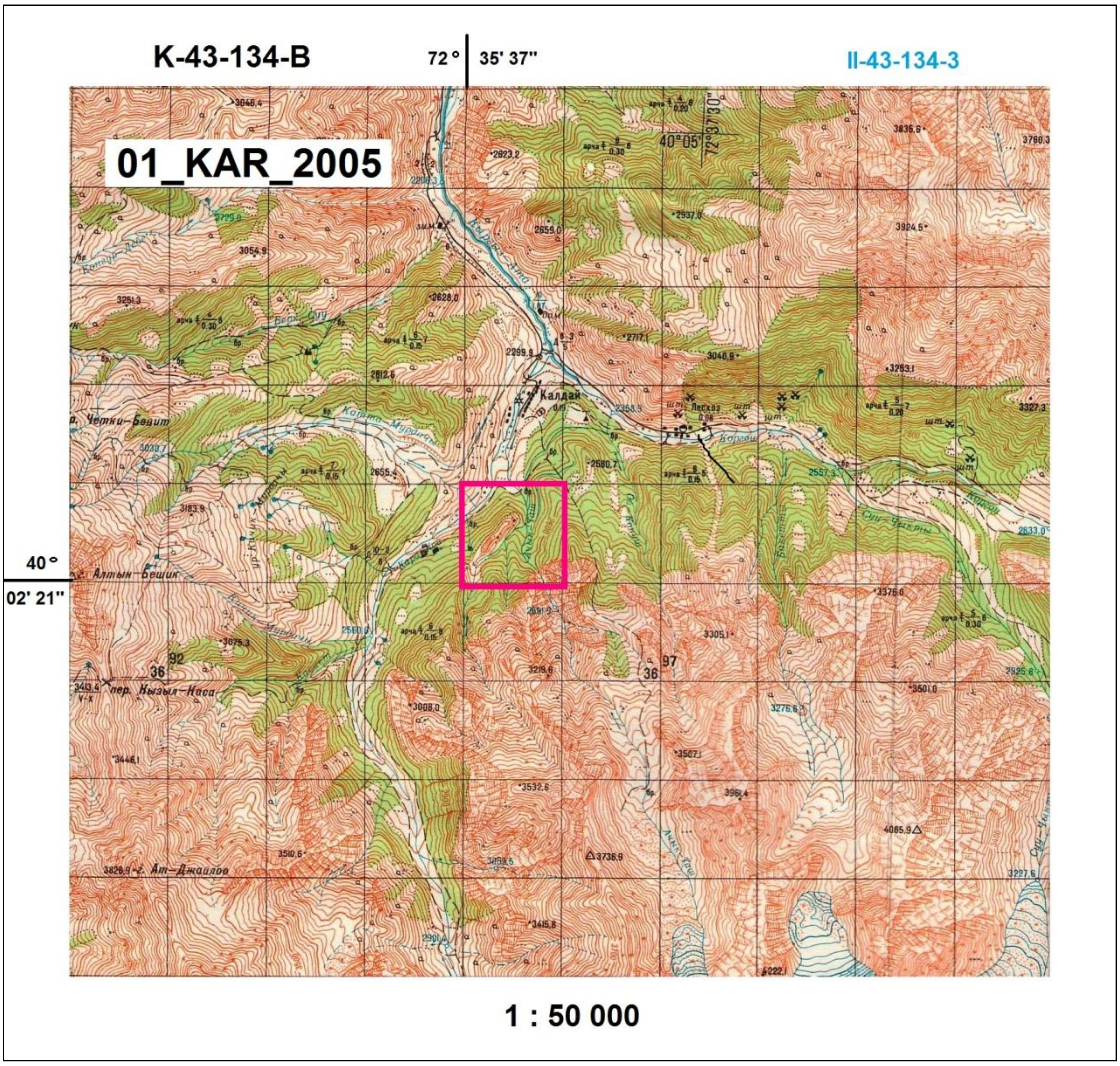

Fig. 1.2. Geographical position of the Kara-Koi monitoring reference area.

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**
KAR 1	2494 m	40°03.034′	072°36.311′
KAR 2	2531 m	40°03.064′	072°36.321′
KAR 3	2561 m	40°36.072′	072°36.256′
KAR 4	2551 m	40°03.009′	072°36.368′
KAR 5	2558 m	40°02.970′	072°36.380′
KAR 6	2588 m	40°02.862′	072°36.351′
KAR 7	2570 m	40°02.787′	072°36.289′
KAR 8	2557 m	40°02.766′	072°36.189′
KAR 9	2518 m	40°02.854′	072°36.196′
KAR 10	2456 m	40°36.016′	072°36.191′

1.2. Forest type, ownership, and conservation status

The mountain forest of Kara-Koi area is dominated by three species of juniper: *Juniperus seravschanica*, *J. semiglobosa*, and *J. turkestanica*. The tree line is climatically very harsh and the growing conditions vary according to aspect and irradiance, moisture, and edaphic conditions. *Juniperus seravschanica* grows on the most xeric sites, and in the reserve this species is only present on southern slopes, usually below 2500 m a.s.l. By contrast *J. semiglobosa* prevails on the northern slopes, but in the highest range from 2500 to 2800 m elevation it is only found on the southern slopes. The tree line, situated between 3000 and 3500 m a.s.l., is composed exclusively of *J. turkestanica*, present mostly as elfin woods in the highest range. *J. turkestanica* prevails up to 3000 m elevation on the northern slopes and up to 3500 m on the southern slopes.

The strictly protected "Kyrgyz Ata" State National Nature Park (SNNP) was established specifically for conservation of the unique juniper forests and for ensuring development of the park as a recreation area. The reserve was established according to Decree #82 of the Government of the Kyrgyz Republic, March 18, 1992, to fulfill measures on conservation and regeneration of juniper forests in the republic.

1.3. Geology, topography, and quaternary deposits

The Kara-Koi site belongs to the tectonic region of South Tien Shan. Its main features are: widely developed geo-synclinal formations of various compositions from the medium and upper Paleozoicum; the main linear folding is hercynian, with many faults, the concluding folding is late hercynian developed in the upper Paleozoic formations; red-colored continental molasses of the perm fill "residual red troughs". Limited occurrence of upper-Paleozoic granitoid intrusions, alkaline magma intrusions are typical (Zinkova & Pushkareva 1987).

The Paleozoic folded base with regional unconformity is overlain with Mesozoic and Cainozoic deposits that fill intermountain and sub-mountain troughs.

Geo-morphologically the Kara-Koi site belongs to the Alai-Turkestan province. The main factor determining the relief formation is related to the epihercynian structures which were subjected to vertical movements of different directions during the Oligocene and Pleistocene.

The relief consists primarily of Paleozoic and Protreozoic bedrocks; its structure depends on the range of heights, the slope exposure and the lithogenic composition of the rocks. There are former troughs filled with Mesozoic and paleogene – neogene deposits, which experienced powerful tectonic rises in late Pliocene. The relief is distinguished with crop-outs of Paleozoic and Proterozoic rocks.

The age of the formation of the tectonic-denudation relief is primarily from neogene to early quaternary and its development continues up to this day.

1.4. Climate

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

1.4.1. TEMPERATURE

The average annual temperature of the forest zone of Kara-Koi site depends on the altitude and fluctuates from +3 to +11 °C (Tab. 1.2). The average monthly summer temperature is 19.5 °C. July is the warmest month (the absolute maximum +29.3 °C) and January is the coldest month (the absolute minimum -22.6 °C).

Tab. 1.2. The average temperature in the region (°C).

Nearest meteorological station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	Year
Osh	-2.9	-1.0	6.1	14.0	18.8	24.0	25.7	23.4	18.8	12.1	5.9	0.4	12.1
Nookat	-4.0	-2.3	3.8	11.4	15.4	20.3	22.9	21.6	16.9	10.2	4.0	-0.9	9.9
Sary-Tash	-16	-15	-9.3	-1.5	3.6	7.2	10.2	10.1	6.0	-0.7	-8.1	-13	-2.2

1.4.2. PRECIPITATION

The maximum precipitation period for the region is in spring or early summer; for sub-mountain sites in March, and from mountain sites from April to June (Tab. 1.3). Autumn is usually dry in the area, and that is the main reason of fast ageing of juniper seeds. The maximum precipitation takes place in the middle part of the juniper zone and reaches 450-500 mm/year.

Tab. 1.3. The average precipitation in the region (mm).

Nearest meteorological station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	year
Osh	33	46	49	42	39	13	7	4	7	29	31	31	331
Nookat	25	31	50	55	58	34	20	10	11	30	28	24	376
Sary-Tash	22	23	34	40	61	52	38	23	13	25	23	22	376

1.5. Vegetation zones

The territory of Kara-Koi belongs to the ancient Mediterranean sub-kingdom of the Holarctic, Western Asian province, in the Fergana Valley region of the Mountain Central Asian area, (Kamelin 2002).

