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

Establishment of monitoring reference area in Dugoba, Batken oblast, the Kyrgyz Republic, 2006. TEMP-CA monitoring site No.3.

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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 Sogot monitoring site in Osh oblast in the Kyrgyz Republic was the second 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.
7: “Gauyan” in Batken oblast, the Kyrgyz Republic.
8: “Zaamin” in Djizak region, the Republic of Uzbekistan.
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 five plots of 1-m^2 were randomly placed.

All trees within the ten 30x30 m plots were marked on a sketch map and a number of tree growth and tree vitality measurements were recorded. The Sogot site consists exclusively of deciduous species. The most abundant species were *Juglans regia* (39,2%) and *Malus kirghisorum* (33,2%). Defoliation for *J. regia* (23%) and *M kirghisorum* (33%) was in the moderate range, while the proportion of discolorated trees was almost insignificant for both species. The *size distribution* of *J. regia* shows that the greatest number of individuals was found among the intermediate size classes (DBH 25-45 cm), rather than in the smallest classes, indicating insufficient regeneration of this species. For *M. kirghisorum* the two smallest size classes (DBH > 15 cm) made up 68% of the trees, pointing to an adequate level of regeneration for this species.

Two abundance measures were recorded for all species in each of the fifty 1-m^2 plots: frequency in subplots (presence/absence of all species in sixteen subplots in the 1-m^2 plots) and percentage cover. Twenty-four vascular plant species were recorded in the fifty 1-m^2 plots and sixteen of these were herbs. Vascular plants present in the 10x10 m macro plots and the 30x30 m extended macro plots were listed. In total thirty-five species were recorded in the plots. Of these species five were endemic to Central Asia: *Rubus caesius, Acer turkestanicum*, *Crataegus songorica, Malus sieversiana* and *Prunus sogdiana*. *Malus sieversiana* is listed in the Red book of the Kyrgyz Republic. The species diversity in the area is low, and the mean species number per 1-m^2 plot was nine. Detrended Correspondence Analysis (DCA ordination) of the subplot frequency data for the fifty 1-m^2 plots was performed in order to reveal the most important vegetation gradients. The ordination axes, i.e. expressing the vegetation gradients, were interpreted by means of Kendall's non-parametric correlation coefficient. Depth of the organic layer, soil depth, aspect, aspect favourability, the micro topography variable *sum concavity/convexity 1-m^2*, and the heat index were some of the most important environmental conditions influencing the species composition according to these results.

The plots were situated in a broad watershed dominated by walnut forests on a deep loess deposition. In a narrower part of the valley, where the loess deposition was shallower, a small stream has carved so red sandstone was visible. All soil profiles were generally deep and well developed with deep developed organic layers. Secondary chalk could often be identified lower in the profile, indicating that the soil type could be a Chernozem. Generally the whole area had a good drainage. Near the stream the soil types Umbrisols, Cambisols and Regosols were identified.

The soils at Sogot had a circumneutral pH with a relatively high base saturation on the cation exchanger. Soil chemical characteristics are in the middle of the range found among the TEMP-CA sites. Spatial variation in soil chemistry was mainly governed by the soil organic content. The soil contents of titanium (Ti) were relatively high (615 mg/kg 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) and Ti content. A Principal Component Analysis (PCA) of the metal content and chemical characteristics of the A- and B-horizons gave a main principal component (PC1), explaining a staggering 72 and 68%, of the variation in the A and B horizons, respectively, that was mainly explained by the Al and Fe content relative to calsium (Ca) and total carbon (C) content. The parameter loadings along the PC2 were to a certain extent correlated to the Covalent index (CI = X^2 r) of the elements (r = 0.424 and 0.445 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.

Dan Aamlid

Adm.dir./Avdelingsdirektør

Oppdragsrapport fra Skog og landskap 06/2011

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Cover Photo: Adilet Usupbaev, Photo: Tonje Økland

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ABSTRACT

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

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

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

The Dugoba monitoring site in Batken oblast in the Kyrgyz Republic was the third of ten monitoring sites established in forests in Central Asia:

1: ”Kara-Koi” in the Osch oblast, the Kyrgyz Republic.
2: ”Sogot in the Jalal-Abad oblast, the Kyrgyz Republic.
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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 each 30x30 m plot. 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 semiglobosa* and *J. seravschanica* were the dominating tree species. The number of trees decreased with increasing diameter, and the two smallest size classes (DBH < 15 cm) constituted as much as 48% of the trees for *J. semiglobosa* and 51.9% for *J. seravschanica.* Defoliation for the *Juniperus* species was quite noticeable, 43-44% (Fig.2.2), while the proportion of juniper trees with discoloration was rather insignificant (< 1.2%). *Juniperus* species may be attacked by fungi, and cutting of branches for firewood in combination with climatic stress may increase the possibility for fungal attack and contribute to the defoliation.

Two abundance measures were recorded for all species in each of the fifty 1-m^2 plots: frequency in subplots (presence/absence of all species in sixteen subplots in the 1-m^2 plots) and percentage cover. All together 72 species was recorded in the 50 1-m^2 plots; 56 vascular plants, 14 bryophytes and 2 lichens. Vascular plants present in the 10 x 10 m plots and the 30 x 30 m plots were listed. In total 69 vascular plants were recorded in the plots. Of these species 11 are endemic to Central Asia: *Rosa alaica, Carex turcestanica, Astragalus alaicus, Astragalus schachimardanus, Fritillaria walujewii, Nepeta podostachys, Phlomoides alaica, Thymus seravschanicus, Viola alaica, Juniperus semiglobosa* and *Juniperus turkestanica.*. Detrended Correspondence Analysis (DCA ordination) of the subplot frequency data for the fifty 1-m^2 plots was performed in order to reveal the most important vegetation gradients. The ordination axes, i.e. expressing the vegetation gradients, were interpreted by means of Kendall’s non-parametric correlation coefficient. The variation in species composition in

ground vegetation in the Dugoba monitoring site is mainly due to variation in topography, nutrient condition, light and litter conditions and influence of domestic animals according to our results.

The plots are placed in a small and steep watershed with variation in aspect. On the northern slope soil organic matter content was higher and the soils were generally deeper developed and much more moist. The macro plots on the southern slope were characterised by shallow soils with a much lower soil organic matter content. A few sites had a western exposition, with intermediate environmental conditions. The whole area was prone to grazing activities. Especially the northern slope was overgrazed. The overgrazing causes solifluction and erosion. The soil types on the northern slope are characterised by Umbrisols; the southern expositions were Cambisols and Leptosols. The soil in the watershed is originating from weathered parent material and river depositions in combination by slope processes. Here soil texture is varying from sandy loam to silt to silt loam.

The soils at Dugoba had a circum neutral pH and a relatively high base saturation on the cation exchanger. Unlike the other studied sites the pH decreased from the A to the B horizon, but then increased again into the C horizon (only found at 4 plots). The average oxide composition of the A and B horizons were practically identical and dominated (60%) by iron (Fe) and aluminum (Al) oxides. The amount of manganese (Mn) was relatively low, while the soil content of titanium (Ti) was relatively high at Dugoba (458 and 784 mg/kg, respectively, in the B horizon). The content of a majority of the 16 measured trace elements were strongly correlated to the Al and Fe content. Important exceptions are the typically soft (or type B) metals and the hard (type A) elements. Strong correlations were found within the soft, borderline and hard elements. 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 42 and 46% of the variation in the dataset in the A and B horizons, respectively. This PCA 1 axis was mainly explained by the Al and Fe content relative to calcium (Ca) and total carbon content, reflecting variations in the calcium carbonate content of the soil. The parameter loadings along the PCA 2 axis was to a certain extent correlated to the Covalent index (CI = X2r) of the elements (r = 0.490 and 0.404 in the A and B horizons, respectively).

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.:

Bakmurat Arabek uluu, Aitkul M. Burhanov, Emma G. Beletskaya, Myskal R. Ganybaeva, , Nuriya S. Isakunova, Salamat B. Imanakunov, Azamat K. Jybykeev, Jangazy K. Kartanbaev, Svetlana G. Nesterova, Margarita Y. Kuznesova, Nurgul K. Kuldanbaeva, Almaz B. Kurmankulov, Abdunaman Maksutov, Ajar K. Madieva, Bakyt A. Mamytova, Oleg R. Mujdabaev, Turatbek S. Musuraliev, Taalai K. Mekishev, Saltanat R. Narynbaeva, Asel Orokbaeva, Oktyabrin A. Sadyrov, Beishekan Sultanova, Vladimir K. Schudro, Omurbek Smat uluu, Venera M. Surappaeva, , Kubanych T. Turgunbaev, Sabira Urmanbetova.

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, 27 December 2010

Tonje Økland

Project leader

CONTENT

INTRODUCTION

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

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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 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 third monitoring site established in the TEMP-CA project, Dugoba in Batken oblast in the Kyrgyz Republic. This monitoring site was established and analysed in 2006. Measurements of a lot of variables for forest tree condition, forest growth, soil chemistry, and soil classification, ground vegetation, and environmental factors were performed in 2006 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 DUGOBA REFERENCE MONITORING AREA

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1: The Public Foundation Relascope, Bishkek
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1.1 Geographical position of the reference monitoring area

The Dugoba monitoring site is located in Batken Oblast, in the Fergana mountain region on the northern macro-slope of the Alai range and only 100 km to the west for the Kara-Koi area (Figs. 1.1 -1.2). Administratively the study area belongs to the Uch-Korgon Leskhoz in Kadamjai District of Batken oblast of the Kyrgyz Republic.

