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

Establishment of monitoring reference area in Gauyan, Batken oblast, the Kyrgyz Republic, 2008. TEMP-CA monitoring site No.7.

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

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Sammendrag: The collapse of the Soviet Union in the Central Asian countries has led to enormous challenges for them in ensuring a sustainable environment. Weak economies and lack of expertise in environmental sciences were important reasons for the Norwegian support to the environmental sector in this region. The State Forest Service of the Kyrgyz Republic and the Norwegian Forestry Group initiated the TEMP project, later renamed TEMP-CA, in the Kyrgyz Republic in 2004. Activities in the Republic of Tajikistan were included in 2007 and in the Republic of Uzbekistan from 2008. The forestry sectors in the 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 Gauyan monitoring site in Batken oblast in the Kyrgyz Republic was the seventh 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" Talas 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.
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9: "Urumbash" in Jalal-Abad oblast, the Kyrgyz Republic.
10: "Umalak Teppa", Tashkent region, the Republic of Uzbekistan.
Ten plots of 30x30 m were placed subjectively in the area in order to represent the variation in the presumed most important environmental gradients. A 10x10 m plot was placed in the centre of the 30x30 m plots. Within each 10x10 m plot (macro plot) five plots of 1-m^2 were randomly placed. All trees within the ten 30x30 m plots were marked on a sketch map and a number of tree growth and tree vitality measurements were recorded. At the Gauyan three juniper species, *Juniperus turkestanica* (45.5%), *J. semiglobosa* (34.5%) and *J. seravschanica* (19.2%) dominated, constituting together over 99% of the forest trees. The size distribution (DBH) of the juniper species was approximately identical and showed highest proportion of the smallest size class (at least 81% of the individuals DBH < 15 cm for all three species), suggesting that regeneration of the three coniferous species is not limited. Defoliation of the juniper species ranged between 24.8 and 30.5%. The proportion of trees with discoloration, however, was insignificant. *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 thus contributing 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. A total of 58 species of vascular plants were recorded in the 50 1-m^2 plots, along with 7 bryophytes and 2 lichens. 47 of the vascular plants were herbs. The total number of vascular plant species in the in the 50 1-m^2 plots + ten 30x30 m plots was 65. Of the recorded vascular plants, 11 species are endemic to Central Asia: *Astragalus severtzovii, Carex turkestanica, Galium pamiroalaicum, Gentiana olgae, Juniperus semiglobosa J. turkestanica. Phlomoides oreophilla, Potentilla asiatica, Rosa kokanica, Thymus seravschanicus* and *Viola alaica.* Detrended Correspondence Analysis (DCA ordination) of the subplot frequency data for the fifty 1-m^2 plots was performed in order to reveal the most important vegetation gradients. The ordination axes, i.e. expressing the vegetation gradients, were interpreted by means of Kendall's non-parametric correlation coefficient. Differences in altitude, aspect, influence of the tree layer on light and litter conditions, as well as nutrient conditions are of the most important environmental conditions influencing the species composition according to the many significant correlations between explanatory variables and DCA 1. Much of the variation in species composition in Gauyan is thus due to variation in one main environmental complex gradients; topographical conditions, soil depths, depth of organic soil layer and the nutrient content in the soil.

The soils in the area are dominantly weathered soils and soils transported due to slope processes. The grazing intensity is much less than in Dugoba (which is also in Batken oblast), and features of soil erosion were not common. The area is used for grazing and it is possible that the grazing triggers erosion. Slopes are generally (very) steep. On the north slopes thick organic profiles could develop with sometimes an A horizon of 100 cm. Umbrisols were very common. Generally in the profiles on the north slope no stones were present (already weathered). The textures on the north slope varied from loamy to clay soils. Sometimes the clay in the underground was very dry or very wet; a sign of different ground water streams. On the south slope Cambisols are dominating. In some places with stones. Parts of the south slope which lie in the shadow of a mountain contains clearly more organic matter (umbric Cambisol). On the south slope the soil is rich in carbonates.

Circum neutral pH to slightly alkaline conditions prevailed at all the sampling plots in Gauyan, having the highest pH among the studied TEMP sites. As commonly found the pH increased with depth, mainly due to the decrease in organic content. Strong correlation was found between organic content (measured as loss on Ignition) and the carbon content, despite a high content of calcareous minerals especially in the C horizon. Furthermore, the % C_{tot} at this site was as commonly found correlated to the high total nitrogen content phosphorous. The main oxide composition of the mineral soils shifted from aluminium (Al) and iron (Fe) in the A horizon, to calcium (Ca) and Al in the C horizon. In the C horizon the base cations constituted 67% of the oxide composition, with the highest content of Ca (129g/kg) and Mg (20g/kg) among the TEMP-CA sites. This fits well with the overall high soil pH found at this site. The content of borderline elements were generally high with values between the normal maximum levels and the various maximum allowable limits. The content of Fe was as usual strongly correlated to Al. Soft metals (high covalent index) were generally found to be negatively correlated to hard (Type A) elements. A large number (30) of strong correlations were found between the 18 measured trace elements. As usual the typical borderline elements showed the largest number of strong correlations. A PCA analysis of the metal content and chemical characteristics of the A and B horizons gave a main principal component (PCA 1), explaining only 35% of the variation in the dataset in the A horizon, and 59% in the B horizon. The PCA 1 axis was mainly explained by the Al and Fe content relative to 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 of the elements in the A and B horizons.

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

Adm.dir./Avdelingsdirektør

Oppdragsrapport fra Skog og landskap 10/2011

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NORWEGIAN FORESTRY GROUP

Cover Photo: Gauyan, Photo: Adilet Usupbaev

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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 Gauyan monitoring site in Batken oblast in the Kyrgyz Republic was the seventh of ten monitoring sites established in forests in Central Asia:

1: ”Kara-Koi” in the Osch oblast, the Kyrgyz Republic.
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PREFACE

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

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

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

Aitkul M. Burhanov, Nicholas Clarke, Aitbaev Djirgalbek Valievich, T.A Arykov, Bakyt A. Mamytova, Beishekan Sultanova, Jantoro Japarov, Jenish A. Ganiev , G.U. Karymbaeva, Antonina I. Knyaz'kova, G.A. Kornilova, I.N. Kurochkina, Lyudmila I. Zvyagina, Abdunaman Maksutov, Oleg R. Mujdabaev, Svetlana G. Nesterova, A.V. Polevaya, M. Rakimbek kyzy, T.A. Rudenko, Saltanat R. Narynbaeva, L.G. Sasova, A.B. Satybaldieva and Seiitbek Turganbaev

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.

All photos in this report are by Adilet Usupbaev.