The juniper forests are located in the sub-alpine zone. The vegetation cover of the Kara-Koi investigation area is included in the Alay type of vertical zones. The most widespread vegetation types of the investigated area are forests represented by three juniper species: *Juniperus seravschanica*, *J. semiglobosa* and *J. turkestanica*. The presence of considerable areas of rocks and stony – rubbly slopes is typical for this region. The area is part of the National Park ”Kyrgyz Ata”, which is one of most important centers of biodiversity in the world.

1.6. Forest history, forest structure, and external influence

1.6.1. HUMAN IMPACT

There are 631 people living in the Park area and its immediate surroundings (Tab. 1.4; unpublished information from The State Agency of the Environmental and Forest Protection).

Tab. 1.4. Number of individuals and houses in the different settlements and counties in the National Park area and sizes of grazing livestock owned by local farmers (A) and by farmers living in the vicinity of the park (B).

№	Rural counties	Settlements	Number of home-steads	Popu-lation	Number of livestock			
					Total	including:		
						Small cattle	Cattle	Horses
A	Gulistan	Chong-Kyshtoo	34	404	401	275	105	21
	Kyrgyz-Ata	Kuragan	4	24	79	63	9	7
	Kara-Tash	Akkochku	2	15	55	37	13	5
	T. Zulpuev's	Kaldai	23	188	193	135	41	17
Total:			63	631	728	510	168	50
B	Kyrgyz-Ata	-	-	-	475	185	276	14
	Gulistan	-	-	-	349	155	189	5
	Kara-Tash	-	-	-	174	57	113	4
	Mirmahmudov	-	-	-	193	67	123	3
	Zulpuev's	-	-	-	852	297	525	30
Total:					2043	761	1226	56
Size of total livestock:					2771	1271	1394	106

The residents are provided with electricity, but for limited use, and the need for furnace heating implies that unauthorized cutting is frequently taking place in the juniper forests. The human impact on the forests in the National Park and adjacent areas are predominantly:

- *Illegal deforestation.* Any type of cutting, except for "sanitary" purposes, is forbidden in the National Park. Nevertheless, local people violate the regulations of the Park by cutting trees for various purposes, such as firewood harvesting, all the year around.
- *Agriculture***.** Flat areas in the valley bottoms consist of agricultural crops which are regularly plowed and sowed. Furthermore, every year the local people mow grass for haymaking in adjacent areas. After the collapse of the Soviet Union, the ploughed fields, hayfields and pastures have been used more irregularly, and without any governmental control.
- *Recreation*. Urban people use the park actively for recreation, and the park is also popular among tourists and pupils. The season for the recreational use lasts from early spring till late autumn.
- *Livestock grazing***.** Almost all of the National Park is used for livestock grazing, and for the local people the park serve this purpose all around the year. In addition, farmers of the valley use the park for livestock grazing on a seasonal basis, from early spring till late autumn every year.

1.6.2. FOREST HISTORY

The mountainous juniper forests have traditionally been the home range for the semi-nomadic people who made their living from cattle-breeding, and juniper was the only source of energy for the herdsmen when they stayed in the mountains. Charcoal from juniper gives a superior energy output, and in the beginning of the 20th century juniper declined due to the great demand for the charcoal (Kornet & Rajapbaev 2004).

During the Second World War the wood resources in all Kyrgyz forests were extensively utilized. As a result juniper and other major forest trees were reduced by about 50%. Due to this all types of juniper harvesting, except sanitary cutting, was forbidden in 1960. Nevertheless, the local people continued cutting high-quality trees under cover of sanitary needs. At the same time, regeneration was restricted by grazing livestock. Before the USSR dissolution the forest also underwent pastoral overpressure. After USSR dissolved, the juniper forest declined further because of the economic crisis in the country. High prices of alternative energy sources (gas, coal, electricity) maintained the pressure on the juniper forests (Buttoud & Yunusova 2001).

The crisis also rammed the leskhozs, the local forest management organization. Direct financial support from the state was reduced, and the technical equipment needed to manage the forestry, such as cars and machines, and to maintain further processing of the timber, were not provided. Most of the leskhozs in areas with junipers suffered from poor economy, and this is reflected in the present development and activity on forest regeneration.

1.6.3. GRAZING

During summer the grazing by livestock of farmers living in the valley is more extensive than that of resident farmers (Tab. 1.4; unpublished information from The State Agency of the Environmental and Forest Protection).
The size of the livestock in the park is c. 3000 individuals and the area is thus partly overgrazed. The grazing is, however, not evenly distributed across the park area. Most grazing is allocated to domestic and recreation areas, and a less proportion of the livestock is transported to high-mountain pastures in juniper forests. Grazing stops for a short period (2-3 months) during the period when the area is covered with snow. Recently, there has been an increase in the quantity of cattle and a decrease of the sheep livestock.

1.6.4. OTHER BACKGROUND INFORMATION

The timber resources in the National Park amount to 98.6 thousand m^3. In the forested part of the park there is an average of 33.14 m^3/ha, while in Nookat district, which has less forest cover, the corresponding value is 22.5 m^3/ha. Here, the basic forest-forming species are arborescent and elfin forms of juniper. The importance of juniper is evident from the fact that the standing volume is estimated to 95.6 thousand m^3, which constitutes 96.9% of the total volume. Thus, the proportion of other species is only 3.1%.

No general cutting of the most common species is allowed in the park, except for improvement cutting in juniper forest cultures. Still, unauthorized cutting in juniper forests is still being done by local dwellers and the wood is used mainly as firewood. It is assumed, however, that about 20% of the wood cut without permission ends up as construction wood, whereas about 30% is sold to dealers who use juniper timber for decoration purposes (houses, bathhouses, saunas etc.). All in all, there is a general concern that the damages by illegal cutting, together with limited regeneration associated with grazing, may cause a decline of the juniper forests. This concern applies specially for the most intensively used forests located around settlements and in woodlands used as summer pastures where temporary settlements are built by the dwellers.

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 Kara-Koi site was dominated by *Juniperus turkestanica* (56%) and *J. semiglobosa* (28%) (Fig. 2.1). The remaining species consisted of planted *Picea shrenkiana* (7.6%) and *Betula turcestanica* (6.2%). In some plots there were also scattered *Larix sibirica* trees.

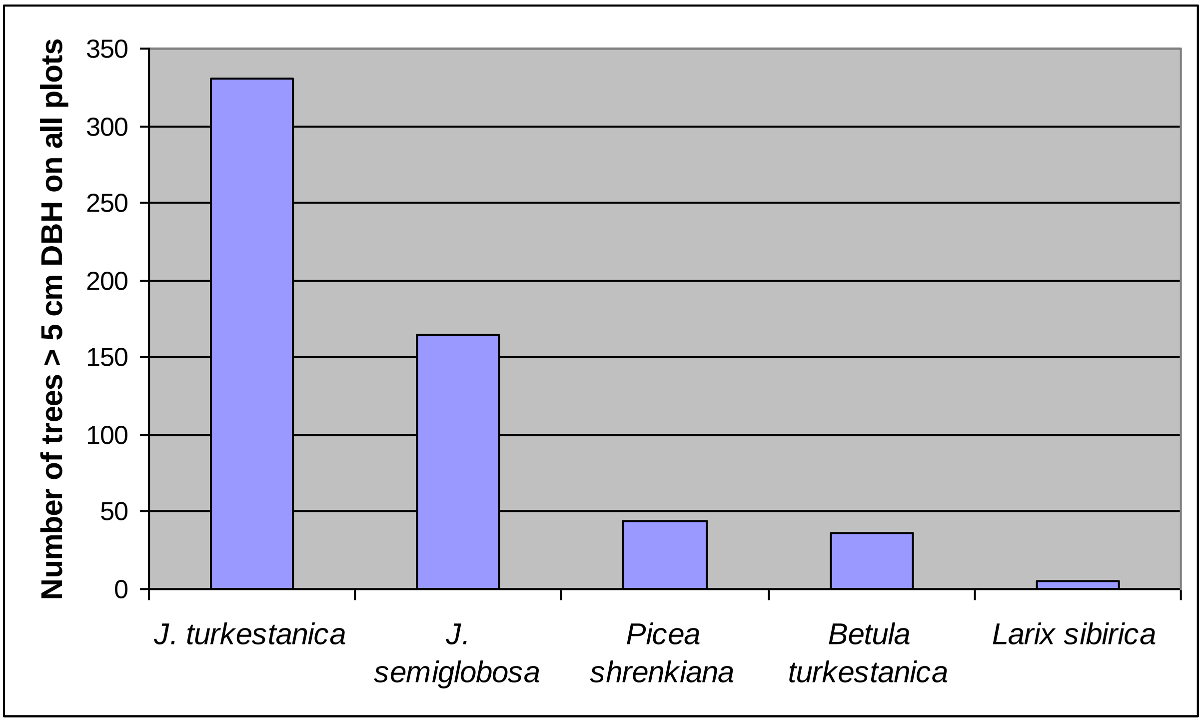

Fig. 2.1. Total number of trees of the different species > 5 cm DBH in all plots.