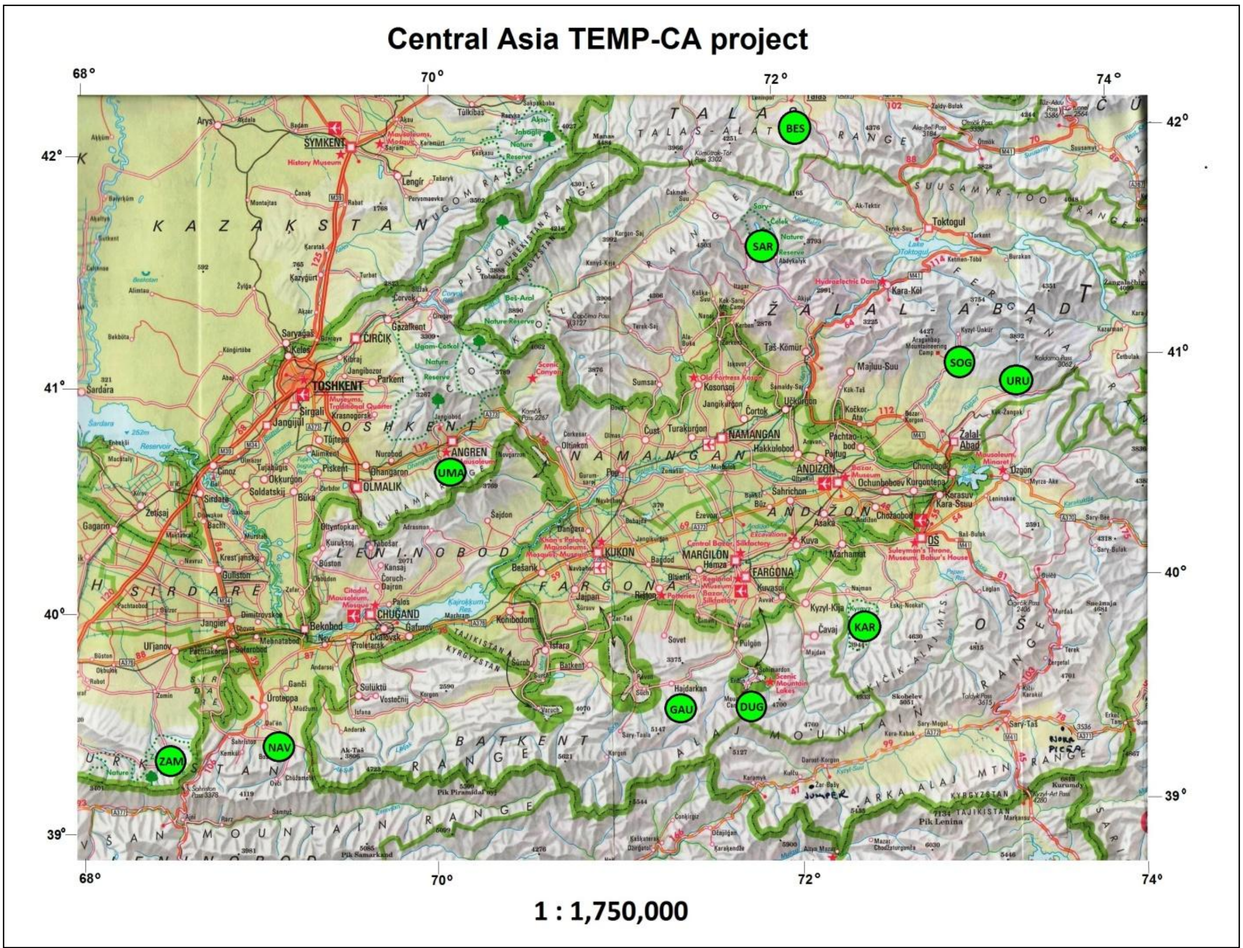

Fig. 1.1. Map of the Dugoba (DUG) and the nine other TEMP-CA monitoring reference areas.

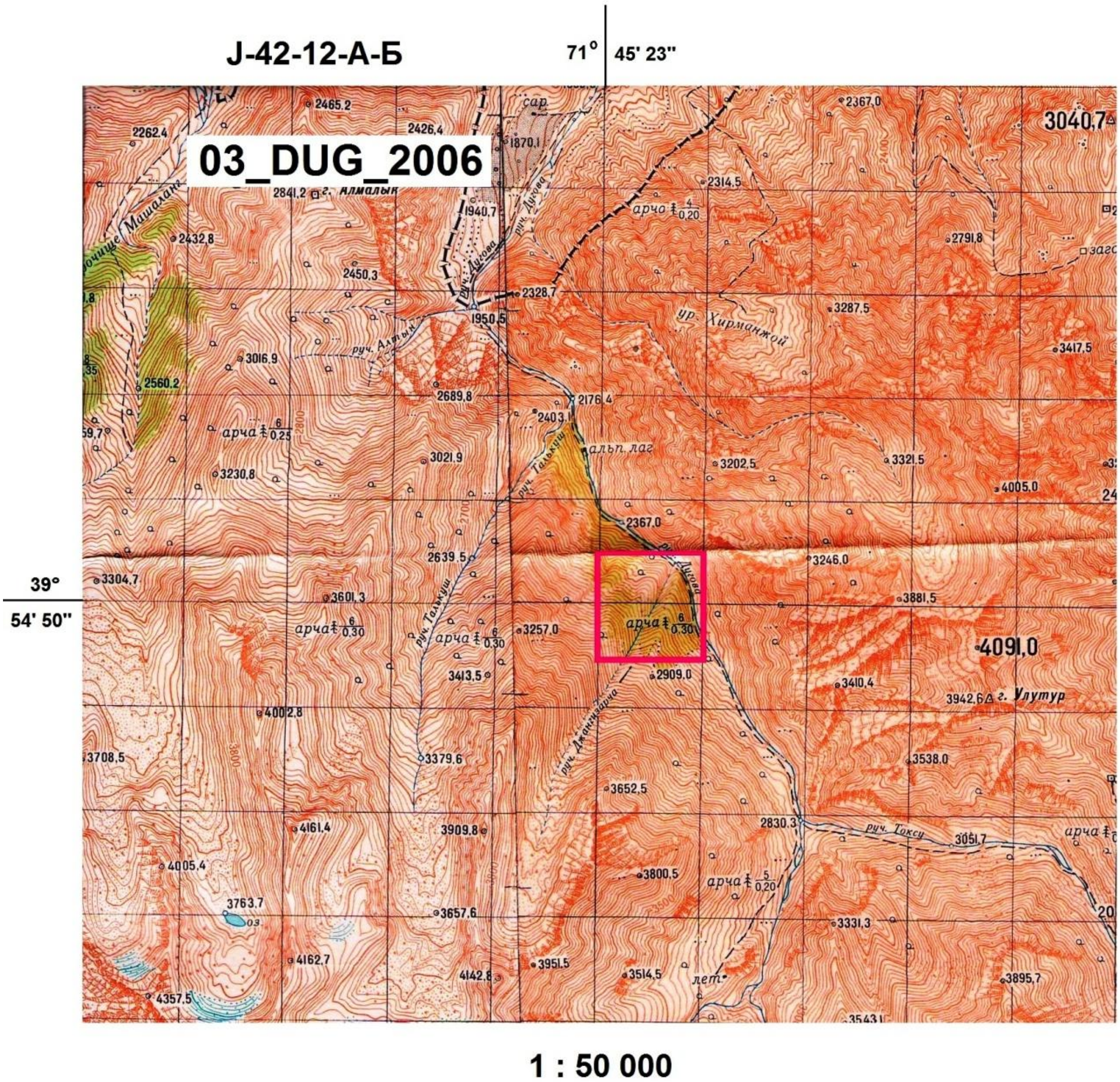

Fig. 1.2. Geographical position of the Dugoba monitoring reference area.

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

Tab. 1.1. GPS coordinates and the altitudes for the ten 10x10 m macroplots

Macro plot:	Elevation	N	E
DUG 1	2518 m	39°54.619′	071°46.002′
DUG 2	2544 m	39°54.605′	071°45.999′
DUG 3	2556 m	39°54.563′	071°45.990′
DUG 4	2589 m	39°54.540′	071°45.967′
DUG 5	2600 m	39°54.521′	071°45.953′
DUG 6	2605 m	39°54.478′	071°45.934′
DUG 7	2654 m	39°54.557′	071°45.977′
DUG 8	2694 m	39°54.566′	071°45.986′
DUG 9	2587 m	39°54.606′	071°45.915′
DUG 10	2694 m	39°54.612′	071°46.017′

1.2 Forest type, ownership, and conservation status

The mountain juniper forests are located in the sub-alpine zone and in the Dugoba monitoring site three juniper species occur: *Juniperus turkestanica*, *J. zeravshanika* and *J. semiglobosa*. However, *J. semiglobosa* and *J. zeravshanika* are the dominating tree species and the number of J. *turkestanica* trees is low.

The Leskhoz is a territorial entity of the forestry management. The main goals of this organization are to ensure forest and forest biodiversity protection, extension of forest covered areas by natural regeneration and artificial forest plantation, increasing of forest productivity and effective use of forest by-products.

1.3 Geology, topography, and quaternary deposits

The Dugoba site, as the Kara-Koi site, belongs to the tectonic region South Tien Shan. Its main features are: widely developed geosynclinal formations of various compositions from the medium and upper Paleozoicum; the main folding is hercynian, linear with many faults and the concluding folding is late hercynian developed in the upper Paleozoicum; red-coloured continental molass of the perm fills “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 Dugoba site belongs to the Alai-Turkestan province. The main factor determining the relief formation is related to epihercynian deposits which were subjected to vertical movements 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 lithologic composition of rocks. The Dugoba site, by its stretch and position, belongs to the South Tien-Shan group (Alai and Turkestan ranges).The tectonic-denudation relief is worked out in Mesozoic and Paleogene – Neogene deposits. These are the former troughs which experienced powerful tectonic rises in late Pleistocene. The relief is distinguished with crop-outs of Paleozoic and Proterozoic rocks. The age for the formation of the tectonic-denudation relief is primarily neogene - early quaternary - and its development continues up to this day.

1.4 Climate

The climate in the Dugoba monitoring site is typical continental, characterized by considerable seasonal variation. The main wind directions for this area are west and south-west.

1.4.1 TEMPERATURE

The average annual temperature is about +9 °C (Table 1.2). Duration of the period with a daily average temperature below 0 °C in the lower part is 70-80 days, at a height of about 2400 m a.s.l. it increases to 130 days. The average annual minimum temperature at a height of 2000 m a.s.l. is +8-9 °C, the absolute minimum is -28 °C. Duration of the warmest period with a daily average temperature above +10 °C at a height of 2000 m is 150 - 155 days and the average temperature of the most hot month of summer (July) is +18 - 19 °C, the absolute maximum at this height is - +33°C.

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

Nearest meteoro-logical station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	Year
Haidarkan	-5.4	-4	0.3	7.3	12	16.1	19.1	18.2	13.5	7.1	1	-2.9	6.9
Batken	-2	-0.4	5.7	13.5	18.3	23.6	26.1	24.7	19.5	12.2	5.8	1	12.3

1.4.2 PRECIPITATION

The maximum precipitation period for the area is early spring or early summer; for sub-mountain sites in March, and from mountain sites from April to June (Tab. 1.3). The autumn is usually dry 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 c. 500 mm/year.

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

Name of the nearest meteorological station	1	2	3	4	5	6	7	8	9	10	11	12	year
Haidarkan	36.2	43.4	68.8	90.3	94.3	52.1	31	15	16	37.4	29.8	33.7	548
Batken	15	17	28	30	35	18	14	4	5	15	13	14	208

1.5 Vegetation zones

The territory of Dugoba 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 vegetation cover of the Dugoba investigation area is included in the Alay type of vertical zones. The most widespread vegetation types of the investigated area, just as in the Kara-Koi site, are forests represented by three juniper species: *Juniperus seravshanica*, *J. semiglobosa* and *J. turkestanica*. The presence of considerable areas of rocks and stony – rubbly slopes is typical for this region.