Ås, 30 December 2010

Tonje Økland

Project leader

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INTRODUCTION

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

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

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

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

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

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

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

The project mandate was:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 DESCRIPTION OF THE GAUYAN REFERENCE MONITORING AREA

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

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

1.1 Geographical position of the reference monitoring area

The Gauyan monitoring site is located on the northern macro-slope of the Alai range, like the sites at Kara-Koi and Dugoba. According to physical and geographical zones the Gauyan

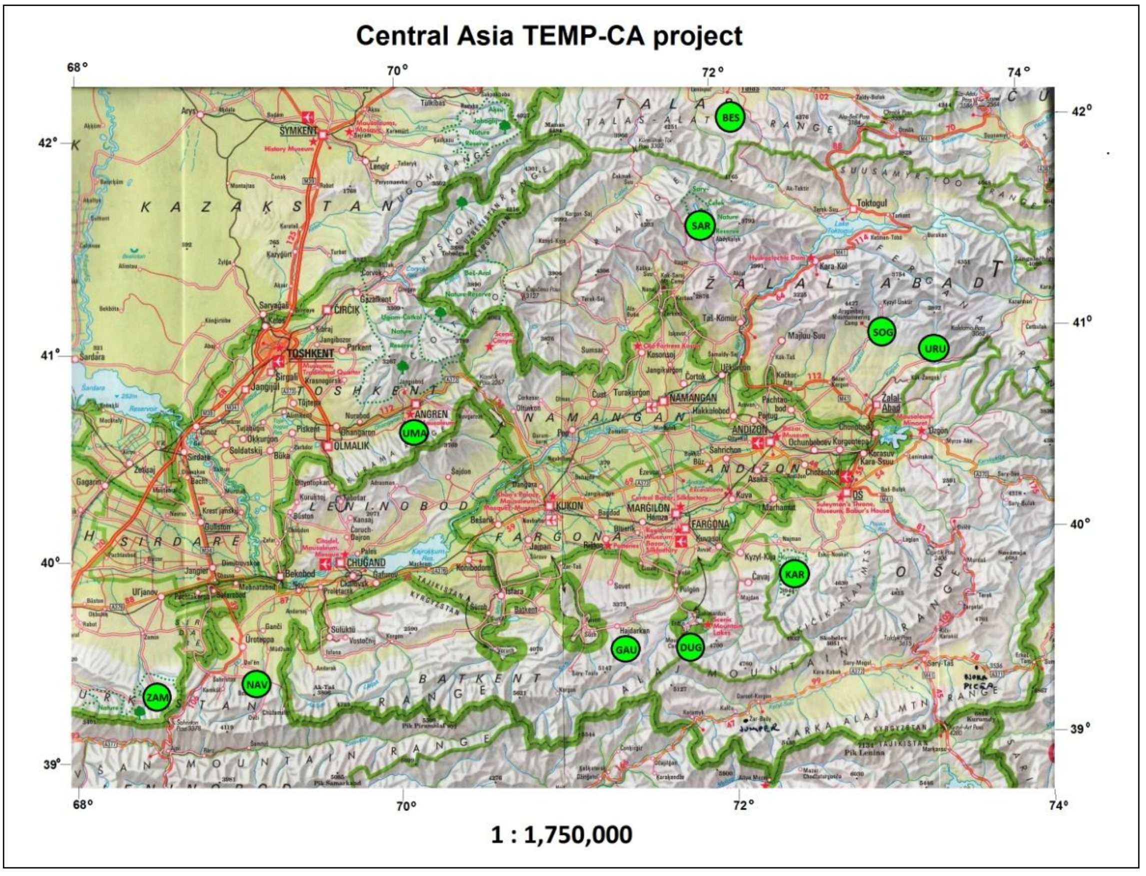

Fig. 1.1. Map of the Gauyan (GAU) and the nine other TEMP-CA monitoring reference areas.

site belongs to the Alai-Turkestan province, Fergana mountain region, the Central Asian mountain area. The Alai-Turkestan province is a vast mountain-valley-depression zone located south of Fergana valley, formed by the Alay and Turkestan mountain ranges (up to 5000-5500 m a.sl.).

The Gauyan monitoring site is part of Uch-Korgon Leskhoz, which is located on the territory of Kadamjai district of Batken oblast.

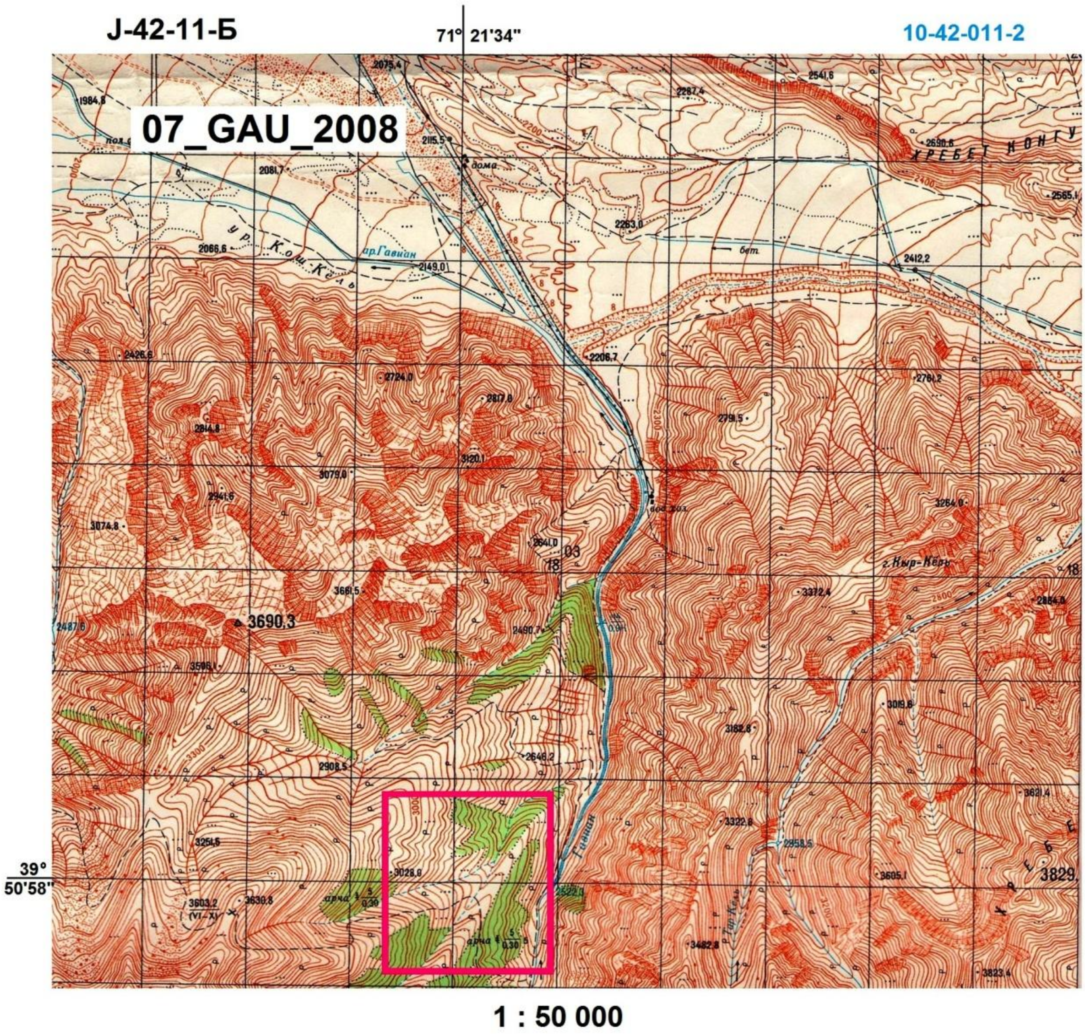

Fig. 1.2. Geographical position of the Gauyan (GAU) monitoring reference area.