2.2.2. TREE CONDITION

Tree condition is presented for the main species, but also associated species if the number of individuals is sufficient to draw reliable conclusions (cf. Fig. 2.1). Defoliation for the juniper species was 35-38% and thus in the moderate range (Fig. 2.2). The proportion of trees with discoloration was rather limited, 4.3% for *J. turkestanica* and 2.5% for *J. semiglobosa*. The less abundant *P. shrenkiana* showed an even less discoloration of only 1%.

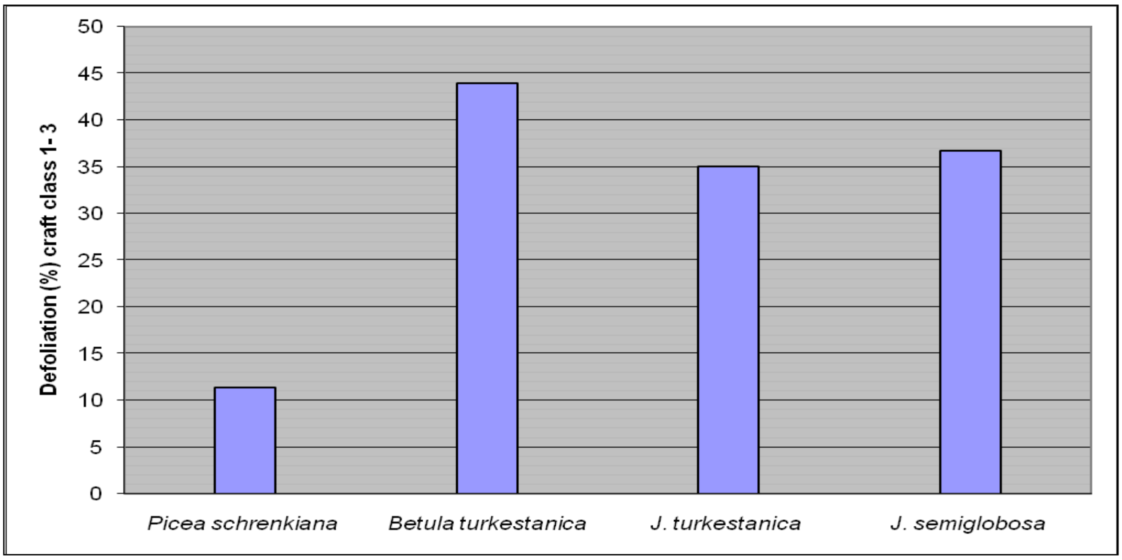

Fig. 2.2. Defoliation for the main species.

2.2.3. DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

The size distribution (DBH) of *J. turkestanica* and *J. semiglobosa* was approximately the same, and there was a considerable decrease in the number of trees with increasing DBH (Fig. 2.3). The two smallest diameter classes (DBH < 15 cm) constituted 65-67% of the total number of trees (Figs. 2.3 and 2.4). In *J. turkestanica* 54 seedlings (< 5 cm DBH) were recorded in the 50 1-m^2 ground vegetation plots. However, the DBH class of 5-10 cm was similar to (Fig. 2.3) or smaller than (Fig. 2.4) the DBH class 10-15 cm for *J. turkestanica* and *J. semiglobosa*, respectively. Trees with DBH > 20 cm amounted to only 15-17%.

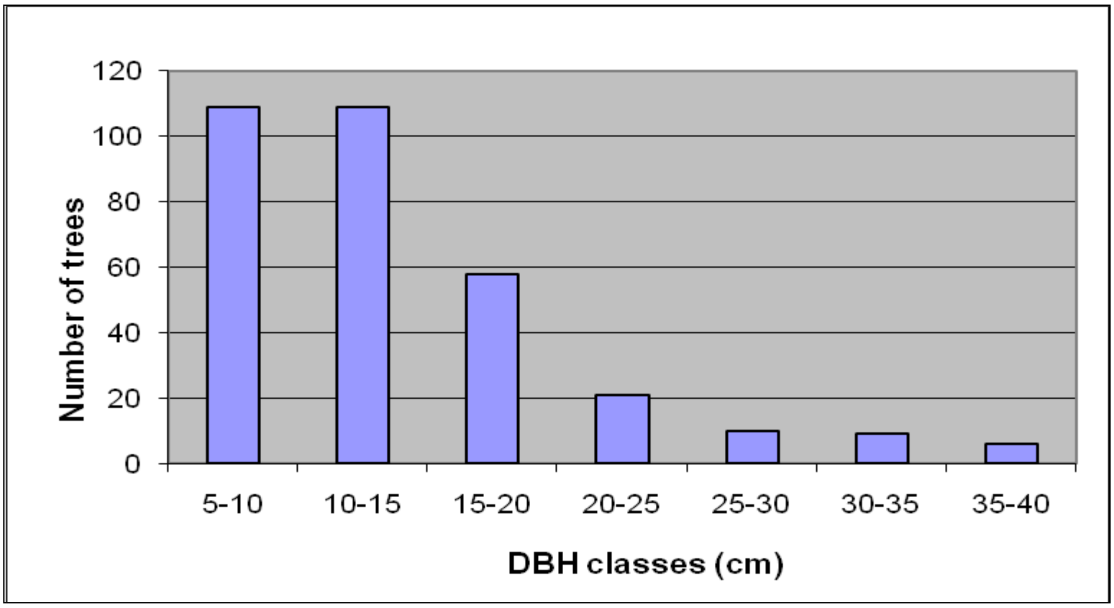

Fig. 2.3. Size distribution (DBH) of *J. turkestanica* (all plots).

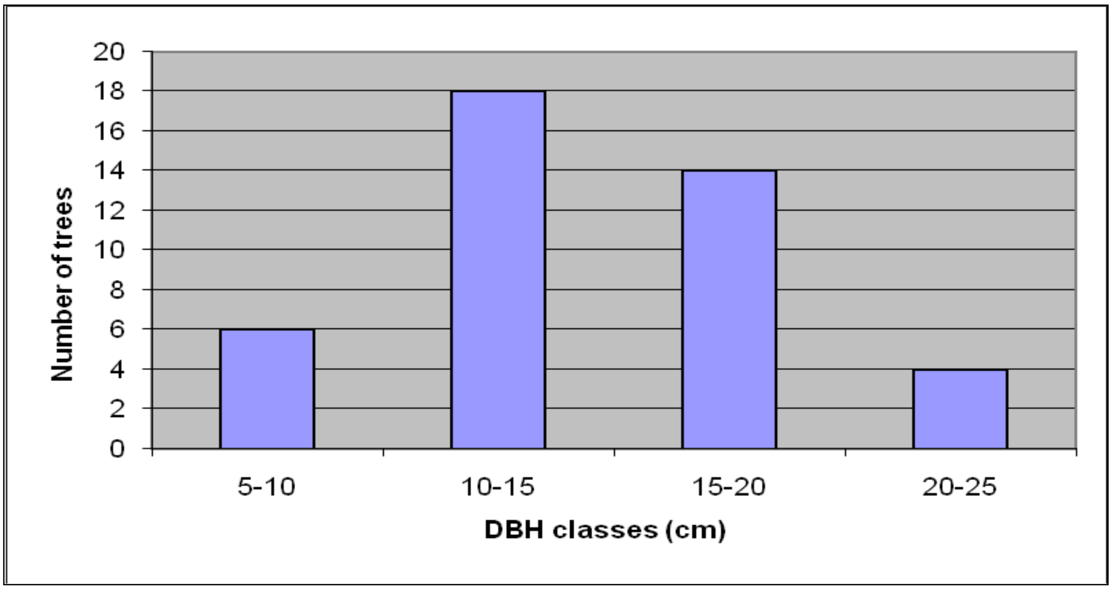

Fig. 2.4. Size distribution (DBH) of *J. semiglobosa* (all plots).

2.3. Discussion

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

At this study site the condition of the juniper forests was strongly influenced by the defoliation which amounted to 35-38%. This was accompanied by only an almost insignificant discoloration. The *Juniperus* species may be attacked by fungal diseases, such as *Gymnosporangium* rusts and rot, which could affect tree vitality. The frequent cutting of branches for firewood in the area may represent entries for rot fungi. It could be possible to compare trees which have been subject to branch cutting with untouched trees. Accordingly, branch cutting should be recorded as a separate parameter during the next assessment to see whether tree vitality may refer to human interference. Similarly, samples of needles, branches and wood should be collected for pathological and entomological investigations when the disease symptoms are observed. It should not be forgotten, however, that the harsh climate close to the tree line could affect the defoliation, without any notable effect on the discoloration of the trees. The harsh climate or other stress factors may influence on i.e. *Gymnosporangium* infections on branches and stems.

Sufficient regeneration is fundamental for sustainable forests. According to the *size distributions* of the juniper species (Figs. 2.3 and 2.4) the greatest number of individuals was found among the smallest size classes. This possibly suggests a similar *age class distribution* and a surplus of young individuals. In *J. turkestanica* seedlings (< 5 cm DBH) were recorded in the ground vegetation quadrants, also suggesting recruitment to be sufficient. However, in *J. semiglobosa*, no seedlings (< 5 cm DBH) were recorded, and we could also suspect regeneration to be limiting based on the lower number of individuals in the smallest size class (DBH 5-10 cm) than in the adjacent class (DBH 10-15 cm) (Fig. 2.4). The project did not, however, set an objective of monitoring natural regeneration as such. To draw firm conclusions on this matter, more specific investigations are needed.