1.6 Forest history, forest structure, and external influence

1.6.1 HUMAN IMPACT

There are 3 settlements (Yntymak, Raz'ezd and Narai) within the territory of Uch-Korgon Leskhoz. There are 135 homesteads and 676 people living in the area (Tab. 1.4).

Tab. 1.4. Population size in the different settlements in the area

Name of settlements	Number of homesteads (families)	Population (person)	Distance from Leskhoz's Office (km)
Yntymak (Kutal)	47	236	25

Raz'ezd	70	349	45
Narai*	18	91	240
Total:	**135**	**676**	**-**

Mining industry (base material exploration, extraction and processing) and agriculture (not intensively where the cattle-breeding branch prevailed) were the leading branches of the national economy in the past in the Kadamjai region where the Uch-Korgon Leskhoz is located. During the last years the degradation of juniper forests and increasingly offences in forests can be observed for the territory of the leskhoz. The main reasons are ecological illiteracy and low consciousness for the village population and absence of governmental social programs for supporting of the poorest of the population. Furthermore increasing cattle stock, poverty and absence of adequate funds for purchasing of the energy carriers (coal, wood) for part of the population and not strong enough legislative basis can be observed, all of it contributing to the increase of offences in the forest. There is also a pronounced un-authorized un-regulated pasturing in the forests where it is actually forbidden; ploughing up of mountainsides and pastures, usurpation of lands and illegal building.

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 20^{th} 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, However, the local people continued cutting high-quality trees under cover of sanitary needs. At the same time, regeneration was restricted by the 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 striked 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 the juniper area suffered from poor economy, and this is reflected in the present development and activity on forest regeneration.

1.6.3 GRAZING

Intensive and un-regulated pasturing in the forest area is one of the main factors which negatively affects on forest condition and development. It leads to strong decrease in natural regeneration of juniper and damage of vegetation cover and promotes the weeds and not eatable grasses. Grazing activity in juniper area occurs at all times and permanently. The local people use the whole forest territory for livestock grazing, by moving from one site to (Tab. 1.5).

Tab. 1.5. Sizes of grazing livestocks in the area.

№	**Name of rural authority**	**Livestock by species, heads**			
		Total	**Including**		
			Small cattle	**Cattle**	**Horses**
1	1. Uch-Korgon	15384	12369	2553	462

The main threat to the juniper forests in the lowland and close to settlements is caused by the livestock as a result of their intensive un-regulated grazing in the spring, before they are moved to summer pastures, and in autumn when they return.

In the recent time the livestock kept in the region has increased year by year, and in several regions its quantity comes near to an extreme level. Intensive un-regulated pasturing is the main reason of un-satisfactory natural renewal and condition of juniper forests.

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 forest trees of the Dugaba site are represented mainly by the *Juniperus* species *J. semiglobosa* and *J. seravschanica*. In addition, there are small amounts of *J. turkestanica, Lonicera microphylla* and *Sorbus tianschanica.* (Fig.2.1).

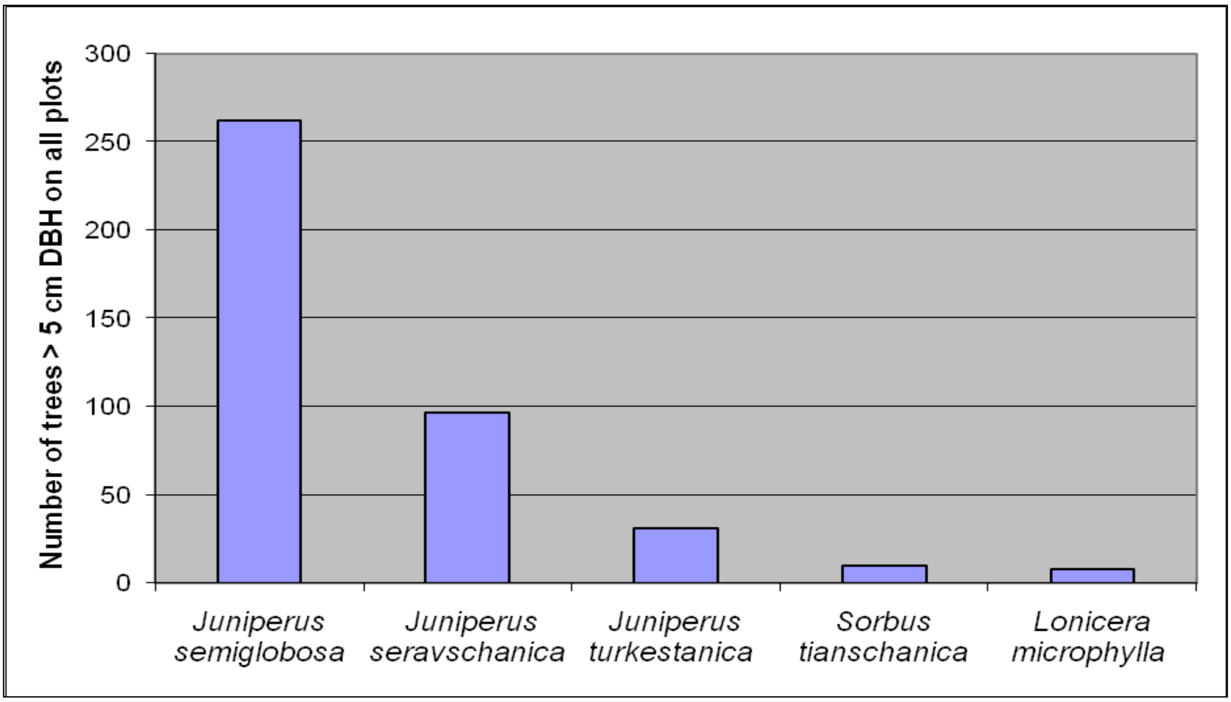

Fig. 2.1. Total number of trees of the different species > 5 cm DBH in all plots.

2.2.2 TREE CONDITION

Tree condition is presented only for the main species for which there are sufficient amounts of individuals to draw reasonable conclusions. Defoliation for the *Juniperus* species was quite noticeable, 43-44% (Fig.2.2). As commonly found, however, the proportion of juniper trees with discoloration was rather insignificant (< 1.2%).

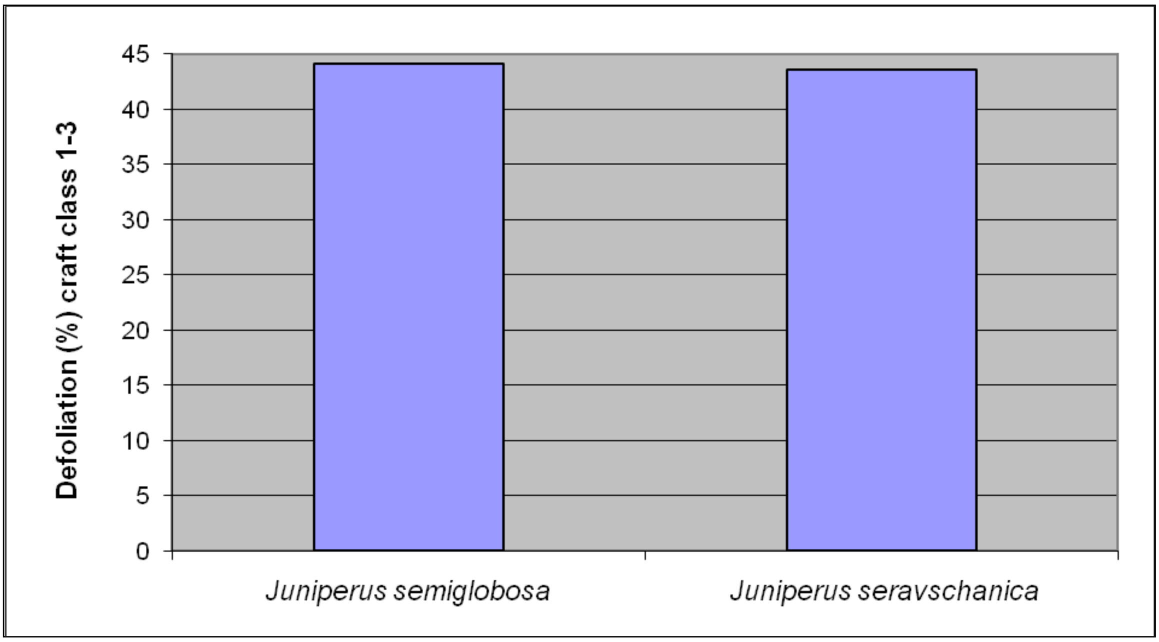

Fig. 2.2. Defoliation for the main species.

2.2.3. DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

The size distributions (DBH) of *J. semiglobosa* (Fig. 2.3) and *J. seravschanica* (Fig. 2.4) was approximately identical (although the total number of *J. semiglobosa was* almost three times that of *J. seravschanica*) and showed a considerable decrease in the number of individuals with increasing DBH. The two smallest size classes (DBH < 15 cm) constituted 48% in *J. semiglobosa* and 51.9% for *J. seravschanica* (Fig.2.3 and 2..4). In *J. semiglobosa* 6 saplings (< 5 cm DBH) were also recorded in the ground vegetation quadrants. Conversely, trees with DBH > 20 cm made up 35.7% in *J. semiglobosa* and 22.1% in *J. seravschanica*.

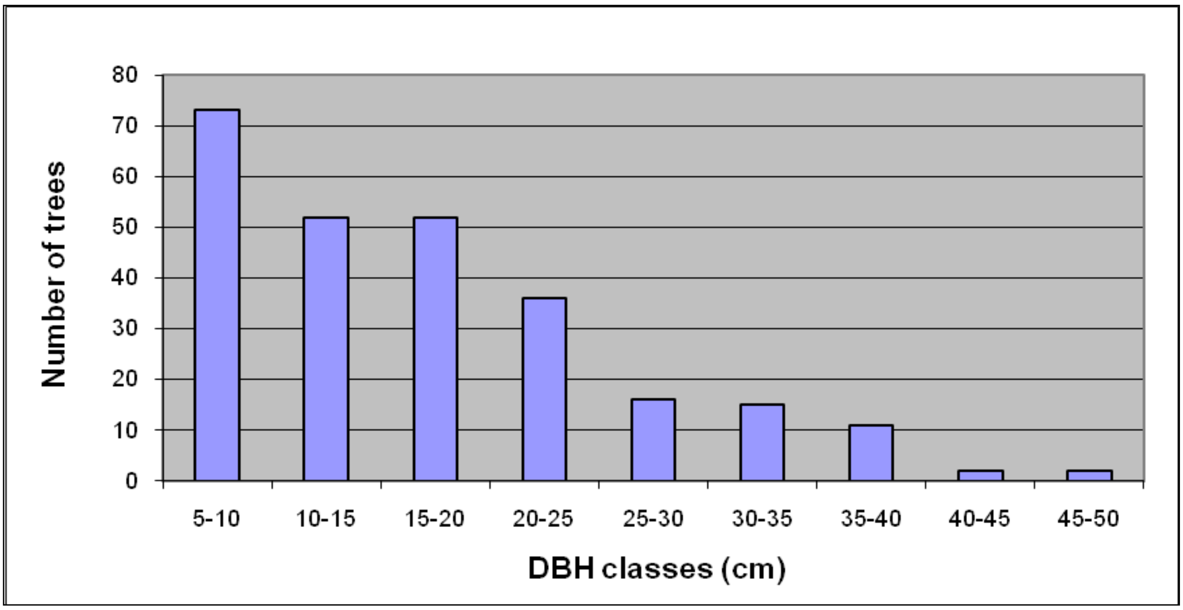

Fig. 2.3. Size distribution (DBH) of *J. semiglobosa* for across all plots.