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

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

Macro plot	Elevation	N	E
1	2489 m	39°51.184′	071°22.344′
2	2523 m	39°51.154′	071°22.254′
3	2510 m	39°51.201′	071°22.257′
4	2530 m	39°51.191′	071°22.227′
5	2567 m	39°51.174′	071°22.182′
6	2578 m	39°51.109′	071°22.184′
7	2596 m	39°51.079′	071°22.110′
8	2615 m	39°51.051′	071°22.120′
9	2672 m	39°50.996′	071°22.012′
10	2713 m	39°50.825′	071°21.846′

1.2 Forest type

The Uch-Korgon Leskhoz is a part of the State Agency of Forestry and Environmental Protection under the Government of the Kyrgyz Republic. The juniper forest at the Gauyan monitoring site is dominated by *Juniperus. zeravshanica*, *J. semigloboza* and *J. turkestanica*, typical for the lower zone (1600-2000 m a.s.l.), the middle zone (1800-2800 m a.s.l.), and the upper zone (2500-3600 m a.s.l.), respectively.

1.3 Geology, topography, and quaternary deposits

The Gauyan site belongs to the tectonic region of South Tien Shan. Its main features are widely developed Paleozoic geo-synclinal formations. The folding is Hercynian, with many faults; red-colored continental molasses of the Permian fill “residual red troughs”. Limited occurrence of upper-Paleozoic granitoid intrusions and alkaline magma intrusions are typical (Zinkova & Pushkareva 1987). The Paleozoic folded base is overlain with Mesozoic and Cenozoic deposits that fill inter-mountain and sub-mountain troughs. Geo-morphologically the site belongs to the Alai-Turkestan province. The main factor determining the relief formation is related to the Epihercynian structures that were subjected to vertical movements during the Oligocene and Pleistocene. The relief consists primarily of Paleozoic and Proterozoic bedrocks; its structure depends on the range of heights, the slope exposure and the lithogenic composition of the rocks. There are former troughs filled with Mesozoic and Paleogene–Neogene deposits. The relief is distinguished with crop-outs of Paleozoic and Proterozoic rocks. The age of the formation of the tectonic-denudation relief is primarily from Neogene to early Quaternary and its development continues up to this day.

1.4 Climate

The climate in the area is continental and characterized by significant seasonal variation (Ryazantseva 1965). The main wind directions for this area are west and south-west.

1.4.1 TEMPERATURE

The average annual temperature of air is about 9 °C (Tab. 1.2). Duration of the period with a daily average temperature below 0 °C in the lower part is 70-80 days, at 2400 m a.s.l. it increases to 130 days. The average annual minimal temperature at 2000 m a.s.l. is 8-9 °C, the absolute min -26-28 °C.
Duration of the warmest period with a daily average temperature above 10 °C at 2000 m a.s.l. is 150-155 days. The average temperature of the warmest summer month (July) is 18-19 °C, the absolute max at this height is 32-33 °C.

Tab. 1.2. The average temperature at the nearest meteorological stations (°C).

Meteorological station	Jan	Feb	Mar	Apr	May	Jun	Jul	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 from early spring (March) to summer (June), depending on the altitude (Tab. 1.3). The autumn is usually dry. The maximum precipitation falls in the middle of the juniper zone and reaches c. 500 mm/year.

Tab. 1.3. The average precipitation at the nearest meteorological stations (mm).

Meteorological station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des	Year
Haidarkan	36	43	69	90	94	52	31	15	16	37	30	34	548
Batken	15	17	28	30	35	18	14	4	5	15	13	14	208

1.5 Vegetation zones

According to its botanical and geographical zoning the Gauyan monitoring area belongs to the ancient Mediterranean sub-kingdom of Holarctic, Western Asian province, Central Asian mountain area, Fergana-Alay region (Kamelin 2002). The vegetation cover is represented by the Alay vertical zonality type.

The most widespread vegetation types are forests with *Juniperus seravshanica*, *J. semiglobosa*, and *J. turkestanica*. The site is characterized by the presence of red listed species *Incarvillea olgae* (CR) and *Iridodictyum kolpakowskianum* (VU) (Red Data Book of Kyrgyz Republic 2006).

1.6 Forest history, forest structure, and external influence

1.6.1 HUMAN IMPACT

There are 3 settlements (Yntymak, Raz'ezd and Narai) directly on the territory of Uch-Korgon Leskhoz. There are 135 homesteads on the list that include 676 people.

Tab 1.4. Information about the settlements of the Uch-Korgon Leskhoz.

#	Settlement name	Number of homesteads (families)	Population (person)	Distance from Leskhoz's Office (km)
1	Yntymak (Kutal)	47	236	25
2	Raz'ezd	70	349	45
3	Narai*	18	91	240
	Total:	135	676	-

In the past the leading branches of economy in the Kadamjai region, where the Uch-Korgon Leskhoz is located, were mining industry (base material exploration, extraction and processing), and not intensively agriculture where the cattle-breeding branch prevailed. During the last years there has been an increase in the degradation of the juniper forests and in offences against the forests of the leskhoz. The main reasons are ecological illiteracy and low consciousness of the village population, and the absence of governmental social programs that support the poorest levels of population with adequate funds for purchasing the required energy carriers (coal, wood). An increased cattle stock, and a legislative basis that is not strong enough, also contribute to an increase in offences against the forest. In addition comes illegal use of the forests for pasturing, ploughing up mountainsides and pastures, usurpation of lands, and illegal building.

1.6.2 FOREST HISTORY

It is known that charcoal produced from juniper (archa) has very good energy qualities. For this reason a great numbers of archa trees were exterminated to produce charcoal in the early 20th century. During the Second World War archa trees were cut down and floated down Mountain Rivers to be used in mining industry for antimony smelting and partly in construction. The collected timber was also stored as an emergency stock. As a result of such activity the juniper forests territory was by 1956 reduced with 43% according to forestry data. In 1960 all types of felling except sanitary felling were forbidden. But local people continued felling of high-quality trees under cover of sanitary felling. Furthermore, in time of the Soviet Union, Kyrgyzstan specialized on sheep and cattle farming. From 1950 to the 1980s the juniper forests were intensively used as pastures. After dissolution of the USSR the situation changed significantly. By 1995-1997 the quantity of pastured livestock decreased to a third, resulting in a better regeneration of juniper forests.

1.6.3 GRAZING

Sparsely distributed juniper trees with alternating clearings and glades make it tempting for local people to let their livestock graze in the forest areas. Intensive and un-regulated pasturing is one of the factors that negatively affect the forest condition and development. It leads to reduced natural young juniper growth, destroys vegetation cover, and promotes reduced productivity and infestation of forest grazing lands by weeds and less eatable grass.

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 were 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 wais defined, in which more intensive assessments were done, such as measurement of tree heights, crown projections, and crown heights.

2.1.2 TREE PARAMETERS

At each site standard crown condition parameters, such as social status, defoliation, and discoloration were recorded. The classification of the defoliation follows ICP-Forest: Class 0 shows healthy trees, with ≤ 10% defoliation; class 1, ”warning stage”, > 10 up to 25%; class 2, “moderately damaged”, > 25-60%; class 3, “severely damaged”, > 60% defoliation; and class 4, dead trees. The assessment of defoliation did not consider dead trees, trees heavily damaged by abiotic factors, or greatly suppressed trees referred to class 4 by Craft’s classification.

Diameter at breast height was recorded for 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 Gauyan site was represented by three juniper species, *Juniperus turkestanica* (45. 5%), *J. semiglobosa* (34.5%) and *J. seravschanica* (19.2%), that together constituted over 99% of the forest trees. The number of individuals of the two remaining species, *Lonicera microphulla* and *Berberis sphaerocarpa* (both bushes), were seven and one, respectively.