The regeneration issue shows that it is important to be aware of the management regime and other human interference when evaluating the forest condition. Accordingly, we will propose additional assessments to find out to what extent the management, including the cutting of fire wood and grazing, affect the current forest condition and regeneration.

3. BIODIVERSITY AND GROUND VEGETATION

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3.1. Methods

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

The key principles are summarised below:

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

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

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

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

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

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

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

3.1.1. SAMPLING DESIGN

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

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

3.1.2. VEGETATION PARAMETERS

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

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

All species* present in the ten 10x10 m plots as well as 30x30 m plots were listed.
(*Bryophytes and lichens were not included in the data sets from 2005, which was the first year for data sampling in this project, due to a misunderstanding concerning collected bryophytes that could not be indentified during the fieldwork).

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

3.1.3. EXPLANATORY VARIABLES

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

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

(1) Topographical variables include:

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

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

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

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

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

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

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

(2) Tree influence variables include:

- Crown cover index
- Litter index
- Basal area

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

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

CC = ∑i **cai** • **cci** /25

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

LitterIi = cci × cai × (hi - chi)

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

LitterI = ∑i cci × cai × (hi - chi)

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

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

(3) Soil physical variables include:

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

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

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

- *Estimations of % cover of litter*.

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

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

(4) Soil chemical variables include:

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

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

(5) Animal impact variables include:

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

- Domestic animal grazing condition
- Grazing intensity
- Average grass height
- Average herb height
- % cover animal manure/dung
- % cover animal traces/footprints
- % cover animal tracks
- % browsing damage on woody plants for each species
- % cover of wild animal holes

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

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

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

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

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

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

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

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

3.1.4. ORDINATION METHODS

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

Ordination methods are used to summarize the main gradients in the vegetation of the sample plots. DCA (Detrended Correspondence Analysis; Hill 1979, Hill & Gauch 1980), one of the most common used multivariate statistical methods, was performed on subplot frequency data on 50 plots by means of CANOCO Version 4.54 (ter Braak & Šmilauer 1998), which are debugged according to Oksanen & Minchin (1997). Standard options were used (i.e. no down-weighting of species, nonlinear rescaling of axes and 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 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 3.1. The number of species within macro 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 (Tab. 3.1).

The ratio a/b and a/c was calculated for each macro plot. All together 60 species were recorded in the 50 1-m^2 plots. Of these species 5 are endemic to Central Asia: *Astragalus aksuensis, Carex turkestanica, Iris sogdiana, Betula turkestanica* and *Juniperus turkestanica.*

The maximum number of species recorded in any 1-m^2 plot was 19, while the minimum number was 3. The average number of species recorded in the 1-m^2 plots was 9.74.

The total number of species recorded within the 50 1-m^2 plots + ten 10x10 m plots was 69. The total number of species in the in the 50 1-m^2 plots + ten 30x30 m plots was 71. Of these species six is endemic to Central Asia (*Phlomis olgae* in addition to the species mentioned above). The maximum number of species recorded in the five 1-m^2 plots in any 10x10 m plot was 33 and the minimum was 12. The maximum number of species recorded in any of the 10x10 m macro plots (the five 1-m^2 plots included) was 35 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 24.6. The ratio a/b varied between 0.75 and 0.94 (Tab. 3.1). The ratio a/c varied between 0.59 and 0.92 in the macro plots.

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

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

Plot number	a Five 1-m^2 plots	b Five 1-m^2 plots + 10x10 m plot	c Five 1-m^2 plots + 10x10 m plot + 30x30 m plot	The ratio a/b	The ratio a/c
1	27	33	34	0.82	0.79
2	33	35	36	0.94	0.92
3	23	28	28	0.82	0.82
4	12	15	18	0.80	0.67
5	16	21	27	0.76	0.59
6	13	16	17	0.81	0.76
7	15	20	24	0.75	0.63
8	26	29	33	0.90	0.79
9	14	15	20	0.93	0.70
10	28	34	36	0.82	0.78
Total number	60	69	71	0.87	0.85

Tab. 3.2. Number of species in different species groups within each 10x10 m macro plot and in total.

Plot number	Tree species	Shrubs	Herbs	Ferns	Graminoids
1	0	0	23	0	4
2	1	2	28	0	2
3	1	2	16	0	4
4	1	0	10	0	1
5	0	0	14	0	2
6	1	1	10	0	2
7	0	0	13	0	3
8	1	2	20	0	3
9	0	1	10	0	3
10	0	0	26	0	2
Total number	2	3	48	0	7

3.2.2. MAIN GROUND VEGETATION GRADIENTS

DCA ordination of 50 plots is shown in Figs. 3.2-3.4. Gradient lengths; β-diversity, and eigenvalues for DCA 1-4 are given in Tab. 3.3.

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

	DCA 1	DCA 2	DCA 3	DCA 4
Eigenvalues	0.440	0.279	0.192	0.130
Gradient lengths	2.921	2.407	2.713	2.142

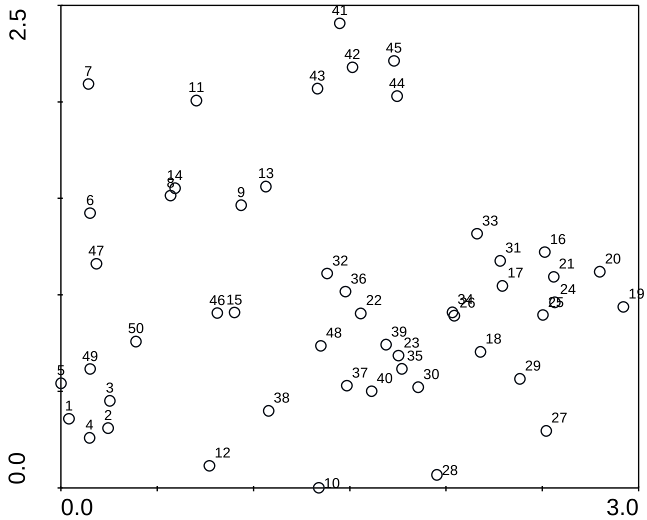

Fig. 3.2. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 2 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

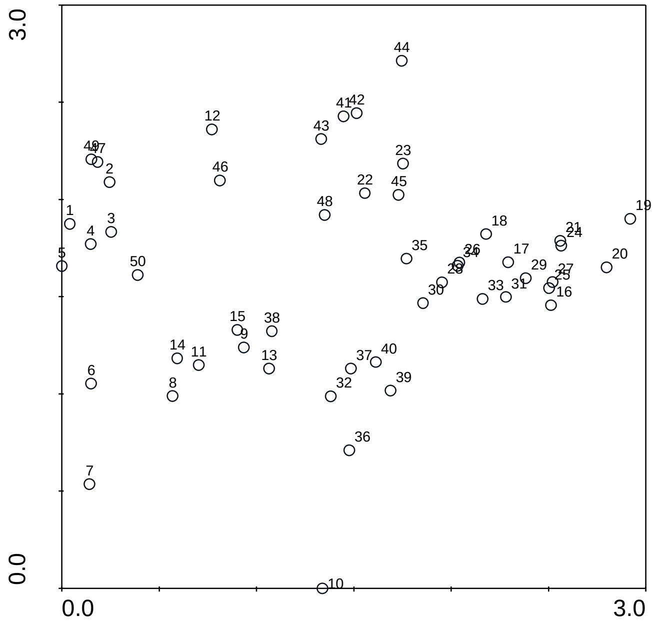

Fig. 3.3. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 3 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

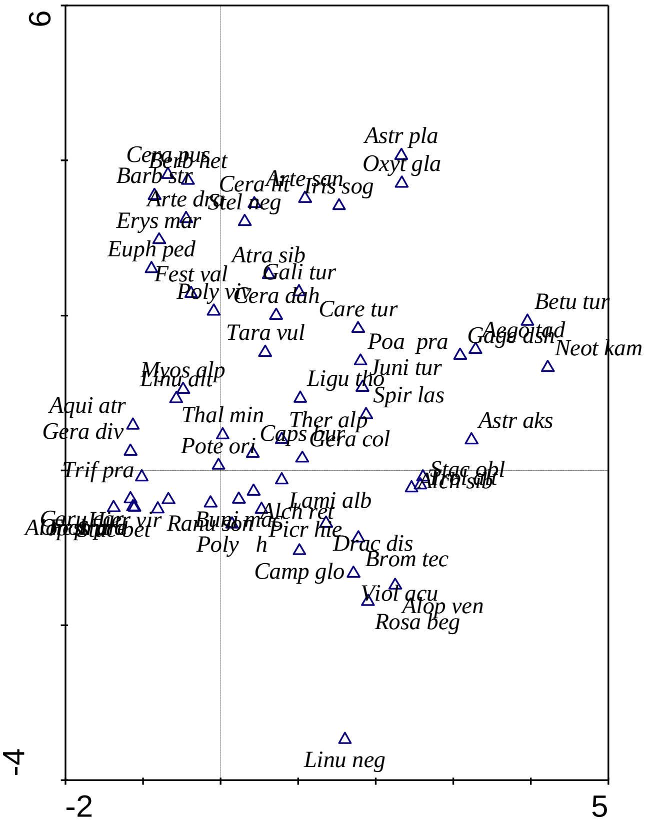

Fig. 3.4. DCA ordination of species in the 50 1-m^2 plots.