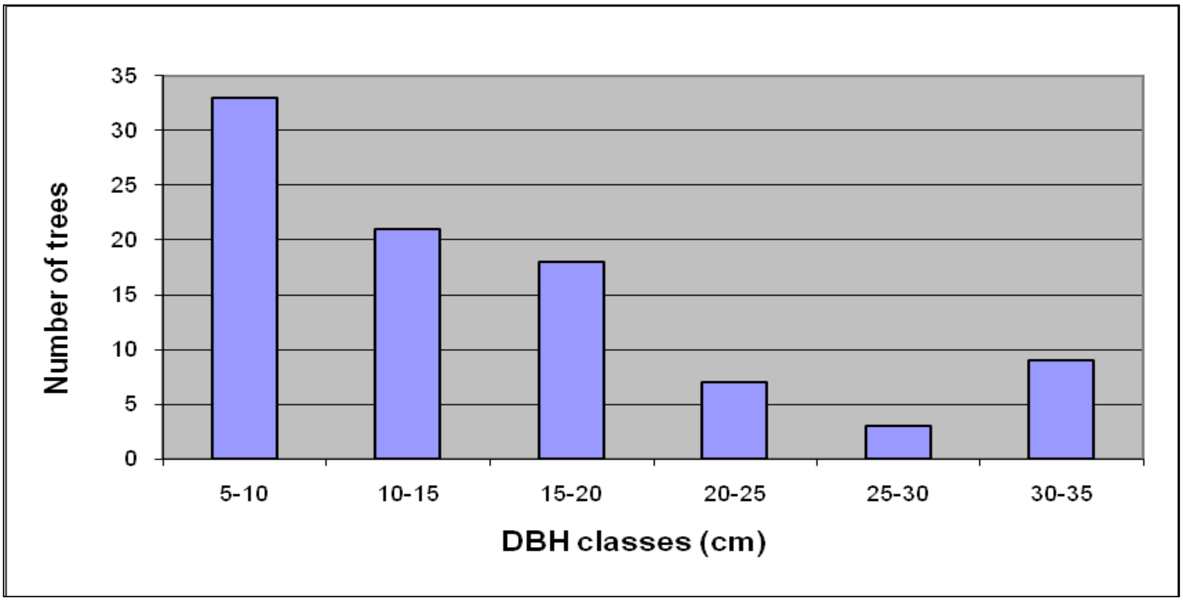

Fig 2.4. Size distribution (DBH) of *J. seravschanica* across all plots.

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. However, the repeated assessments, which are the basic idea of monitoring, will always provide crucial information about temporal development in forest condition.

At this site the defoliation for the juniper species was rather high (43-44%) and the trees can be classified as “moderately damaged”. This could be an effect of the very hot and dry summers during the past 2-3 years. At the same time, there were essentially no trees with considerable discoloration. The *Juniperus* species may be attacked by fungal diseases, such as *Gynnosporangium* rusts and rot, which could affect tree vitality. The 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. The harsh climate close to the tree line could affect the defoliation, without any notable effect on the discoloration of the trees. The climatic conditions or other stress factors may also 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 the highest proportion of individuals was found among the smallest size classes. This possibly reflects a similar *age class distribution* and a surplus of young individuals, suggesting satisfactory regeneration. In favor of this view, some *J. semiglobosa* saplings (< 5cm DBH) were recorded in the ground vegetation quadrants. Nevertheless, even the regeneration appears sufficient expressed as proportion of small individuals, the actual amount of *J. seravschanica* trees is still low because thinning and excessive exploitation (cutting, grazing) of long duration. The frequent drought episodes could also be decisive for survival of *Juniperus* saplings. 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 in which saplings and trees < 5 cm DBH are recorded.

3 BIODIVERSITY AND GROUND VEGETATION

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3.1 Methods

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

The key principles are summarised below:

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

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

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

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

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

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

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

3.1.1 SAMPLING DESIGN

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

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

3.1.2 VEGETATION PARAMETERS

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

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

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

3.1.3 EXPLANATORY VARIABLES

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

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

(1) Topographical variables include:

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

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

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

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

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

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

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

(2) Tree influence variables include:

- Crown cover index
- Litter index
- Basal area

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

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

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

Litter index 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 BIODIVERSITY

The number of species, α-diversity, is reported in this chapter, while β-diversity (variation in species composition along gradients) will be reported in chapter 3.2.2 below. The total species list is given in Appendix 3.1. 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. 72 species was recorded in the 50 1-m^2 plots, 56 vascular plants, 14 bryophytes and 2 lichens. The maximum number of species recorded in any 1-m^2 plot was 35, while the minimum number was 4. The average number of species recorded in the 1-m^2 plots was 17,7.

The total number of vascular plant species recorded within the 50 1-m^2 plots + ten 10x10m2 plots was 64. The total number of vascular plant species in the in the 50 1-m^2 plots + ten 30x30m^2 plots was 69. Of these species 11 are endemic to Central Asia: *Rosa alaica, Carex turcestanica, Astragalus alaicus, Astragalus schachimardanus, Fritillaria walujewii, Nepeta podostachys, Phlomoides alaica, Thymus seravschanicus, Viola alaica, Juniperus semiglobosa* and *Juniperus turkestanica.*

The maximum number of vascular plant species recorded in the five 1-m^2 plots in any 10 x 10 m plot was 32 and the minimum was 18. The maximum number of vascular plant species recorded in any of the 10x10 m macro plots was 39 (the five 1-m^2 plots included), and the minimum number was 21. The average number of species in the 10x10 m macro plots (the five 1-m^2 plots included) was 30.1. The maximum number of vascular plant species recorded in any of the 30x30 m macro plots was 41 (the five 1m^2 plots included), and the minimum number was 23. The ratio a/b varied between 0.67and 0.96 (Tab. 00). The ratio a/c varied between 0,59 and 1.00 in the macro plots.

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	32	36	41	0.89	0.78
2	30	35	39	0.86	0.73
3	26	39	31	0.67	0.67
4	29	32	35	0.91	0.94
5	28	33	37	0.85	0.80
6	18	22	26	0.82	0.49
7	25	29	30	0.86	0.96
8	23	24	26	0.96	0.77
9	26	30	32	0.87	1.00
10	19	21	23	0.90	0.59
Total number	56	64	69	0.88	0.81

The plant species were divided into species groups, tree species and bushes herbs, ferns, and graminoids (Tab.3.2). Most of the vascular plants, in total 45 were herbs.

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

Plot number:	Tree species	Shrubs	Herbs	Ferns	Grami-noids	Bryo-phytes	Lichens
1	1	2	26	0	3	8	0
2	2	1	25	0	2	11	1
3	1	2	20	0	3	10	2
4	1	3	21	1	3	10	2
5	1	2	22	1	2	11	0
6	0	2	15	0	1	2	0
7	0	3	19	1	2	6	0
8	2	4	14	0	2	6	1
9	0	3	20	0	3	5	0
10	0	2	15	0	2	3	0
Total number	2	5	45	1	3	14	2

3.2.2 MAIN GROUND VEGETATION GRADIENTS

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

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

	DCA 1	DCA 2	DCA 3	DCA 4
Eigenvalues	0.272	0.194	0.144	0.094
Gradient lengths	2.032	2.463	2.367	1.657

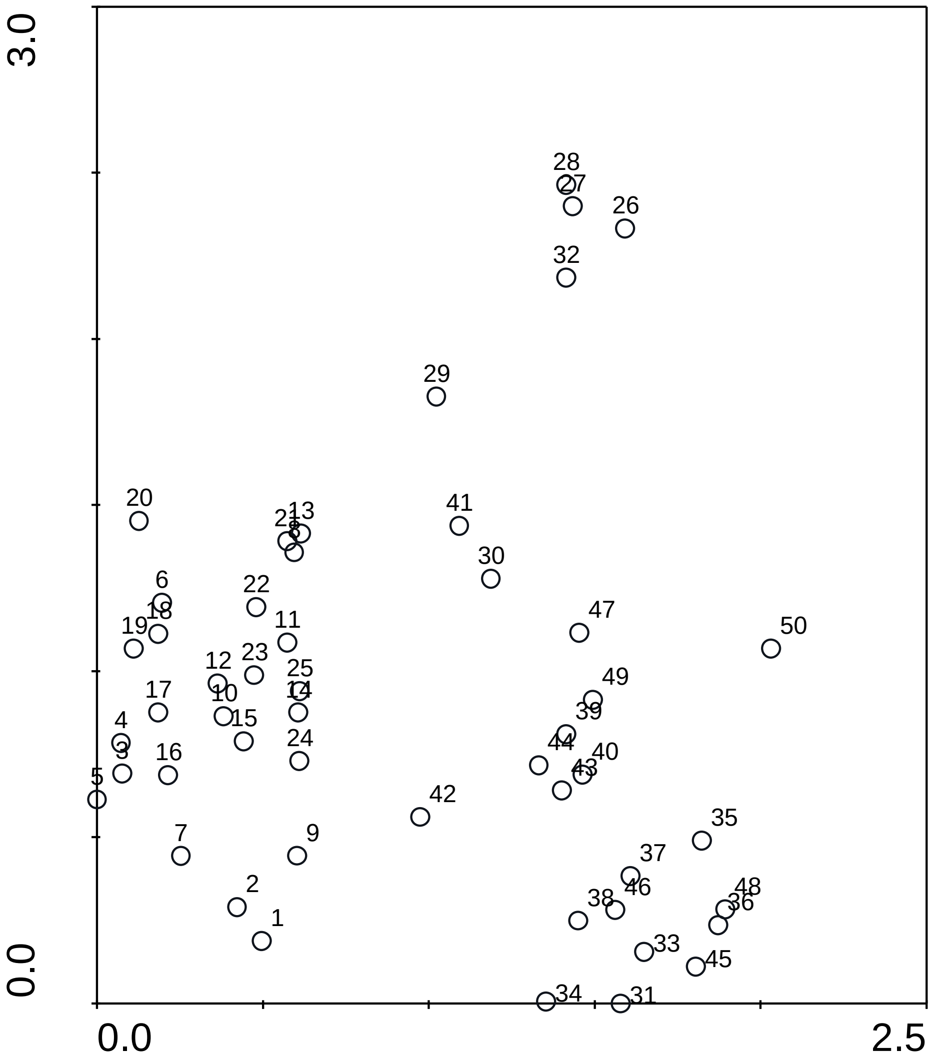

Fig. 3.1. DCA ordination of 50 1 m^2 plots, axes 1 (horizontal) and 2 (vertical). Plot numbers for the 50 1 m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