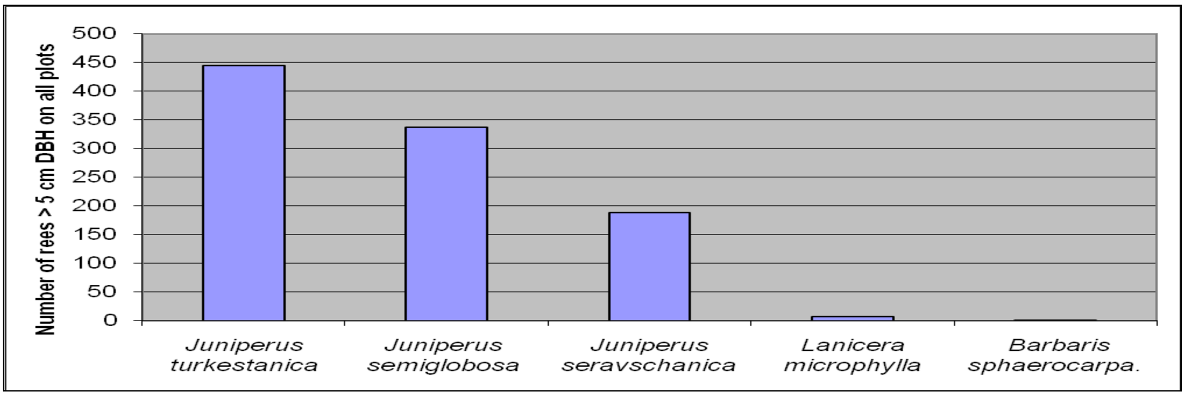

Fig. 2.1. Total number of trees of the different species > 5 cm DBH in all plots.

2.2.2 TREE CONDITION

Defoliation of the juniper species ranged between 24.8 and 30.5% (Fig.2.2). The proportion of trees with discoloration, however, was insignificant (≤ 1.4%).

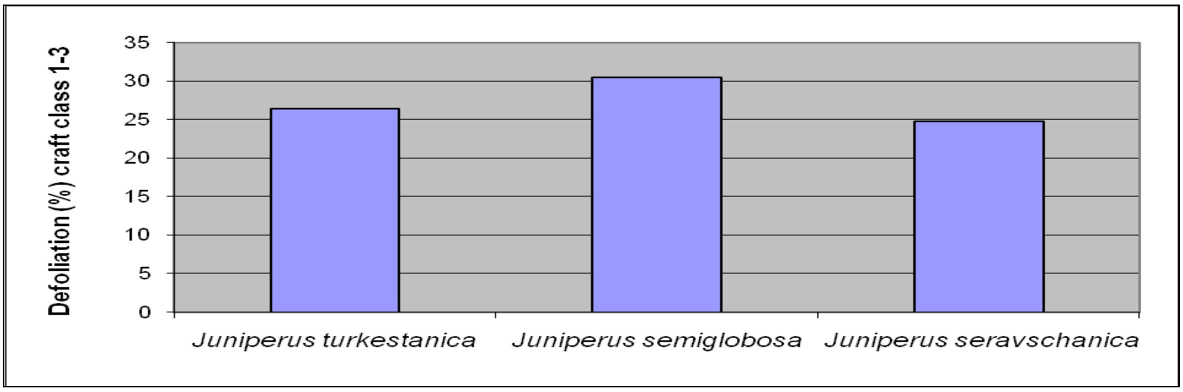

Fig. 2.2. Defoliation for the main species.

2.2.3. DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

The size distribution (DBH) of the juniper species was approximately identical and showed highest proportion of the smallest size class (DBH 5-10 cm), and a considerable decrease in the number of individuals with increasing DBH. The two smallest size classes (DBH < 15 cm) constituted 81.7% for *J. turkestanica*, 88.1% for *J. semiglobosa* and 91.4% for *J. seravschanica* (Figs. 2.3, 2.4 and 2.5), and the number of trees with DBH 5-10 cm was more than two times greater than the adjacent size class (DBH 10-15 cm). Conversely, the proportion of trees with DBH > 20 cm was modest, being 6.4% for *J. turkestanica*, 4.15% for *J. semiglobosa,* and 8.5% for *J. seravschanica*. In the 1-m^2 ground vegetation quadrants 12 and 35 saplings (DBH < 5 cm) of *J. turkestanica* and *J. semiglobosa* were found, respectively.

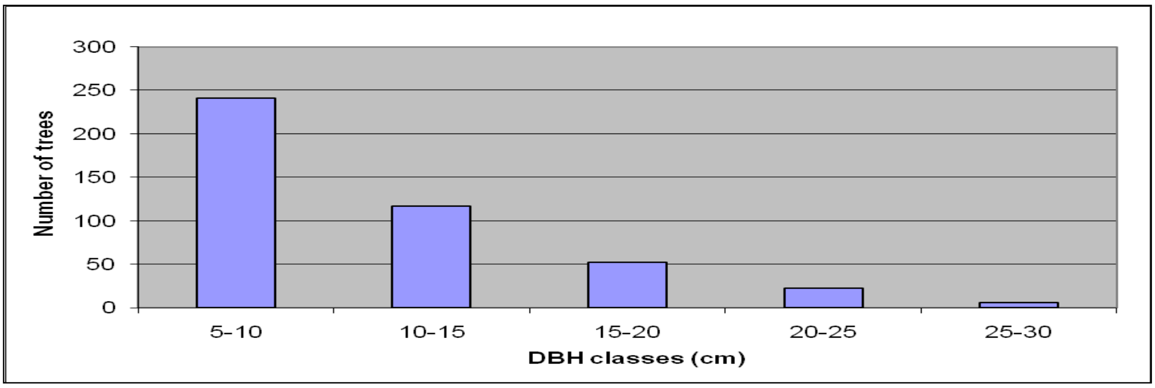

Fig. 2.3. Size distribution (DBH) for *Juniperus turkestanica* (all plots).

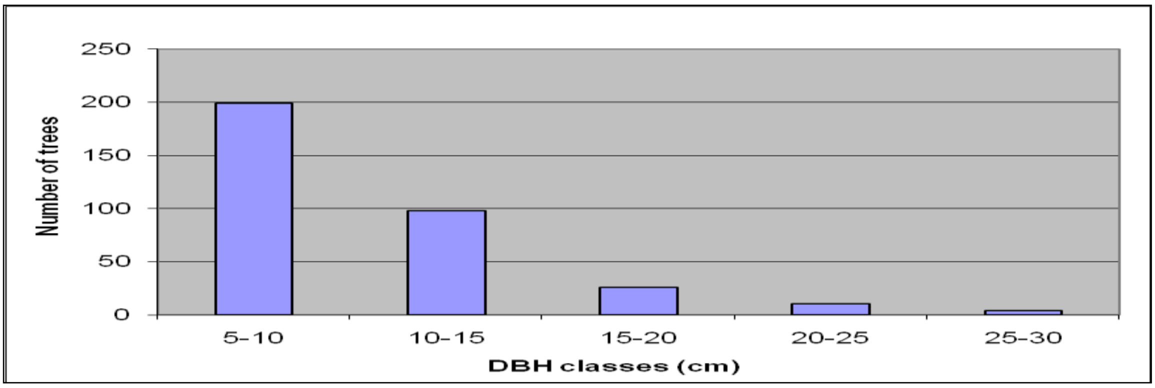

Fig 2.4. Size distribution (DBH) for *J. semiglobosa* across all plots.