3.2.3. CORRELATION ANALYSIS BETWEEN EXPLANATORY VARIABLES AND DCA ORDINATION AXES

Kendall´s non-parametric correlation coefficient 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	1.000	.000.	.045	.645	.040	.682	-.122	.213
DCA 2	.045	.645	1.000	.000.	-.037	.707	.167	.086
DCA 3	.040	.682	-.037	.707	1.000	.000.	-.069	.477
DCA 4	-.122	.213	.167	.086	-.069	.477	1.000	.
Soil moisture	.049	.616	-.038	.700	.130	.186	.235*	.017
Inclination	.148	.137	.202*	.043	-.157	.116	.103	.302
Aspect	.198*	.044	-.115	.241	.143	.145	-.117	.234
Aspect favourability	-.236*	.017	.066	.503	-.063	.524	-.082	.402
Heat index	-.173	.078	.148	.130	-.109	.266	-.078	.427
Max. inclination	.065	.508	.152	.125	-.175	.077	.155	.117
Sum conc 1x1 m	.209*	.039	.011	.913	.020	.846	-.108	.284
Var. conc 1x1 m	-.140	.161	-.121	.224	-.073	.465	.034	.731
Abs.sum conc.1x1m	-.161	.113	-.116	.252	-.080	.428	.029	.774

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	-.038	.717	-.115	.277	.091	.388	.132	.214
Var. conc 3x3 m	-.077	.459	-.153	.141	.109	.295	-.103	.319
Abs.sum conc 3x3m	-.089	.397	-.166	.114	.069	.510	-.109	.301
Rel. decid. trees	.370**	.001	.071	.540	.052	.651	-.235*	.042
Rel. conif. trees	.106	.290	-.194	.051	-.296**	.003	.015	.880
Rel. total	.226*	.023	-.124	.214	-.303**	.002	-.054	.591
Crovn cover index	.368**	.000	.160	.101	-.157	.108	.060	.536
Litter index	.340**	.002	.147	.175	-.088	.418	.160	.140
Average grass height	.186	.103	-.018	.877	.271*	.017	-.203	.074
Max. soil depth	.101	.303	-.108	.273	-.222*	.024	-.238*	.016
Min. soil depth	.163	.097	.046	.639	-.153	.120	-.189	.054
Med. soil depth	.132	.178	.073	.456	-.222*	.023	-.153	.118
Max. org. l. depth	.132	.195	-.179	.080	-.096	.348	-.177	.083
Min org. l. depth	-.007	.946	-.045	.661	-.137	.177	-.156	.125
Med. org l. depth	.064	.523	-.089	.373	-.126	.208	-.162	.107
Max. litter depth	.349**	.001	.063	.564	-.051	.638	-.003	.979
Min. litter depth	-.001	.991	.034	.771	-.265*	.023	.187	.109
Med. litter depth	.275*	.014	.088	.435	-.038	.734	-.005	.963
Altitude	.386**	.001	-.088	.386	-.233**	.006	-.093	.359
pH	-.222*	.024	.271**	.006	-.153	.120	.161	.101
H+	.222*	.024	-.271**	.006	.153	.120	-.161	.101
Ctot, %	.096	.324	-.147	.132	-.209*	.032	.114	.242
Dry matter, %	.182	.062	-.190	.051	-.123	.207	.035	.719
LOI, %	.106	.277	-.162	.098	-.106	.277	.077	.432
Ctotal, %	.107	.273	-.146	.134	-.197*	.044	.115	.238
Ca cmol/kg	.131	.178	-.184	.060	-.260**	.008	.058	.553
Mg cmol/kg	.277**	.005	-.159	.103	-.089	.362	-.136	.162
K cmol/kg	.077	.432	-.064	.514	-.178	.068	.090	.357
CEC målt	-.050	.610	-.068	.488	-.092	.345	.020	.834
Total N	-.221*	.023	-.004	.967	-.035	.719	.120	.219
Ca, ppm	-.131	.181	-.142	.145	-.175	.073	.147	.132
Mg, ppm	-.331**	.001	.105	.281	.047	.633	-.037	.707
Na, ppm	-.308**	.002	.069	.477	.053	.587	.141	.148
K, ppm	-.246*	.012	.141	.148	-.011	.913	.020	.834
Al, ppm	-.160	.101	.178	.068	.131	.181	-.067	.493
Fe, ppm	-.122	.213	.141	.148	.107	.273	-.091	.353
Mn, ppm	.112	.252	-.011	.913	.109	.266	-.109	.266
P, ppm	.020	.834	-.024	.808	-.084	.389	.166	.089
Zn, ppm	-.195*	.046	.140	.153	.233*	.017	.132	.178
Tot N/LOI*100	-.319**	.001	.081	.408	-.029	.770	.051	.598
Ca/LOI*100	-.014	.887	-.002	.980	-.269**	.006	-.025	.795
Mg/LOI*100	.143	.143	-.002	.980	-.024	.808	-.224*	.021
K /LOI*100	-.025	.795	.045	.645	-.042	.670	.009	.927
CEC/LOI*100	-.149	.126	.182	.062	.050	.610	.097	.320
Ca, ppm/LOI*100	-.283**	.004	.009	.927	-.146	.134	.156	.110
Mg, ppm/LOI*100	-.195*	.046	.143	.143	.082	.398	-.096	.328
Na, ppm/LOI*100	-.234*	.016	.211*	.030	.131	.178	.012	.900
K, ppm/LOI*100	-.159	.103	.198*	.042	.082	.398	-.040	.682

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	-.127	.195	.192*	.049	.112	.252	-.096	.328
Fe, ppm/LOI*100	-.133	.173	.176	.072	.125	.201	-.069	.477
Mn, ppm/LOI*100	-.063	.520	.144	.139	.133	.173	-.104	.288
P, ppm/LOI*100	-.210*	.032	.180	.065	.097	.320	.033	.732
Zn, ppm/LOI*100	-.158	.106	.220*	.024	.198*	.042	.014	.887

3.3. Discussion

3.3.1. GENERAL DESCRIPTION OF VEGETATION AND GROUND VEGETATION BIODIVERSITY

The Kara-Koi area has rich species diversity because of wide range of environmental conditions, as e.g. altitudes and local climate conditions. In total 71 vascular plant species were recorded in the monitoring plots. However, the species number per 1-m^2 plot was in average low.

The species composition of shrubs includes: *Lonicera lanata, Rhamnus cathartica, Euonymus semenovii, Rosa kokanica.* The grass and herb’s layer in the area is frequently dominated by *Bromopsis ramose,* but also *Ligularia thompsonii* and *Geranium collinum* are dominating on some sites. Other species occurring are among others *Alopecurus pratensis, Hieracium virosum, Alchimilla retropilosa, Campanula glomerata, Cerastium pusillum, Carum carvi, Geranium collinum* and *Polygala comosa. Carex diluta, Saxifraga sibirica Cirsium esculentum and Corydalis ledebouriana* occur in the area but were not recorded in the plots.

The area has many meadow herb species. Most of the vascular plants are herbs and out of 60 species recorded in the fifty 1-m^2 plots 49 were herbs.

3.3.2. INTERPRETATION OF GROUND VEGETATION GRADIENTS

The variable altitude was strongly and positively correlated with DCA 1, expressing that the variation in species composition along DCA 1 is partly due to differences in altitude. The difference in altitudes in Kara-Koi varies with c. 130 m from the lowest altitude (plots 46-50) to the highest altitude (plots 26-30).

The variables *relascope sum of deciduous trees* and *crown cover index* are also strongly positively correlated with DCA 1, both expressing gradients in tree influence on the ground vegetation. The *litter index* and the *maximum litter depth* are also strongly correlated with DCA 1. Thus tree density and influence of litter vary along the gradient expressing the greatest variation in vegetation (DCA 1). The only plots with deciduous trees are plot 16–20, which have some of the highest DCA 1 scores. Apparently influence of deciduous trees has considerable influence on the species composition. The lowest number of species per plot was recorded in these five plots (see Tab. 3.1); only 12 vascular plants were recorded in total for these plots and in average only five species per plot. Thus the litter from deciduous trees may possibly prevent the establishment and survival of many species.

The variable most strongly negatively correlated with DCA 1 is the total amount of nitrogen in soil, expressed as fraction of loss on ignition. Also some other cation concentrations in soil are negatively correlated with DCA 1, thus a gradient in nutrient conditions is partly expressed along this vegetation gradient.

Very few variables are correlated with DCA 2 but pH and inclination are both positively correlated along this vegetation gradient, though the correlation with inclination is less strong.