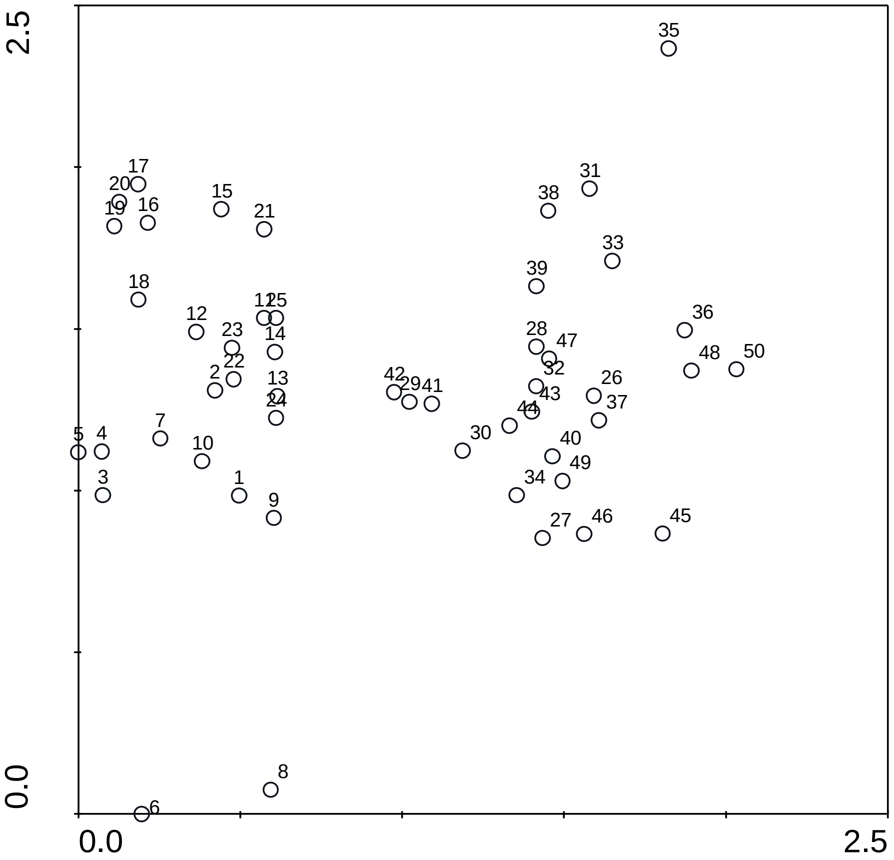

Fig. 3.2. DCA ordination of 50 1 m^2 plots, axes 1 (horizontal) and 3 (vertical). Plot numbers for the 50 1 m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

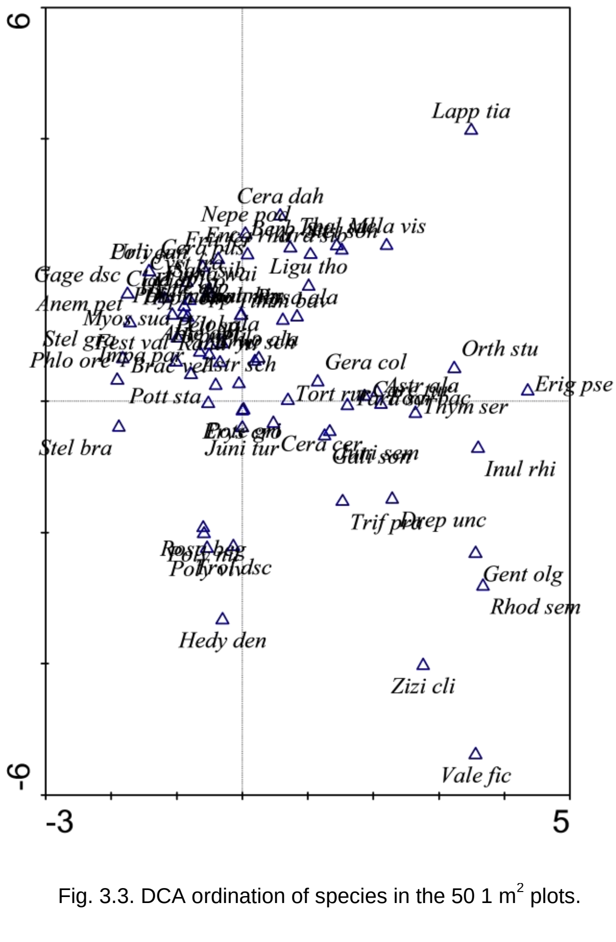

Fig. 3.3. DCA ordination of species in the 50 1 m^2 plots.

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	0.000	-0.120	0.219	-0.018	0.854	0.033	0.732
DCA 2	-0.120	0.219	1.000	0.000	0.029	0.763	0.011	0.913
DCA 3	-0.018	0.854	0.029	0.763	1.000	0.000	-0.096	0.324
DCA 4	0.033	0.732	0.011	0.913	-0.096	0.324	1.000	0.000
Soil moisture	**- 0.285****	**0.004**	0.091	0.353	-0.178	0.068	0.130	0.184
Inclination	**-0.216***	**0.030**	**0.319****	**0.001**	**0.200***	**0.044**	-0.081	0.416
Aspect	**-0.465****	**0.000**	0.194*	0.049	0.185	0.061	-0.098	0.319
Aspectfav	**-0.264****	**0.007**	0.164	0.097	-0.016	0.874	-0.112	0.255
Heatindex	0.095	0.332	0.096	0.324	0.135	0.167	0.085	0.384
Max. incl.	-0.064	0.518	0.093	0.351	**0.211***	**0.034**	-0.078	0.435
Sum concavity /convexity 1x1 m	-0.156	0.132	0.000	1.000	-0.043	0.675	-0.147	0.155
Variance concavity /convexity 1x1 m	**-0.342****	**0.001**	**0.208***	**0.039**	0.004	0.966	-0.070	0.488
Abs. sum concavity /convexity 1x1 m	**-0.324****	**0.001**	0.197	0.053	-0.006	0.953	-0.071	0.487
Sum concavity /convexity 3x3 m	-0.168	0.102	-0.003	0.980	-0.198	0.054	-0.053	0.605
Variance concavity /convexity 3x3 m	**-0.367****	**<0.001**	-0.006	0.953	-0.039	0.699	**-0.201***	**0.045**
Abs. sum concavity /convexity 3x3m	**-0.381****	**<0.001**	0.014	0.892	-0.080	0.436	**-0.229***	**0.025**
Rel. deciduous trees.	-0.089	0.410	0.067	0.535	-0.086	0.426	-0.017	0.875
Rel. conifer trees	**0.262****	**0.009**	-0.111	0.268	0.023	0.821	-0.013	0.893
Rel. total	0.235*	0.019	-0.094	0.347	-0.056	0.574	-0.010	0.92
Crovn cover index	0.007	0.947	0.033	0.738	**-0.220***	**0.024**	-0.109	0.262
Litter index	-0.052	0.631	0.110	0.308	-0.154	0.152	-0.099	0.356
Grazing intensity	**0.333****	**0.003**	-0.158	0.157	0.098	0.381	-0.038	0.736
Average grass height	**0.250***	**0.014**	-0.012	0.906	**-0.213***	**0.037**	0.165	0.105
Average shrub height	**-0.212***	**0.039**	0.184	0.074	0.119	0.248	-0.051	0.623
% cover animal traces/footprints	0.078	0.459	-0.096	0.361	0.123	0.243	-0.052	0.620
% cover animal tracks	0.020	0.857	-0.042	0.709	**0.277***	**0.014**	-0.012	0.914
Max. soil depth	-0.179	0.070	0.040	0.688	-0.162	0.102	-0.084	0.393
Min. soil depth	0.003	0.980	0.095	0.342	0.034	0.737	-0.008	0.940
Med. soil depth	0.106	0.280	0.102	0.296	0.020	0.841	-0.125	0.200
Max. org. layer depth	-0.167	0.105	**0.432****	**<0.001**	-0.143	0.164	0.025	0.806
Min. org. layer depth	-0.140	0.176	**0.272****	**0.009**	-0.185	0.074	0.069	0.502