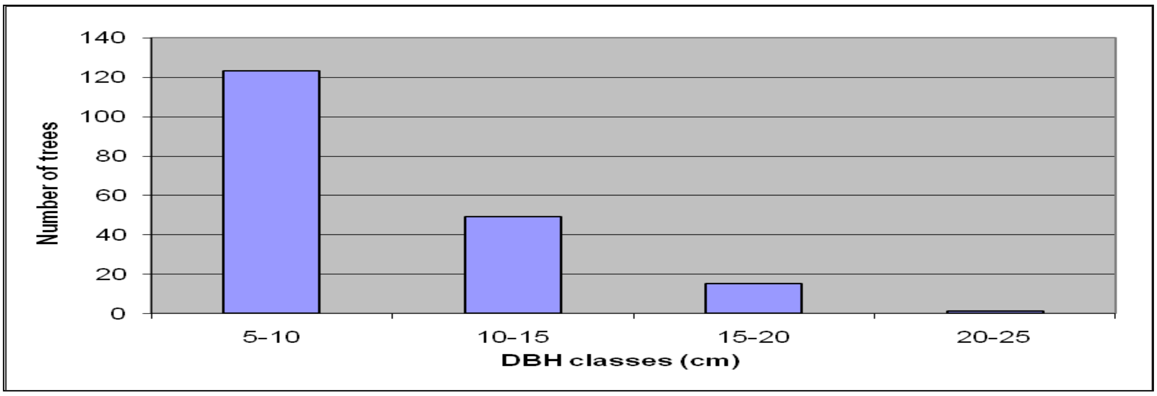

Fig. 2.5. Size distribution (DBH) *J. seravshanica* across all plots.

2.3 Discussion

The forest condition was evaluated by level of defoliation and proportion of trees with discolorated needles/ leaves. These indicators are also influenced by natural factors such as climate and soil condition, as well as human impacts (e.g. grazing and cutting of firewood). It is sometimes difficult to relate reduced tree vitality to specific causes based on conventional forest monitoring, not supported by experimental studies, but repeated assessments - which is the basic idea of monitoring, will always provide useful information about temporal development.

The Gauyan site was characterised by rather extensive defoliation (24.8-30.5%), which according to the ICP Forests classification is denoted as moderate damage. The reason for the low proportion of discolorated trees could be that discolorated needles were already shed at the time of the assessment, and that the discoloration preceded the defoliation. Fungal diseases, such as *Gynmosporangium* rust and rot, may attack the juniper species and thereby affect the vitality of the tree. Cutting of branches for firewood creates potential entries for rot fungi. In order to compare trees which have been subject to branch cutting with untouched trees, branch cutting should be recorded as a separate parameter during the next assessment. This will make it possible to see whether tree vitality may refer to human interference. Similarly, wood and needle samples should be collected for pathological and entomological investigations when the injury cannot be assessed precisely in the field. It should not be forgotten, however, that the harsh climate close to the tree line may affect the defoliation, without any notable effect on the discoloration of the trees.

Sufficient regeneration is fundamental for sustainable forests. According to the size distributions the greatest number of juniper individuals was found in the smallest size class (Figs. 2.3, 2.4, 2.5), and saplings (DBH < 5 cm) of *J. turkestanica* and *J. semiglobosa* were found in the 1-m^2 plots. Thus, the combination of data on actual regeneration and size class distribution of trees > 5 cm DBH suggest that regeneration of the juniper species at this site is sufficient. However, to establish this scientifically, more thorough and specific studies of regeneration are required. The Gauyan site is dominated by small individuals and has no juniper trees > 30 cm DBH, whereas the Dugaba and Sary-Chelek sites have juniper trees even in the DBH 50-55 cm class. This may indicate that the forest at the Gauyan site is relatively young and in the establishing phase.

It is important to know the history of use and management of the forests to be able to interpret the data on tree condition and regeneration. Although our data suggests that the natural regeneration in the Gauyan site is good, it can easily decline if the grazing pressure increases. Accordingly, assessment of the regeneration should be more thorough and specific.

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. 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.

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 (Fig. 3.1).

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)]

Fig. 3.1. Measuring inclination of a 1-m^2 plot at the Gauyan monitoring site.

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

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

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

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

(2) Tree influence variables include:

- Crown cover index
- Litter index
- Basal area

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

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

CC = ∑i **cai • cci** /25

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

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

Four different cases were distinguished, the first three relating to trees with the stem centre within the crown perimeter, the fourth addressing eccentric trees.

(i) The line has one point of intersection with the sample plot margin within the crown perimeter (it intersects the crown perimeter once within the plot). This is the most usual case.

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

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

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

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

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

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

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

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

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

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

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

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

LitterIi = cci × cai × (hi - chi)

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

LitterI = ∑i cci × cai × (hi - chi)

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

(1) The relascope sum for coniferous trees

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

(3) Soil physical variables include:

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

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

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

- *Estimations of % cover of litter*.

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

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

(4) Soil chemical variables include:

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

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

(5) Animal impact variables include:

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

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

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

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

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

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

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

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

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

Browsing damage on woody plants: A short description of the domestic browsing on each of the woody plants that were browsed upon by domestic animals was given: Species; name of the woody plant, s*tem%;* how much of the stem in % that are browsed, shoots*;* how many of the shoots that approximately have been browsed.

% cover of wild animal holes: Estimations of the percentage cover of traces and digging holes made by wild animals were performed for each 1-m^2 plot.

3.1.4 ORDINATION METHODS

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

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

3.1.5 INTERPRETATION OF GROUND VEGETATION GRADIENTS

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

3.2 Results

3.2.1 GROUND VEGETATION BIODIVERSITY

The number of species, α-diversity, is reported in this chapter, while β-diversity (variation in species composition along gradients) will be reported in chapter 3.2.2 below. The total species list is given in Appendix 3.4. The number of vascular plant species in the 1-m^2 plots was calculated as the sum of the five 1-m^2 plots in each 10x10 m macro plot (a), as the total number of vascular plant species in each 10x10 m^2 macro plot including the species in the 1-m^2 plots (b), and as the total number of vascular plant species in each 30x30 m^2 extended macro plot including the species in the 1-m^2 plots (c, Tab. 3.1). The ratio a/b and a/c was calculated for each macro plot. All together 68 species was recorded in the 50 1-m^2 plots. Of these species 11 are endemic to Central Asia: *Astragalus severtzovii, Carex turkestanica, Galium pamiroalaicum, Gentiana olgae, Juniperus semiglobosa J. turkestanica. Phlomoides oreophilla, Potentilla asiatica, Rosa kokanica, Thymus seravschanicus* and *Viola alaica.*

The total number of vascular plant species recorded within the 50 1-m^2 plots + ten 10x10m^2 plots was 63. The total number of species in the in the 50 1-m^2 plots + ten 30x30m^2 plots was 65. Of this one species is in the Red data book of Kyrgyz Republic (2006); *Iridodictyum kolpakowskianum* (Fig. 3.2). The maximum number of species recorded in five 1-m^2 plots within a macro plot was 26, while the minimum number was 12. The average number of species recorded in five 1-m^2 plots within a macro plot was 20. The maximum number of species recorded in any of the 10x10 m macro plots was 39 (the five 1-m^2 plots included), and the minimum number was 15. The average number of species in the 10x10 m macro plots (the five 1-m^2 plots included) was 24.4. The ratio a/b varied between 0.62 and 0.96 (Tab. 3.1). The ratio a/c varied between 0.60 and 0.93 in the macro plots.