The parameters expressing the impact of domestic animals are not strongly correlated with any of the DCA axes, though the average grass height was somewhat correlated with DCA 3 (τ = -0.271). Though grazing by domestic animals is forbidden by law in Kara-Koi, illegal grazing occurs and has great impact of the ground vegetation. However, the impact of grazing is heavy all over the area. Plots 41-45 have high positions along both DCA 2 and DCA 3, indicating somewhat lower impact of grazing in the sites with these plots. These plots are placed on an open and steep slope, indicated by the strong negatively correlations of relascope sum of coniferous trees and total relascope sum with DCA 3 and by the less strong but positive and significant correlation of inclination with DCA 2.

The variation in species composition in ground vegetation in Kara-Koi is thus mainly due to influence by trees affecting light and litter conditions as well as differences in altitude and nutrient conditions and impact by domestic animals.

3.4. APPENDIX

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

Scientific names of species:	Kyrgyz names of species:	Russian names of species:
Aegopodium tadschicorum	Тажик элик балтырканы	Сныть таджикская
Alchimilla retropilosa	Кайрылган түктүү тогуз төбөлү	Манжетка отклоненно-волосистая
Alchimilla sibirica	Сибирь тогуз төбөл	Манжетка сибирская
Alopecurus pratensis	Шалбаа түлкү куйругу	Лисохвост луговой
Alopecurus arundinaceus	Көпкөлгөн түлкү куйрук	Лисохвост камышевидный
Anisantha tectorum	Арпакан түбү бош	Анизанта кровельная
Aquilegia atrovinosa	Кочкул-кызыл бүргүн	Водосбор темно-пурпуровый
Artemisia dracunculus	Шыраалжын шыбагы	Полынь эстрагон
Artemisia santolinifolia	Кара шыбак	Полынь сантолинолистная
Astragalus aksuensis	Ак-Суу астрагалы	Астрагал аксууйский
Astragalus platyphyllus	Жазы жалбырактуу астрагал	Астрагал плосколистный
Atragene sibirica	Сибирь атрагенасы	Княжик сибирский
Barbarea stricta	Түз кычы	Сурепка прямая
Berberis sphaerocarpa	Бөрү карагат	Барбарис разноножковый
Betula turkestanica	Түркстан кайыңы	Береза туркестанская
Bistorta vivipara	Жөргөмүш бистортасы	Бисторта живородящий
Conium maculatum	Сасык балтыркан	Болиголов пятнистый
Campanula glomerata	Топтолгон коңгуроо гүл	Колокольчик сборный
Capsella bursa pastoris	Кадимки койчу баштык	Пастушья сумка обыкновенная
Carex turkestanica	Түркстан ыраңы	Осока туркестанская
Carum carvi	Кадимки карум	Тмин обыкновенный
Cerastium davuricum	Даурия серастиуму	Ясколка даурская
Cerastium lithospermifolium	Таранчы чөптөй серастиум	Ясколка воробейниковая
Cerastium pusillum	Кичинекей серастиум	Ясколка маленькая
Dracosephalum discolor	Ар түстүү аркар от	Змееголовник разноцветный
Erysimum hieracifolium	Хиерациумжалбырактуу даргыны	Желтушник ястребинколистная
Euphrasia peduncularis	Гүл сапчалуу ефразия	Очанка цветоножковая
Festuca pratensis	Шалбаа бетегеси	Овсяница луговая
Festuca valesiaca	Валезия бетегеси	Овсяница валезийская
Gagea dshungarica	Даур каз пиязы	Гусиный лук джунгарский
Galium turkestanicum	Түркстан галиуму	Подмаренник туркестанский
Geranium collinum	Шалбаа каз таманы	Герань холмовая
Geranium divaricatum	Чачыраган каз таман	Герань раскидистая
Hieracium virosum	Уулу херациум	Ястребинка ядовитая
Iris sogdiana	Согдия чекилдеги	Ирис согдийский
Juniperus turkestanica	Түркстан (өрүк) арчасы	Можжевельник туркестанский
Lamium album	Ак дүлөй чалкан	Яснотка белая
Ligularia thomsonii	Томсон кой жалбырагы	Бузульник Томсона
Linum altaicum	Алтай зыгыры	Лен алтайский
Linum corymbulosum	Калканча сымал зыгыр	Лен щиточковатый
Myosotis arvensis	Талаа бото-көз	Незабудка полевая
Neottia kamtschatea	Камчатка гнездовкасы	Гнездовка камчатская
Onobrychis arenaria	Кум эспарцети	Эспарцет песчаный
Oxytropis glabra	Түксүз кекек	Остролодочник голый
Picris hieraciodies	Хиерациум өңдүү горечник	Горечник ястребинковидный
Poa pratensis	Шалбаа жылганы	Мятлик луговой
Polygala comosa	Аргын истод	Истод гибридный
Potentilla orientalis	Чыгыш каз таманы	Лапчатка восточная
Ranunculus songoricus	Жунгар байчечекейи	Лютик джунгарский
Rosa beggeriana	Беггер ит муруну	Роза Беггера
Spireae lasiocarpa	Түктүү мөмөлүү табылгы	Таволга волосистоплодная
Stachyopsis oblongata	Узун жалбырактуу стахиопсис	Стахиопсис продолговатолистный
Stachys betonicaeflora	Бетоника гүлдүү стахис	Чистец буквицацветковая
Stellaria neglecta	Байкалбаган жилдызча	Звездочка незамеченная
Taraxacum montanum	Тоо какымы	Одуванчик горный
Thalictrum minus	Кичинекей тармал чөп	Василистник малый
Thermopsis alpina	Альпы сары мыясы	Термопсис альпийский
Trifolium pratense	Шалбаа уй бедеси	Клевер луговой
Trollius altaicus	Алтай троллиусу	Купальница алтайская
Viola acutifolia	Учтуу жалбырактуу ала гүл	Фиалка остролистная

4. SOIL CLASSIFICATION AND SOIL DESCRIPTION

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4.1. Methods

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

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

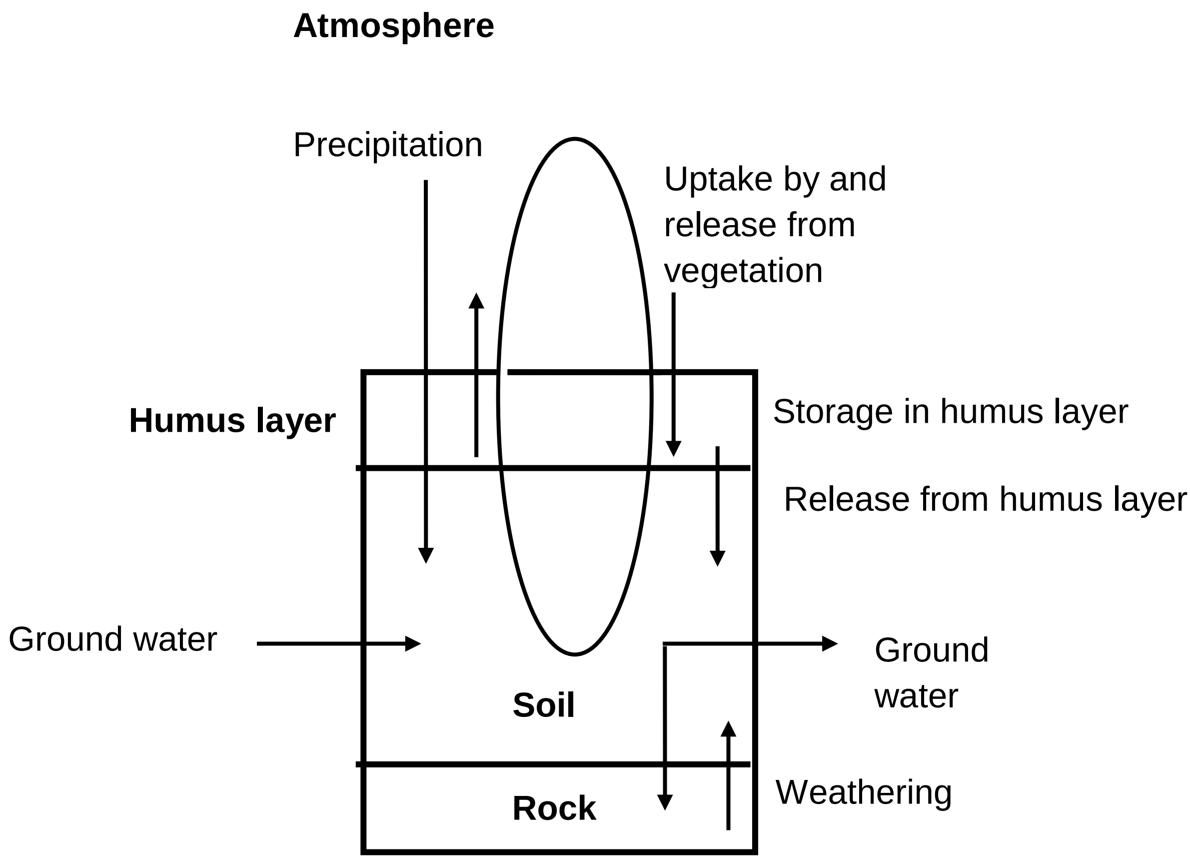

Fig. 4.1. Simplified model of biogeochemical cycling of elements.