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

Med. org. layer depth	-0.158	0.119	**0.486****	**<0.001**	-0.154	0.129	0.050	0.619
Max. litter depth	**0.282****	**0.008**	0.205	0.054	-0.147	0.168	0.006	0.959
Min. litter depth	**0.336****	**0.003**	0.095	0.399	-0.172	0.127	**0.234***	**0.038**
Med. litter depth	**0.232***	**0.033**	0.211	0.054	-0.092	0.399	0.122	0.262
Altitude	**0.251***	**0.013**	**0.258***	**0.011**	0.070	0.49	0.168	0.097
pH	0.132	0.178	0.160	0.103	0.056	0.569	0.137	0.162
H+	-0.132	0.178	-0.160	0.103	-0.056	0.569	-0.137	0.162
Dry matter%	**-0.252****	**0.010**	0.094	0.336	-0.101	0.3	0.097	0.32
Ctotal%	**-0.228***	**0.020**	0.151	0.122	-0.106	0.277	0.060	0.541
Ca	-0.101	0.320	**0.270****	**0.008**	-0.120	0.24	0.103	0.311
Mg	-0.144	0.158	0.173	0.090	-0.162	0.112	0.088	0.389
K	**0.297****	**0.004**	**0.300****	**0.003**	-0.091	0.373	0.069	0.501
CEC	**0.461****	**<0.001**	-0.119	0.244	0.002	0.985	-0.034	0.740
Total N, mkg/g	**-0.208***	**0.033**	0.063	0.520	-0.106	0.277	0.050	0.610
PO4 mg/kg	0.020	0.841	-0.126	0.198	-0.016	0.874	-0.155	0.112
Ca, ppm	-0.058	0.553	**0.220***	**0.024**	0.091	0.349	**0.233***	**0.017**
Mg, ppm	0.019	0.847	-0.024	0.808	0.124	0.204	-0.089	0.362
Na, ppm	**-0.316****	**0.001**	0.141	0.148	0.108	0.27	-0.179	0.067
K, ppm	**0.447****	**0.000**	-0.063	0.52	-0.062	0.525	0.019	0.847
Al, ppm	0.141	0.148	-0.084	0.389	-0.021	0.828	-0.140	0.153
Fe, ppm	0.149	0.126	-0.060	0.541	-0.062	0.525	-0.115	0.238
Mn, ppm	**0.203***	**0.037**	-0.117	0.232	**-0.211***	**0.031**	-0.012	0.900
P, ppm	-0.118	0.225	0.009	0.927	**-0.269****	**0.006**	0.113	0.245
Zn, ppm	**0.210***	**0.032**	**-0.228***	**0.020**	**-0.260****	**0.008**	0.050	0.61
Ca/Ctot*100	-0.002	0.980	**0.272****	**0.005**	0.036	0.713	-0.087	0.371
Mg/Ctot*101	0.058	0.553	-0.027	0.783	0.073	0.452	-0.158	0.106
K/Ctot*102	**0.378****	**<0.001**	0.127	0.195	0.044	0.651	-0.043	0.658
CEC/Ctot*100	**0.326****	**0.001**	-0.125	0.201	0.095	0.332	-0.076	0.437
Total N/Ctot*100	-0.113	0.245	-0.071	0.467	-0.085	0.384	-0.002	0.98
PO4/Ctot*100	0.091	0.353	**-0.193***	**0.047**	-0.023	0.815	-0.148	0.13
Ca, ppm/Ctot*100	0.177	0.069	0.030	0.757	**0.245***	**0.012**	0.050	0.610
Mg, ppm/Ctot*100	**0.202***	**0.039**	-0.158	0.106	0.122	0.21	-0.086	0.380
Na, ppm/Ctot*100	0.120	0.219	-0.102	0.296	0.136	0.165	-0.148	0.130
K, ppm/Ctot*100	**0.357****	**<0.001**	-0.189	0.053	0.062	0.525	-0.087	0.371
Al, ppm/Ctot*100	**0.195***	**0.046**	**-0.197***	**0.044**	0.080	0.412	-0.099	0.311
Fe, ppm/Ctot*100	**0.218***	**0.026**	**-0.193***	**0.047**	0.083	0.394	-0.096	0.328
Mn, ppm/Ctot*100	**0.291****	**0.003**	**-0.247***	**0.011**	0.013	0.894	-0.097	0.320
P, ppm/Ctot*100	0.179	0.067	-0.187	0.055	0.060	0.536	-0.069	0.477
Zn, ppm/Ctot*100	**0.301****	**0.002**	**-0.254****	**0.009**	0.003	0.973	-0.084	0.389

3.3 Discussion

3.3.1 EVALUATION OF BIODIVERSITY

Three different *Juniperus* species, *Juniperus seravshanica, J. semiglobosa and J. turkestanica* were dominating the tree layer in the monitoring site of Dugoba.

The species composition of shrubs includes *Caragana alaica, Ephedra intermedia, Rosa kokanica and Cerasus alaica.*

The grass and herb layer in the plots is mainly dominated by *Festuca valesiaca* and *Carex turkestanica but. Ligularia thompsonii* dominated occasionally. Examples of other species that occurred in the plots are*, Saxifraga sibirica, Cerastium pusillum, Cirsium esculentum, Corydalis ledebouriana, Thalictrum sultanabadense and Geranium collinum*. *Campanula glomerata, Carex diluta, Carex orbicularis, Juncus articulatus* and *Alopecurus pratensis* are examples of species that occur in the area but were not recorded in the plots

Most of the vascular plants are herbs and out of 72 species recorded in the 50 1-m^2 plots 45 were herbs, and most of the herbs was xeromorphic and thermophytic species. The area has many steppe species and also several bryophyte species.

3.3.2 INTERPRETATION OF GROUND VEGETATION GRADIENTS

The variable most strongly correlated with DCA 1 was *aspect*, which was negatively correlated and *CEC* and the *total amounts of K* in soil, both positively correlated. *Aspect favourability* was also negatively correlated with DCA 1, but not so strong. This means that difference in *aspec*t is and nutrient conditions are some of the most important factors influencing the species composition in the Dugoba monitoring site.

Variables expressing *density of conifer trees*, *grazing intensity*, *nutrient conditions* and *depth of the litter layer* (all positively correlated) as well as *soil moisture* and variation in *microtopography* (both negatively correlated) were also more or less strongly correlated with DCA 1, i.e. influencing the gradient in species composition expressed along DCA 1. The influence of grazing on the ground vegetation was more severe on some of the driest sites which also had high CEC; i.e. high content of nutrients available for plants. Some of the plots were also on stony sites and with more variation in microtopography than the other plots. Density of conifer trees (juniper) and depth of litter layer were also positively correlated with DCA 1.

The variables most strongly (positively) correlated with DCA 2 were *maximum and median values* (in cm) *of depth of organic laye*r. *Inclination* and *altitude* were also positively correlated as well as concentrations of *K* and *Ca* in soil

According to our results the variation in species composition in ground vegetation in Dugoba is thus mainly due to variation in topography, nutrient conditions, light and litter conditions and influence of domestic animals.

3.4 Appendix

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

Latin names of species:	Kyrgyz names of species:	Russian names of species:
Anemone petiolulosa	Саптуу анемона	Ветреница черешковая
Astragalus alaicus	Алай астрагалы	Астрагал алайский
Astragalus schachimardanus	Шахимардан астрагалы	Астрагал шахимарданский
Atragene sibirica	Сибирь атрагенасы	Княжик сибирский
Berberis sphaerocarpa	Бөрү карагат	Барбарис разноножковый
Bistorta elliptica	Мекери бистортасы	Бисторта красивая
Bistorta vivipara	Жөргөмүш бистортасы	Бисторта живородящая
Carex turkestanica	Түркстан ыраңы	Осока туркестанская
Cerastium davuricum	Даурия серастиуму	Ясколка даурская
Cerastium pusillum	Кичинекей серастиум	Ясколка маленькая
Clementsia semenovii	Семенов клементсиясы	Клементсия Семенова
Cystopteris fragilis	Морт цистоптериси	Пузырник ломкий
Dichodon cerastoides	Үч мамычалуу диходон	Диходон трехстолбиковый
Erigeron pseudoseravschanicus	Жалган зеравшан жылтыр гүлү	Мелколепестник ложнозеравшанский
Erysimum croceum	Шафран даргыны	Желтушник шафранный
Festuca valesiaca	Валезия бетегеси	Овсяница валезийская
Fritillaria walujewii	Валуев чаар гүлү	Рябчик Валуева
Fumaria vaillantii	Вайлант фумариясы	Дымянка Вайланта
Gagea dschungarica	Жунгар каз пиязы	Гусиный лук джунгарский
Galium songoricum	Жунгар галиуму	Подмаренник джунгарский
Gentiana olgae	Ольга көк базини	Горечавка Ольги
Geranium collinum	Шалбаа каз таманы	Герань холмовая
Hedysarum denticulatum	Тишчелүү тыйынчанак	Копеечник зубчатый
Impatiens parviflora	Майда гүлдүү кына	Недотрога мелкоцветковая
Inula rhizocephala	Сабаксыз карындыз	Девясил корнеглавый
Juniperus semiglobosa	Сары арча	Можжевельник полушаровидный
Juniperus turkestanica	Түркстан (өрүк) арчасы	Можжевельник туркестанский
Lappula tianschanica	Тянь-Шань кара кызы	Липучка тяньшанская
Ligularia thomsonii	Томсон кой жалбырагы	Бузульник Томсона
Myosotis caespitosa	Чымдак бото көз	Незабудка дернистая
Nepeta podostachys	Машактуу непета	Котовник ножкоколосый
Palulita alpine	Альпы паулитасы	Паулита альпийская
Phlomioides alaica	Алай шимүүрчөгү	Фломоидес алайский
Phlomoides oreophila	Тоо шимүүрөгү	Фломоидес горный
Poa bactriana	Бактерия жылганы	Мятлик бактрийский
Potentilla grisea	Боз түктүү каз таман	Лапчатка серая
Ranunculus monophyllus	Бир жалбырактуу байчечекейи	Лютик однолистный
Ranunculus natans	Калкыган байчечекей	Лютик плавающий
Rosa alaica	Алай ит муруну	Роза алайская
Rosa beggeriana	Беггер ит муруну	Роза Беггера
Saxifraga sibirica	Сибирь саксифрагасы	Камнеломка сибирская
Silene viscose	Жабышчак силена	Смолевка липкая
Stellaria brachypetala	Кыска желекчелүү жылдызча	Звездочка коротколепестная
Stellaria graminea	Дан жылдызчасы	Звездочка злачная
Stellaria songorica	Жунгар жылдызчасы	Звездочка джунгарская
Taraxacum syriacum	Сирия какымы	Одуванчик сирийский
Thalictrum minus	Кичинекей тармал чөп	Василистник малый
Thalictrum sultanabadense	Султанабад тармал чөбү	Василистник султанабадский

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

Thymus seravschanicus	Зеравшан кийик оту	Тимьян зеравшанский
Trifolium pratense	Шалбаа уй бедеси	Клевер луговой
Trollius dschungaricus	Жунгар троллиусу	Купальница джунгарская
Urtica cannabina		
Valeriana ficariifolia	Жазы жалбырактуу мышык тамыр	Валериана чистяколистная
Viola alaica	Алай ала гүлү	Фиалка алайская
Viola isopetala	Тең желекчелүү ала гүл	Фиалка равнолепестная
Ziziphora clinopodioides	Жыттуу көкөмерен	Зизифора пахучковидная
Abietinella abietina		
Brachythecium velutinum		
Bryum schleicheri		
Distichium capillaceum		
Drepanocladus uncinatus		
Encalypta rhaptocarpa		
Hypnum lindbergii		
Hypnum cupressiforme		
Orthotrichum sturmii		
Pohlia nutans		
Polytrichum juniperinum		
Pottia starkeana		
Timmia bavarica		
Tortula ruralis		
Cladonia sp.		
Peltigera sp.		

4 SOIL CLASSIFICATION AND SOIL DESCRIPTION

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

4.1 Methods

The chemical composition of the soil layers is due to the biogeochemical cycling (Fig. 4.1). In the 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.