Fig. 3.2**.** The red listed species *Iridodictyum kolpakowskianum.*

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

Tab. 3.1. Total number of vascular plant species in five 1-m^2 plots (a), five 1-m^2 plots + 10x10 m macro plot (b), five 1-m^2 plots + 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	24	39	31	0.62	0.77
2	25	30	31	0.83	0.81
3	13	15	18	0.87	0.72
4	12	15	20	0.80	0.60
5	15	18	19	0.83	0.79
6	26	27	28	0.96	0.93
7	23	28	29	0.82	0.79
8	19	22	25	0.86	0.76
9	23	26	27	0.88	0.85
10	20	24	29	0.83	0.69
Total number	**58**	**63**	**65**	**0.94**	**0.91**

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

Plot number	Tree species	Shrubs	Herbs	Ferns	Graminoids	Bryophytes	Lichens
1	0	1	20	0	3	5	2
2	1	1	20	0	3	6	2
3	1	0	9	0	3	2	0
4	0	1	8	0	3	1	0
5	1	0	11	0	3	1	0
6	0	1	22	0	3	2	1
7	2	1	18	0	2	1	0
8	1	1	14	0	3	2	2
9	2	1	16	0	4	1	0
10	1	0	16	0	3	0	0
Total number	**2**	**3**	**47**	**0**	**6**	**7**	**2**

3.2.2 MAIN GROUND VEGETATION GRADIENTS

DCA ordination of 50 plots is shown in Figs. 3.3.-3.4 Gradient lengths; β-diversity, and eigenvalues for DCA axes 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	0.529	0.271	0.193	0.175
Gradient lengths	3.629	2.129	2.200	2.759

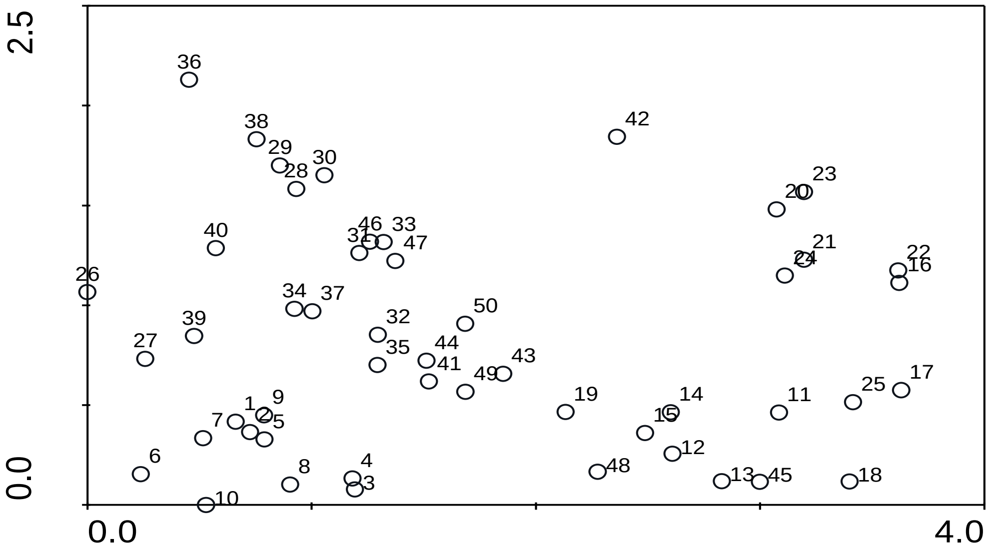

Fig. 3.3. DCA ordination of 50 1-m² plots, axes 1 (horizontal) and 2 (vertical). Plot numbers for the 50 1-m² plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.

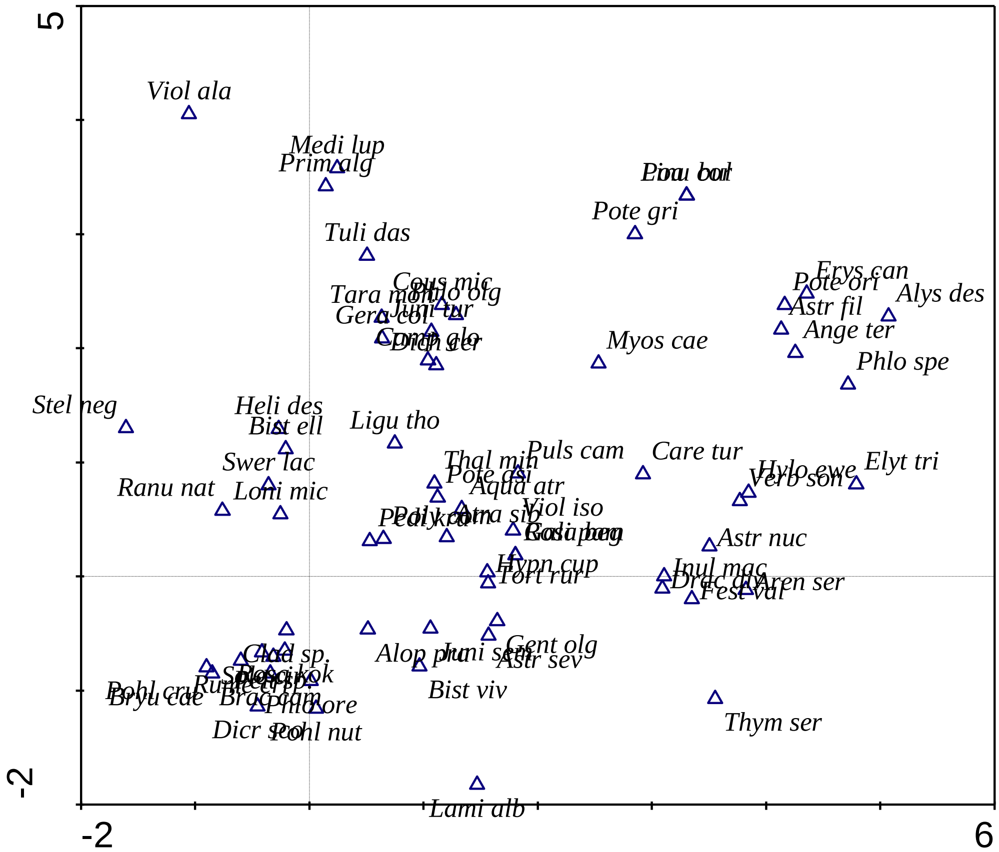

Fig. 3.4. DCA ordination of species in the 50 1-m² plots.

3.2.3 CORRELATION ANALYSIS BETWEEN EXPLANATORY VARIABLES AND DCA ORDINATION AXES

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

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

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

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

3.3 Discussion

3.3.1 GENERAL DESCRIPTION OF VEGETATION AND GROUND VEGETATION BIODIVERSITY

The forest at the Gauyan site was dominated by three *Juniperus* species (*J. turkestanica*, *J. semiglobosa* and *J. seravschanica*), each dominating at different altitude intervals (see chapter 1.2). The shrub-layer included specie like *Rosa kokanica* and *Cerasus alaica*, while the field layer was dominated by *Festuca valesiaca* and *Carex turkestanica*, and occasionally *Ligularia thompsonii* and *Alopecurus pratensis*. Other typical field layer species were *Campanula glomerata*, *Geranium collinum*, *Dichodon cerastoides*, *Galium pamiroalaicum* and *Polygala comosa*.