The methodology for placing the macro plots and 1-m^2 vegetation plots is described in 3.1.1. During the 20th – 23rd of October 2004 soil samples were taken from each 1-m^2 plot. The weather before the sampling was sunny. During sampling the temperatures were below and around freezing point. Soil moisture samples were taken in the beginning of June 2005.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

All plots are situated in a steep valley. The surrounding mountains are from limestone. The slopes have varying exposition.

Down in the valley the soils are characterized by Umbrisols. On the lower part of the slopes with a southern exposition the soils are dominantly Cambisols. On the wetter northern slopes deep organic profiles were found to be classified in either Umbrisols or may be even Chernozems. For classifying Chernozems special technology is needed which is not available (and relevant) for this project. On the top of the slopes, especially these with a more southern exposition the soils are stony and can be classified as Leptosols.

In general the texture of the soil is varying from a silt to loam to loamy clay. The surrounding mountains are from limestone origin so CEC and nutrient supply is relatively good. The soils at the top of the slopes are generally more stony and shallow and are clearly prone to lack of water during longer dry periods.

All soils do have 2 horizons, an A and B horizon. The plots in the lower part of the slopes do have generally a deeper profile than the plots further up.

Due to overgrazing in the lower part of the slopes soil transport is quite a common feature throughout the whole area.

The altitude of the macro plots varies from 2457 m to 2609 m a.s.l.

Soil moisture levels are in general around 25%, without extreme variations. The pH is around and above pH 7. The subsoil has in general a higher pH.

The variation in the total carbon levels in the A layer was small. An exception is plot 6 and 7 where much higher levels were observed (9-10%).

When looking at heavy metal concentration levels in the soil samples the following facts can be noted (see also chapter 5):

- As: levels are not higher than the critical levels for the Kyrgyz Republic (for the urban environment), but the levels are higher than the notified background levels for the Kyrgyz Republic. As the higher levels are also present in the subsoil this means that the As in the environment is in general coming from the geological substrate.
- Cadmium (Cd): Some high levels are seen in both the top and subsoil in macro plot 7 and 8. Ca is also originating from the geological underground.
- Mercury (Hg), lead (Pb), and antimony (Sb) do not have high levels.
- Strontium (Sr): In general no samples have levels regarded as the critical level for the Kyrgyz Republic. In some cases the subsoil has higher levels of Sr.
- Zink (Zn): In general the level is high in both top and subsoil. Zn is originating from the geological substrate.

4.3. Discussion

As the area has a limestone origin the effects of acid precipitation will only be visible after a long period, may be many thousands of years.

Changes in soil conditions will be a resultant from both biogeochemical cycling, land use change (the change in amount and period of overgrazing, forest planting, and forest management), the natural development of the vegetation, and the influence of long and short transported pollutants. At present the indication is that the heavy metals are mainly originated from the local geological underground.

To prevent degradation of the area the amount of grazing should be in balance with the soil and terrain conditions. Probably this is not the case in the area and reducing overgrazing is a challenge.

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 Kara-Koi were analyzed at Alex Steward Laboratories, Kara Balta, the Kyrgyz Republic.

5.1.3.1 Dry matter

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

5.1.3.2 Soil pH

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

5.1.3.3. Total and organic carbon (C)

Total C includes both inorganic and organic C. Inorganic C is principally found in carbonate minerals, whereas most organic C is present in the soil organic matter fraction.
The measurement of total C is conducted according to ISO10694 on air-dried soil passed through a 2.00 mm aperture sieve. This is conducted by a dry combustion technique on a LECO carbon analyzer (SC-225). The soil sample is oxidized to CO_2 at 940 ºC on CuO in a flow of oxygen-

containing gas that is free from carbon dioxide; the released gases are scrubbed; and the CO_2 in the combustion gases is measured using an infrared (IR) detector.

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

5.1.3.4 Total nitrogen (N)

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

5.1.3.5 Effective CEC

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

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

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

5.1.3.6 Loss on ignition (LOI)

Procedure from Krogstad (1992):

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

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

where:

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

5.1.3.8 Inorganic Sulphate adsorption

Principle:

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

Reagents:

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

Procedure:

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

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

Detection:

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

Calculation:

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

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

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

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

5.2.1. SOIL CHEMISTRY DATA

Average soil chemical data for each horizon are presented in Tab. 5.2. Circumneutral pH conditions prevail at the sampling plots. As commonly found the pH increases with depth along with decreasing organic content. Studying all samples (across horizons) we find that the organic content, measured as loss on ignition (LOI), is strongly correlated to total carbon content (% C_{tot}; r = 0.882), implying that the soils content of inorganic Carbon is less important at this site. Studying only the mineral soils we find that also the total N is in fact strongly related to the % C_{tot} content. The C_{tot} is strongly negatively correlated to the acid cations Al and Fe and several trace elements (Cr, Ni, V, La, Be, Sc, Y), and positively correlated to the total phosphorous (P; r = 0.709) content. Adsorbed sulphate (Ads. SO_4^{2-})
were in 40 and 50% of the samples below the detection limit (0.01 g kg^{-1}) in the A and B horizons, respectively.

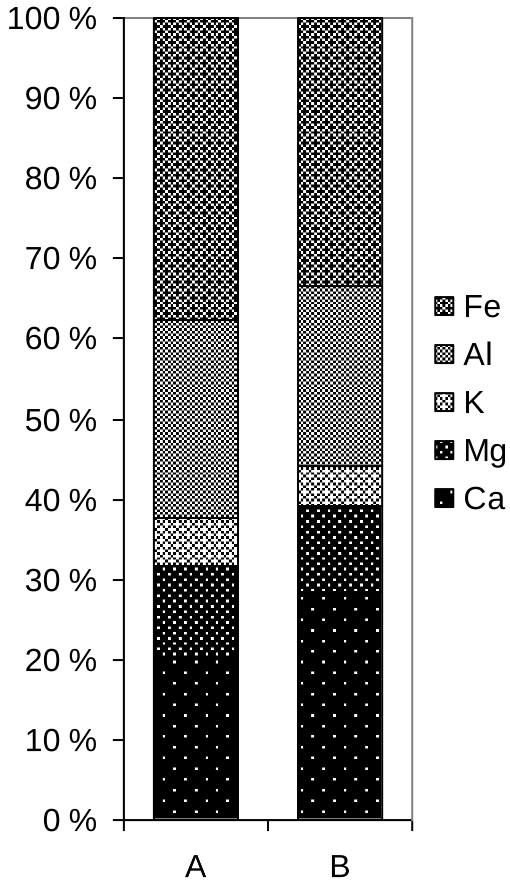

Fig. 5.1. Main (avg. value > 3.5 mg/g) oxide composition of the mineral soils.

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

Horizon	Samples #	pH_{H2O}	LOI	C total	Total N	Ads. SO_4^{2-}
			w/w%		µg/g	
A	50	6.84	17.1	5.7	2643	60.1
		6.8 – 7.3	12–21	3–9	1248–3050	0–100
B	50	6.98	10.8	3.9	1948	52.7
		7.2 – 7.7	8–12	2–5	1170–2655	0–78

In addition to silicates (SiO_2; not measured) the main (avg. value > 3.5 mg/g) oxide composition of the A horizon mineral soils (Fig. 5.1) is made up by iron (Fe) and aluminium (Al), followed by calcium (Ca) and magnesium (Mg). The base cations (Ca, Mg, Na, K) account for 38 and 44% of the oxide composition in the A and B horizons, respectively. The B horizon follows somewhat the same trend except that Ca dominates over Al. This is only found at this site which has the slightly highest base cation content in the B horizon. The values are somewhat misleading as samples with an elemental content greater than a maximum analytical value, e.g. 50 mg g^{-1} for Ca, are set to this analytical maximum value. This is the case for 34% of the Ca data in the B horizon.

The content of Fe and Al are strongly correlated (r = 0.936). The Fe content is also as commonly found correlated with both Mg (r = 0.834) and potassium (K) (r = 0.785), while Al, as found in all the TEMP-CA sites, is negatively correlated to Ca, though this correlation is poor (r = -0.667) in Kara-Koi.

The major oxide elements presented in Fig. 5.1 are followed in abundance by titanium (Ti), manganese (Mn) and phosphorous (P) (Tab. 5.3). The amount of Ti was relatively high, especially at this site, compared to e.g. Na. Ti is correlated with Al (r = 0.842), Fe (0.764) and several trace elements (Cu, Ni, Co, V). The spatial variation in lathanum (La) is correlated to Mg (0.875), Fe (r = 0.817), along with a few trace elements (Cr, Sc and Y). P appears to be governed by the organic content (LOI; r = 0.823) and is also strongly positively correlated to cadmium (Cd; r = 0.730) and negatively correlated to scandium (Sc; r = -0.756). No strong correlations were found with Mn and Na.