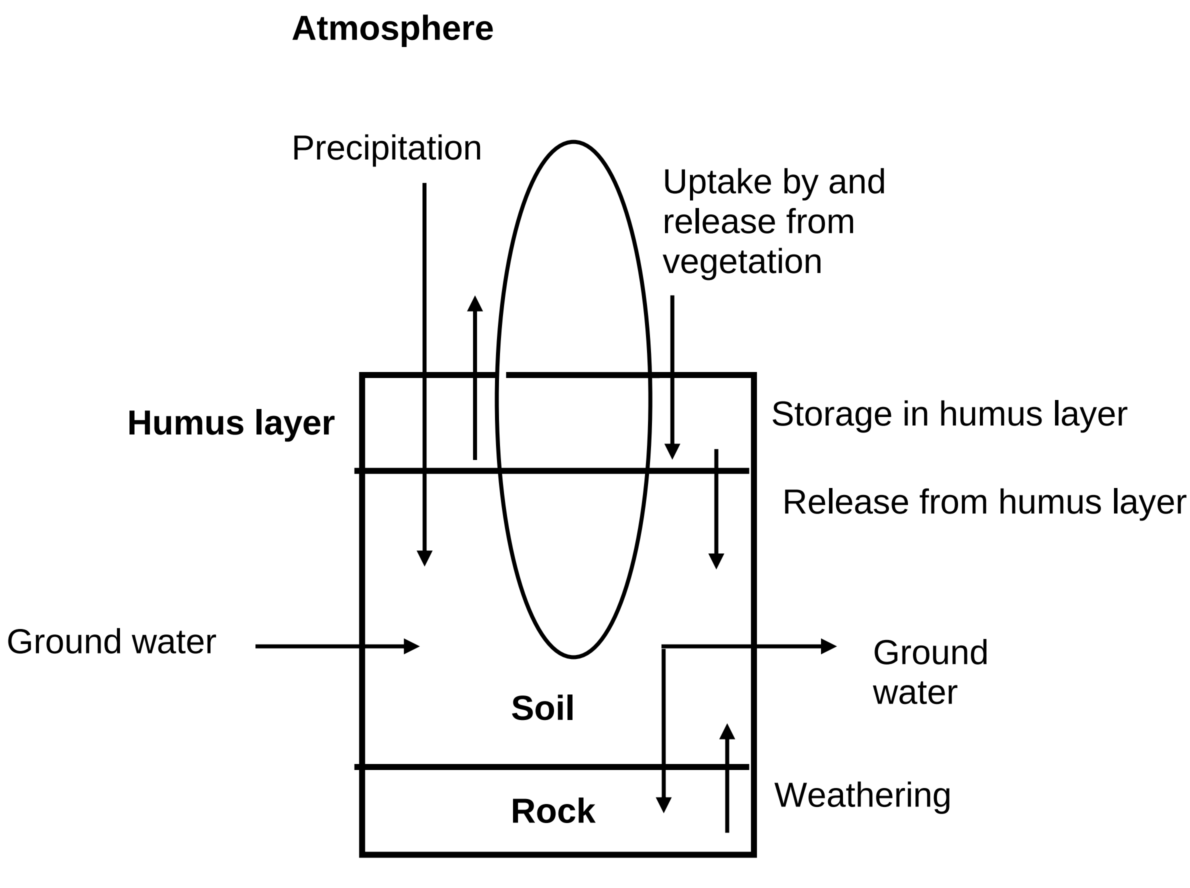

Fig. 4.1. Simplified model of biogeochemical cycling of elements.

The methodology for placing the macro plots and 1-m2 vegetation plots is described in 3.1.1. During the 1st – 4th of June 2006 soil samples were taken from each 1-m2 plot. The weather before the sampling was sunny. During sampling the temperatures were below and around the freezing point. Soil moisture samples were taken on the 4th of June 2006.
For long term monitoring it is important to get information from all the soil horizons. Accordingly, the soil sampling was done per soil horizon. For each 1-m^2 plot the sampling horizon and the depth of sampling was recorded. Samples were taken (see chapter 5 for more details) from 3 sides outside each of the 1-m^2 plots. Soil samples were not collected at the slope above the 1-

m^2 plots in order to avoid disturbances. Sampling was done with the help of an Edelman auger and the maximum reachable sampling depth was 1.20 m. In cases where the presence of free chalk was expected this was controlled with the aid of a solution of 1M HCl. Per 1-m^2 plot one mixed soil sample was collected and put in a 0.5 litre sample box. After field work the boxes were stored at a cool and dry place.

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

4.2. Results

The monitoring plots were placed in a small and steep watershed with two main exposures. On the northfacing slope the soil organic matter content was higher and the soils were generally deeper developed and more moist than the plots on the southfacing slope which were characterised by shallow soils with a lower soil organic matter content. A few sites were selected with a western exposition. Here the conditions were intermediate between the northern and southern slope. The altitude of the plots varies from 2508 m. to 2606 m.

The whole area was prone to grazing activities. Especially the northern slope was (severe) overgrazed. The overgrazing causes solifluction and erosion.

The soil types on the northern slope are characterised by Umbrisols and in case of a stony soil at the top Leptosols.

The soil in the watershed is originating from weathered parent material and river depositions in combination by slope processes. The texture is varying from sandy loam to silt to silt loam. In macro plot 5 clay was found in the underground. The topsoil of the northern exposed macro plots (1 – 6) is rich to very rich in black humus. The humus is mostly a mull, as a result of the good nutrient conditions (weathered soils). The Macro plots 7 and 8 do have a more southern exposition and are dry and lack the high humus content.

On several places buried A horizons were noticed, signalising the presence of slope processes (influence of cattle; macro plot 1, 5, 8). In the area weathered glimmer was found (macro plot 5) and in some cases free chalk was shown (macro plot 6).

In general 2 horizons were sampled per micro plot (mostly A and B horizon). In some 1-m^2 plots only the A horizon could be sampled due to stoniness of the soil. In some other plots both A, B, and C hrizons were present. In some places the occurrence of many stones made sampling a challenge (macro plot 1, 2, 3, 4, 6, 7, 8, 9 and 10). The occurrence of many stones causes at the same time a strongly reduced soil depth.

The damper conditions in the macro plots 1 – 6 show clearly in the soil moisture data. Other plots are in general drier, but variable. The pH is in general above pH 7 and in some cases above pH 8. This means that it will take very long time before acid precipitation has an influence.

LOI is very variable; from 6.1% to 60%. The northern exposed plots are more moist and do have higher LOI and the influence of the cattle, causing mixing and eroding the soil, is visible.

Concerning heavy metals, arsenic (As), cadmium (Cd) and mercury (Hg) show very low levels. Antimonium (Sb) shows also low levels, but in the macro plots 1, 2, 5 and 9 some remarkable higher levels are present. Strontium (Sr) and zink (Zn) show higher levels, with not much variation between top and subsoil.

4.3 Discussion

Over long time changes in the ecosystem are influenced by biogeochemical cycling, land use and climate change and the possible effects of long or short transported air pollution should be considered.

In the monitoring area the pressure from overgrazing is too large and may lead to irreversible degradation processes. Due to the better hydrological conditions in macro Plot 1 – 6 and 9 – 10, the resilience against disturbances is better.

The nutrient situation and the CEC are so good that the negative influence of acid precipitation will only be actually after a very long time. With changes in heavy metal content in the topsoil one should also look at the effects of biogeochemical cycling. As some of the soils originate from weathered parent material some surprises may show up, as the chemical data already show.

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. A clear C horizon was present and sampled. for this site.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 excicator.

Calculations:

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

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

5.1.3.7 Available phosphate (P)

Principle:

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

The Mehlich's method uses a mixture of sulphuric and hydrochloric acid to de-sorb the phosphate according to the method described by Olsen & Sommers (1982). This method is effective in extracting Ca-P, Fe-P and Al-P in acid and neutral soils.
In the high pH soils (>7.5) the acid extractants become less effective. These soils contain free calcium carbonate which neutralizes the acid and prevents the extraction of P into solution. Instead, the Olsen's extractant (Olsen 1953) uses a buffered 0.5 M sodium bicarbonate solution ($NaHCO_3$ at pH 8.5) which is alkaline and designed for use on calcareous soils. This extractant suppresses Ca^{2+} by both the high HCO_3^- concentration and high pH, allowing phosphates to dissolve out of calcium phosphate minerals (by the common ion principle). This extractant is therefore excellent at extracting calcium-P, the dominant form of P in calcareous soils.

Reagents:

1. Extracting solution, Mehlich's :

Add 12 mL of conc. sulphuric acid (H_2SO_4) and 73 mL of conc. hydrochloric acid (HCl) to 15 litres of ion exchanged water. Dilute the solution to 18 litres with Milli-Q or double distilled ion exchanged water. This extracting solution is approximately 0.05N HCl and 0.025N H_2SO_4.
Extracting solution, Olsen's :
Dissolve 84.008 g dry $NaHCO_3$ with approx. 1.8 L of Milli-Q or double distilled ion exchanged water. Titrate the solution with NaOH to pH 8.5. Dilute the solution to 2 L in a volumetric flask. This extracting solution is approximately 0.5 M $NaHCO_3$.

2. Molybdate-vanadate solution:

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

3. Standard phosphate solution:

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

Procedure:

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

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

Detection:

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

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

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

Calculation:

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

where:

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

5.1.3.8 Inorganic Sulphate adsorption

Principle:

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

Reagents:

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

Procedure:

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

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

Detection:

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

Calculation:

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

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

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

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

5.1.3.9. ICP-AES metal scan

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

5.1.3.10 Extractable sulphate

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

5.2 Results

Average soil chemical data for each horizon are presented in Tab. 5.2. Circum neutral pH conditions prevail at all sampling plots. pH decreases from A to B horizon and then increases with depth in a few samples from C horizon. Organic content is not measured. No strong correlations (i.e. r > .7) were found between total carbon content (%C_{tot}), adsorbed phosphate (ads. PO_4^{3-}) and sulphate (SO_4^{2-}), total nitrogen, and base cations, nor between them and the trace elements. Across the site values of adsorbed phosphate (Ads. PO_4^{3-}) (Tab. 5.2) are negatively correlated to average soil pH_{H2O} (r = -.643). Adsorbed sulphate (Ads. SO42-) were in 87% of all the samples below the detection limit.

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. PO_4^{3-}
	#		w/w %		µg/g	
A	50	7.22	N/A	6.8	3323	119
		6.7-7.8	N/A	4.6-8.8	1387-4961	6.4-169
B	46	7.07	N/A	3.0	1211	71.5
		7.1-8.1	N/A	2-3	640-1654	2-12
C	4	7.90	N/A	2.7	424	3.2
		7.9-8.6	N/A	2-3	315-547	1-5

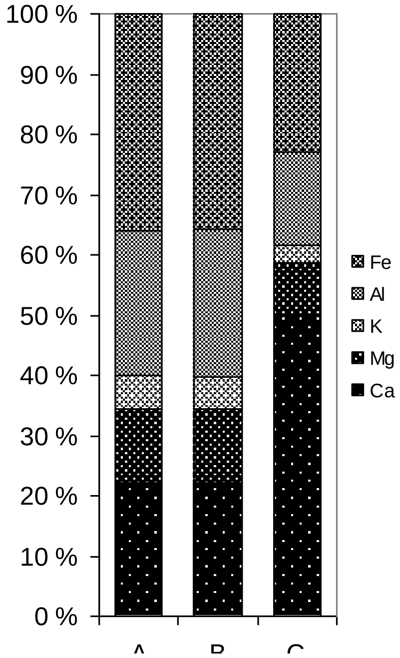


Fig. 5.1. Main (avg. value > 3.5 mg/g) oxide composition of the mineral soils in Dugoba.