Of the 67 species (58 vascular plants + 7 bryophytes + 2 lichens) recorded in the 50 1-m^2 plots there were 47 herb species, mainly xeromorphic and thermophytic species. The area has many steppe species.

3.3.2 INTERPRETATION OF GROUND VEGETATION GRADIENTS

In this site many of the measured variables were significantly and relatively strongly correlated with DCA 1, the main vegetation gradient, while only a few variables were significantly correlated with DCA 2. The variable with strongest positive correlation with DCA 1 was *aspect favourability*, and the variables with the strongest negative correlation were *minimum* and *median depth of organic* *soil layer*, and *minimum* and *median soil depths.* Other more or less strong, negative correlations were obtained by *% loss on ignition*, and several nutrient varables as content *total N*, *CEC* and *exchangeable Ca* and *Mg* in soil, among others. Thus DCA 1 expresses a gradient in species composition from sites with “unfavourable” aspects (more or less north facing), thick organic soil layer and, deep soil, and a high content of nutrients in the soil, to the opposite. However, the content of exchangeable *Ca* and *Mg* calculated as a fraction of loss on ignition, as well as the total amounts of several soil cations were positively correlated with DCA 1.

The content of PO_4 and *Zn* in the soil, and *altitude* were the variables with the strongest positive correlation DCA 2, while *inclination* and *grazing intensity* showed strong negative correlations with this ordination axis. Thus, to some degree the influence of grazing is (not surprisingly) higher on the steep sites at lower altitudes. No variables were strongly correlated with DCA 3 or DCA 4.

Much of the variation in species composition in Gauyan is thus due to variation in one main environmental complex gradients; topographical conditions, *soil depths*, *depths of organic soil layer* and the content of nutrients in soil. This is probably mostly due to difference in *aspects*, since deeper and moister soil can develop on north facing aspects compared with south facing aspects. However, also factors like grazing intensity and altitude influence the variation in species composition. The importance of topography for ground vegetation is similar to several other TEMP-CA monitoring sites, but tree density seem to be less important than in the monitoring sites in the juniper forest in e.g. Kara-Koi and Zaamin.

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
Alopecurus pratensis	Шалбаа түлкү куйругу	Лисохвост луговой
Alyssum desertorum	Чөл бурачогу	Бурачок пустынный
Angelica ternata	Үчүлүктүү кереч	Дудник тройчатый
Aquilegia atrovinosa	Кочкул-кызыл бүргүн	Водосбор темно-пурпуровый
Arenaria serpyllifolia	Кийик от жалбырактуу кумдакчы	Песчанка тимьянолистная
Astragalus filicaulis	Ичке сабактуу астрагал	Астрагал тонкостебельный
Astragalus nuciferus	Жаңгактай мөмөvvk астрагал	Астрагал орехоносный
Astragalus severtzovii	Северцов астрагалы	Астрагал Северцова
Atragene sibirica	Сибирь атрагенасы	Княжик сибирский
Bistorta elliptica	Мекери бистортасы	Бисторта красивая
Bistorta vivipara	Жөргөмүш бистортасы	Бисторта живородящая
Campanula glomerata	Топтолгон коңгуроо гүл	Колокольчик сборный
Carex turkestanica	Түркстан ыраңы	Осока туркестанская
Cousinia microcarpa	Майда мөмөлүү кокуй тикени	Кузиния мелкоплодная
Dichodon cerastoides	Үч мамычалуу диходон	Диходон трехстолбиковый
Dracosephalum diversifolium	Түрдүү жалбырактуу аркар от	Змееголовник разнообразнолистный
Elytrigia trichophora	Түктүү буудайык	Пырей волосоносный
Erysimum canescens	Чачырак даргын	Желтушник раскидистый
Festuca valesiaca	Валезия бетегеси	Овсяница валезийская
Galium pamiroalaicum	Памир-алайлык галиум	Галиум памиро-алайский
Gentiana olgae	Ольга көк базини	Горечавка Ольги
Geranium collinum	Шалба каз таманы	Герань холмовая
Helictotrichon desertorum	Чымдак тоо сулусу	Овсец дернистый

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

Latin names of species	Kyrgyz names of species	Russian names of species
Hylotelephium ewersii	Эверс седуму	Очиток Эверса
Inula macrophylla	Чон жалбырактуу карындыз	Девясил крупнолистный
Juniperus semiglobosa	Сары арча	Можжевельник полушаровидный
Juniperus turkestanica	Түркстан (өрүк) арчасы	Можжевельник туркестанский
Lamium album	Ак дүлөй чалкан	Яснотка белая
Ligularia thomsonii	Томсон кой жалбырагы	Бузульник Томсона
Linum corymbulosum	Калканча сымал зыгыр	Лен щиточковатый
Lonicera microphylla	Майда жалбырактуу шилби	Жимолость мелколистная
Medicago lupulina	Хмель сымал беде	Люцерна хмелевидная
Myosotis caespitosa	Чымдак бото көз	Незабудка дернистая
Pedicularis krulovii	Крылов ак шыраалжыны	Мытник Крылова
Phlomis olgae	Ольга шимүүр	Зопник Ольги
Phlomoides oreophila	Тоо шимүүрчөгү	Фломоидес горный
Phlomoides speciosa	Кооз шимүүрөгү	Фломоидес красивый
Poa bulbosa	Коңур баш жылганы	Мятлик луковичный
Polygala comosa	Аргын истод	Истод гибридный
Potentilla asiatica	Азия каз таманы	Лапчатка азиатская
Potentilla grisea	Боз түктүү каз таман	Лапчатка серая
Potentilla orientalis	Чыгыш каз таманы	Лапчатка восточная
Primula algida	Суукчул примула	Первоцвет холодный
Pulsatilla camponella	Коңгуроодой кундуз гүл	Прострел колокольчатый
Ranunculus natans	Калкыган байчечекей	Лютик плавающий
Rosa beggeriana	Беггер ит муруну	Роза Беггера
Rosa kokanica	Кокон ит муруну	Роза кокандская
Rumex crispus	Тармал ат кулак	Щавель курчавый
Solenanthus circinnatus	Үлүлдөй соленантус	Трубкоцвет завитковый
Stellaria neglecta	Байкалбаган жылдызча	Звездочка незамеченная
Swertia lactea	Ак сверция	Сверция молочно-белая
Taraxacum montanum	Тоо какым	Одуванчик горный
Thalictrum minus	Кичинекей тармал чөп	Василистник малый
Thymus seravschanicus	Зеравшан кийик оту	Тимьян зеравшанский
Tulipa dasystemon	Түктүү аталыктуу мандалак	Тюльпан волосистотычиночный
Verbascum songoricum	Жунгар аюу кулагы	Коровяк джунгарский
Viola alaica	Алай ала гүлү	Фиалка алайская
Viola isopetala	Тең желекчелүү ала гүл	Фиалка равнолепестная
Brachythecium campestre	--	--
Bryum caespiticium	--	--
Dicranum scoparium	--	--
Hypnum cupressiforme	--	--
Pohlia cruda	--	--
Pohlia nutans	--	--
Tortula ruralis	--	--
Cladonia sp.	--	--
Peltigera sp.	--	--

4 SOIL CLASSIFICATION AND SOIL DESCRIPTION

Arnold Arnoldussen[1] and Talant N. Sydykbaev[2]

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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.