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	729	778	868	291	21,7
	600–901	714–838	680–1014	240–320	18–25
B	622	689	913	314	23,1
	549–666	580–788	773–1023	251–352	21–26

Soil composition of measured trace elements along with the composition of continental crust (Taylor & McLennan 1985) and selected heavy metal contamination norms (Lacatusu 1998) are presented in Tab. 5.4. The bedrocks in the studied site are generally secondary minerals (sandstone, clay and limestone) that are apparently partly transformed to shale and marble by metamorphosis. The contents of trace elements are therefore generally depleted compared to continental crust, except for soft (type B) elements arsenic (As), lead (Pb) and cadmium (Cd). In addition zinc (Zn) is especially high in Kara-Koi compared to earth crust. Nevertheless, the heavy metal contents are generally high at all the TEMP-CA sites 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						
Kara-Koi	A	18	187	57	24	0.7	41	49	119	48	18	56	4.7	12	3.0	1.3	0.8
	B	18	175	87	20	0.6	40	48	108	48	18	58	4.8	12	2.7	1.3	0.7

[1] Taylor & McLennan (1985).
[2] http://eusoils.jrc.it/esdb_archive/eusoils_docs/esb_rr/n04_land_information_systems/5_7.doc
[3] World mean concentration in uncontaminated soils (Allaway1968)

Fe content is strongly correlated to the content of a majority of the 16 measured trace elements (Fig. 5.2). Important exceptions are the soft (or type B) metals Pb, molybdenum (Mo) and Cd and the hard (type A) elements barium (Ba) and strontium (Sr). Soft metals (high covalent index) were instead generally found to be correlated only to each other (Tab. 5.5.) and somewhat negatively correlated to hard (Type A) metals (e.g. Ba and Sr). Samples at Kara-Koi deviating from the relationship with Fe (see Fig. 5.3) are from two plots (3 & 9) with relatively low Ca and high Ti content. Variation in strontium (Sr) content followed closely the Ca levels (r = 0.792).

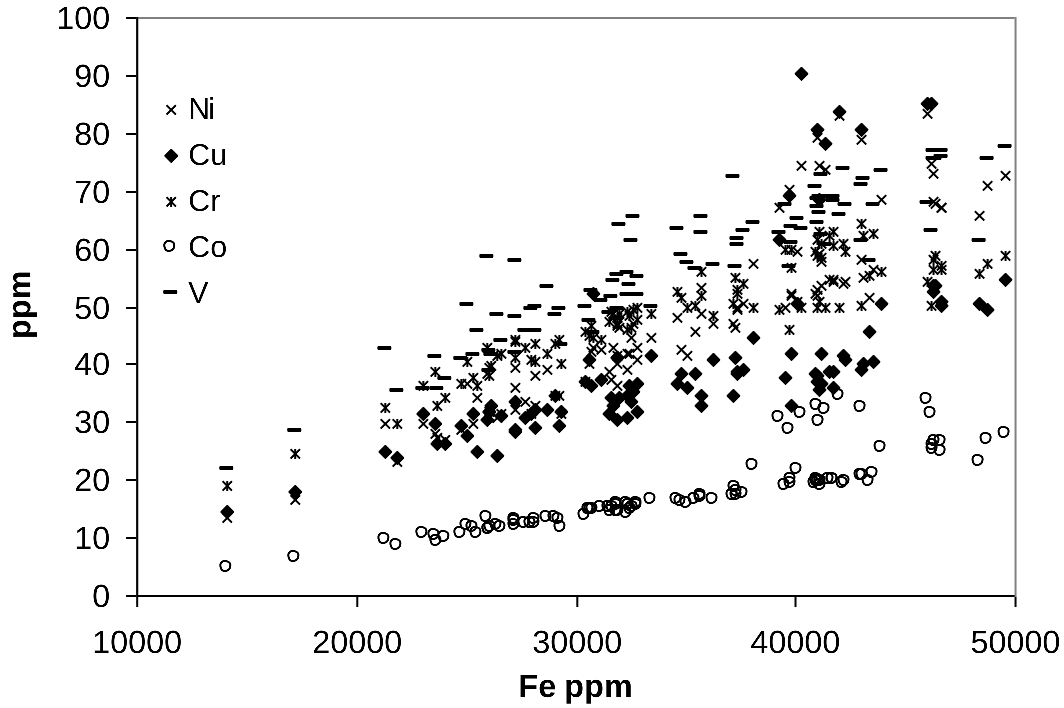

Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements nickel (Ni), copper (Cu), chrome (Cr) cobolt (Co) and vanadium (V).

The majority of 16 measured trace elements co-varied in the soils leading to that 21 strong correlations were found (Tab.5.5). The typical borderline elements Ni, Co and vanadium (V) showed the largest number of strong correlations (Tab. 5.5). The type B elements (Pb, Mo, Cd, As) and the type A elements (Zr, Ba, Sr) showed poorest correlation or were correlated to the same type of elements (e.g. Pd and Cd). As commonly found there were few strong correlations with zinc (Zn). Considering the lack of correlation, that the amount of Zn was especially 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 > 0.7) found for each of the measured 16 trace elements in 50 A and 50 B horizon samples from Kara-Koi. 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 (r > 0.7) correlations.

	# of corr.	Vs.	r
Pb	1	Cd	0.740
Mo	1	Co	0.733
Cd	1	Pb	0.740
As	1	Cr	0.746
Cu	4	Co	0.886
Co	7	Ni	0.976
Ni	8	Co	0.976
Zn	1	Cu	0.700
V	7	Cr	0.923
Be	3	V	0.822
Cr	4	Sc	0.937
Sc	3	Cr	0.937
Y	5	Ni	0.888
Zr	0	-	-
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 clearly be illustrated by a Principal Component Analysis (PCA) (Minitab®). The same pattern is found in all the studied sites. In the plane of the first two principal components (PCA 1 and PCA 2) in both the A- and B horizons the Fe is clustered together with Al and most trace elements (except Sr, Cd and Pb) (Fig. 5.3). Negatively loaded to this cluster along the PCA 1 we find a cluster of Ca and Sr, often together with C-tot. The PCA 1, explaining more than half of the variation in the dataset, is mainly explained by the Al and Fe content relative to Ca and C_{tot}. The PCA 2 may partly be explained by the Covalent index ($CI = X^2r$) of the elements. Elements with low CI, commonly referred to as hard or type A elements, prefer to bind to carbonates, while elements with high CI, commonly referred to as soft or type B elements, forming more stable complexes, e.g. with sulphides. Type A elements (Ca, Mg, Na, K) have generally opposite loading to more Type B elements (Pb, Cd, As). Borderline metals have generally low loading along the PCA 2. Instead they are strongly clustered with Fe. PCA 2 is correlated to the Covalent index with r = - 0.437 and -0.598 in the A and B horizons, respectively.

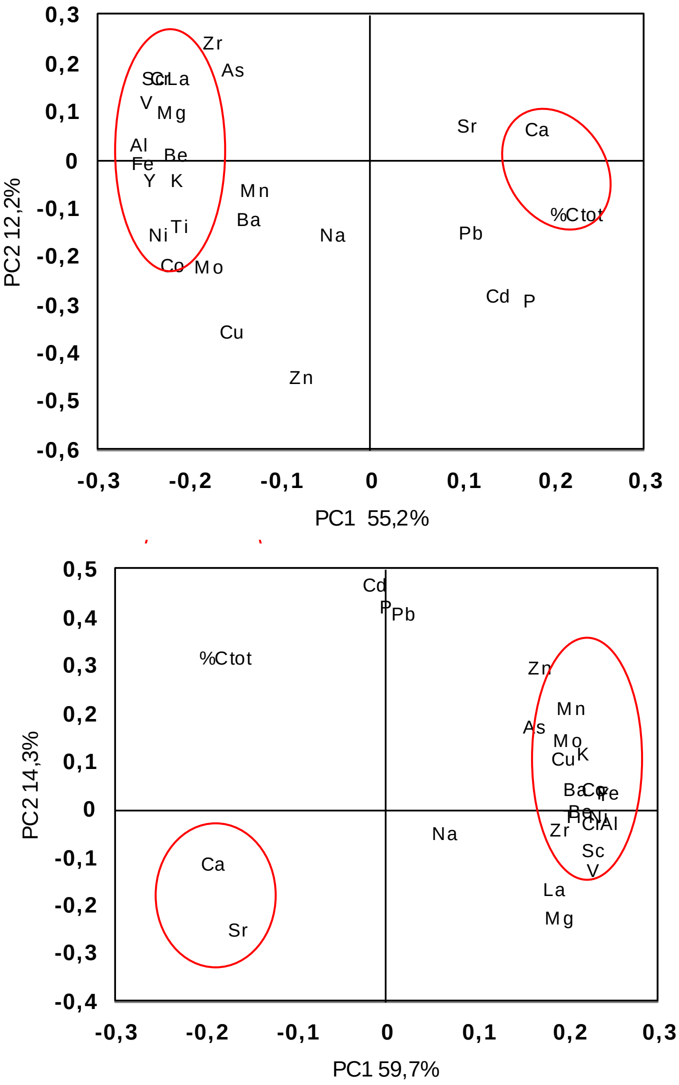

Fig. 5.3. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 67.4% and 74.0% of the variation in soil elemental composition, respectively.

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