In addition to SiO_2 (not measured) the main (avg. value > 3.5 mg/g) oxide composition of the mineral soils (Fig. 5.1) is made up by iron (Fe) and aluminium (Al), followed by calcium (Ca) and magnesium (Mg). The A and B horizon have practically an identical composition. Base cations (Ca+Mg+Na+K) account for 40% of the oxide composition. The C horizon differs substantially, though this is not representative as this horizon was only found in 4 plots.

The content of Fe and Al are strongly correlated (r = 0.966). The Al and Fe content are also as commonly found correlated with both Mg (r = 0.750 and 0.713, respectively. The major oxide elements presented in Fig. 5.1 are followed in abundance by titanium (Ti) phosphorous (P), and manganese (Mn) (Tab. 5.3). The amount of Ti was relatively high compared to e.g. sodium (Na). Only a few correlations between these oxide elements and other parameters were found and Ti and Lanthanum (La) are not strongly correlated with Fe, Al and trace elements as found at the other sites. Instead Mn is found to be correlated with lead (Pb; r = 0.779) and zinc (Zn; r = 0.880).

Tab. 5.3.Soil average and quartile content of less abundant oxide elements in 50 A-, 46 B-, and 4 C horizon samples from Dugoba.

Horizon	P	Mn	Ti	Na	La
			mg/kg		
A	689	447	765	192	15,7
	596 - 772	403 - 500	595 - 931	171 - 213	13 - 17
B	654	458	784	194	17,4
	509 - 784	416 - 497	628 - 906	178 - 211	14 - 19
C	571	342	850	195	15,2
	533 - 624	273 - 430	766 - 910	185 - 202	15 - 15

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

Tab. 5.4. Soil content of measured trace elements.

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	.1	75	185	80	105	29	230	30	20	100	1.5	1.0
Normal Min[2]					.1	.1	1	2	3	2	1						
World mean[3]		6		300	10	.06	20	100	50	40	8						
M.A.L. (Pl) [2]					100	3	100	100	300	100	50						
Dugoba	A	6.3	166	51	13	.3	19	30	64	23	12	32	3.1	6.4	1.9	.7	.5
	B	8.0	162	47	13	.3	22	33	65	26	14	36	3.5	7.6	1.9	.8	.8
	C	6.6	149	81	9.9	.3	12	25	46	20	11	27	2.6	5.8	1.4	.6	.5

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

Al and Fe content is strongly correlated to the 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 negatively correlated to hard (Type A) metals (e.g. Ca, Mg, Ba and Sr). Variation in Sr content followed closely the Ca levels (r = 0.944) and Ba was weakly correlated to Mn (r = 0.520).

The amounts of most trace elements co-varied in the soils; 19 strong correlations were found between the 16 measured trace elements (Tab.5.5). The borderline elements Co, Ni and Vanadium (V) showed the largest number of strong correlations (Tab5.5.). The type B elements (Pb, Mo, Cd, As) and the type A elements (Zr, Ba and Sr) were poorest correlated to the other trace elements. As commonly found there were few strong correlations found for Zn, though it was negatively correlated to base cations and Sr (r = -0.501).

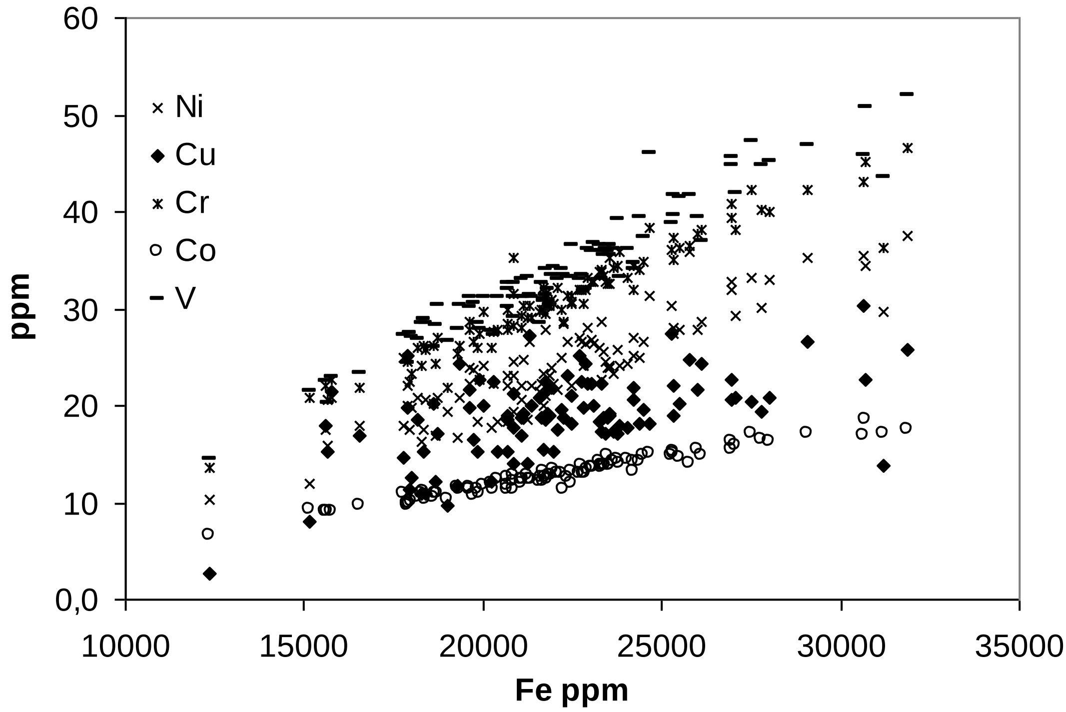


Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements nickel (Ni), copper (Cu), chrome (Cr) cobolt (Co) and vanadium (V) in 100 soil samples from the A, B, and C horizons at Dugoba.

Considering the low number of correlation and that the Zn concentration was higher in the top horizon than deeper in the soil profile (Tab.5.4.) could indicate that there may be an anthropogenic deposition of zinc at this site.

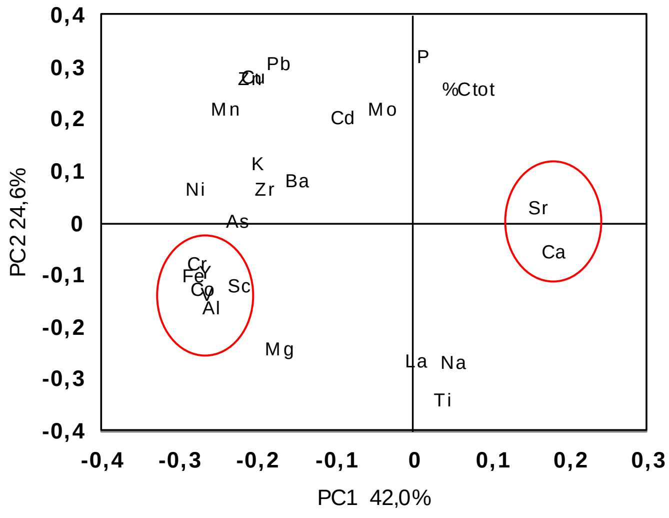
Tab. 5.5. The strongest sets of correlations (i.e. r > 0.700) found for each of the measured 16 trace elements in 100 samples from Dugoba. The elements are sorted in the order of their covalent index with type B elements on the top and type A elements in the bottom. - indicates no strong correlations (r < 0.7).

Element	# of corr.	Vs.	r
Pb	1	Zn	0.880
Mo	1	Ni	0.710
Cd	0	-	-
As	0	-	-
Cu	1	Be	0.733
Co	5	Cr	0.966
Ni	6	V	0.894
Zn	1	Pb	0.880
V	6	Co	0.957
Be	4	Co	0.868
Cr	6	Co	0.966
Sc	3	V	0.921
Y	4	V	0.946
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 Fe is clustered together with Al and most trace elements (except Sr, Mo, Ti, and Cd) (Fig. 5.3). Negatively loaded to this cluster along the PCA 1 axis we find a cluster of Ca and Sr. The % C_{tot} had low loading along the PCA 1 axis at this site. The PCA 1 axis, explaining more than half of the variation in the dataset, is therefore mainly explained by the Al and Fe relative to Ca content.

The PCA 2 axis at these sites may partly be explained by the Covalent index ($CI = X^2r$) (r = 0.404) of the elements. Elements with low CI, commonly referred to as hard or type A elements, prefer to bind to carbonates, while elements with high CI, commonly referred to as soft or type B elements, forming more stable complexes, e.g. with sulphides. Type A elements (Ca, Mg, Na, K) have generally opposite loading to more Type B elements (Pb, Cd, As). Borderline metals have generally low loading along the PCA 2 axis. Instead they are strongly clustered with Fe. This is clearly seen at this site where the PCA 2 axis in the A and B horizons is correlated to the Covalent index with an r = 0.490 and r = 0.404, respectively.



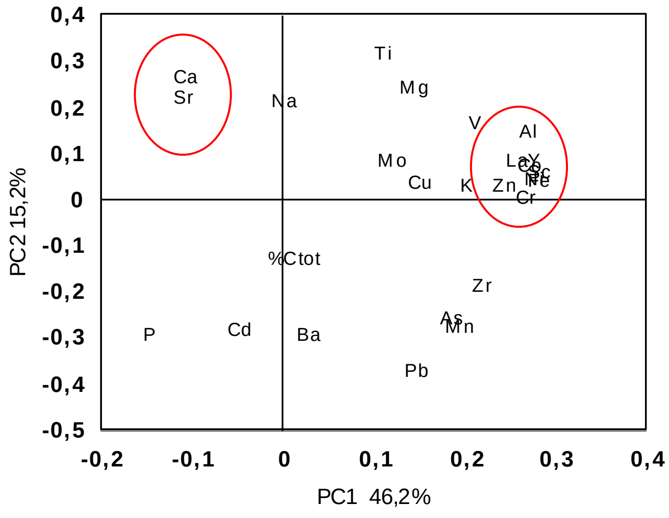


Fig.5.3. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 66.6 and 61.4% of the variation in soil elemental composition, respectively.

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