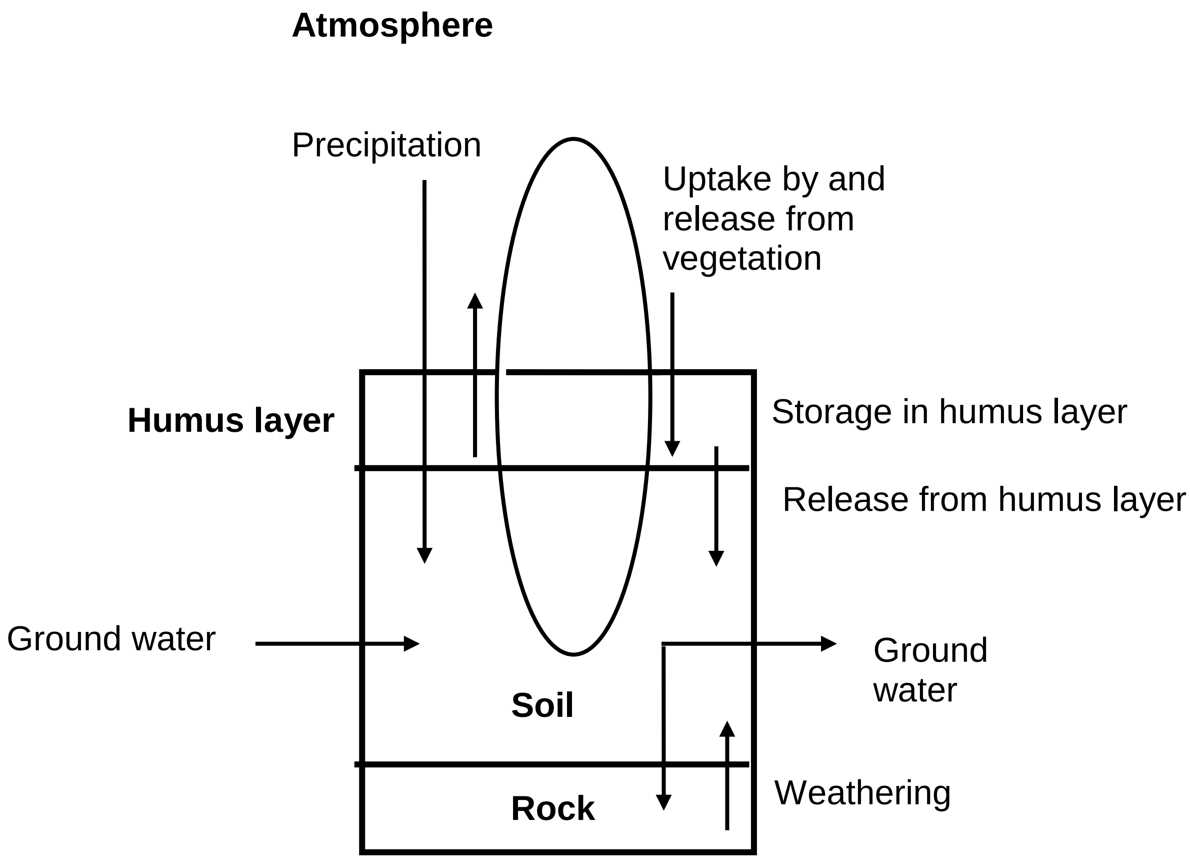

Fig. 4.1. Simplified model of biogeochemical cycling of elements.

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

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

4.2. Results

Due to a small river and the dominant slopes, the *Juniperus*-forest was exposed primarily to the north and to the south. The soils were mainly weathered soils and soils transported due to slope processes. Slopes were generally (very) steep. The area had been used for grazing and it is possible that grazing triggers erosion. However, the grazing intensity was much less than in other areas (e.g. Dugoba), and features of soil erosion were not common.

Umbrisols were very common on the northern slopes. Thick organic profiles with an A horizon up to 100 cm were found. Due to weathering there were usually no stones in these profiles. The soil texture varied from loamy to clay soils. Sometimes the underground clay was very dry or very wet; indicating different ground water streams. On the northern slopes only, signs of digging mice from the previous winter were found several times.

Cambisols dominated on the southern slopes, in some places with stones. However, southern slopes that lie in the shadow of a mountain contain more organic matter (umbric Cambisol). The southern slope soils are rich in carbonates, while northern slope soils did not react with HCl neither in the A horizon nor the first part of the B/C horizon.

4.3 Discussion

Gauyan represent a quite high altitude mountain environment without a lot of erosion, but with an extreme difference in soil development, hydrology and vegetation.

Soils on the northern slopes are often deeply weathered Umbrisols with a thick A horizon, while dry Cambisols dominate the southern slopes. The northern slopes seems most important for the biodiversity, a feature observed on more places, but may be more extreme in Gauyan.

On the northern slopes the soil is decalcified to the C horizon, while many profiles on southern slopes are calcareous in all horizons.

5 SOIL CHEMISTRY

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5.1 Methods

5.1.1 SAMPLING DESIGN

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

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

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

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

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

5.1.2 SOIL CHEMISTRY PARAMETERS

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

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

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

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

5.1.3 SOIL CHEMISTRY ANALYSES

Samples from Gauyan were analyzed at the Central laboratory of the Ministry of natural resources of the Kyrgyz Republic in Bishkek (Vogt & Wibetoe 2009).

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

5.2.1 Soil chemistry data

Average soil chemical data for each horizon are presented in Tab. 5.2. Circum neutral pH to slightly alkaline conditions prevailed at all the sampling plots, having the highest pH among the studied TEMP sites. As commonly found the pH increased with depth mainly due to the decrease in organic content, based on Loss on Ignition (LOI). A strong correlation (i.e. r > 0.7) was found between LOI and the carbon content (% C_{tot}; r = 0.863), despite a high content of calcareous minerals especially in the C horizon (see below and chapt. 4). Furthermore, the % C_{tot} at this site was as commonly found correlated to the high total nitrogen content (tot N; r = 0.843) and phosphorous (P; r = 0.787). Adsorbed sulphate (Ads. SO_4^{2-}) were generally high, especially in the B horizon. The total N content was the highest among the TEMP sites. Total N and adsorbed phosphorous (Ads. PO_4^{3-}) decreased with depth. Almost 75% of the C horizons samples had Ads. PO_4^{3-} below detection limit.

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

Horizon	Samples	pH_{H2O}	LOI	C total	Total N	Ads. PO_4^{3-}
	#		w/w %		µg/g	
A	50	7.86 7.80 – 8.00	15 8.1 – 20	7.9 4.2 – 11	5852 3577 – 7337	72 34 - 80
B	50	7.94 7.90 – 8.10	5.6 4.5 – 6.7	3.0 1.7 – 4.0	2187 1390 - 2842	20 1 – 32
C	35	7.98 7.90 – 8.10	4.2 3.7 – 4.7	4.9 4.5 – 6.0	1436 981 – 1819	5.3 0.5 - 51

In addition to silicates (SiO_2; not measured) the main (avg. value > 3.5 mg/g) oxide composition of the mineral soils (Fig. 5.1) shifted from aluminium (Al) and iron (Fe) in the A horizon, to calcium (Ca) and Al in the C horizon. The data indicated that the soil mineral base cation (Ca+Mg+Na+K) content in the A and B horizons were relatively high and increased further into the C horizon. The base cations constituted 46, 49 and 67% of the oxide composition in the A, B and C horizons, respectively. This fits well with the overall high soil pH found at this site.

The content of Fe was as usual strongly correlated to Al (r = 0.825) and both Fe and Al were strongly correlated to potassium (K; r = .830 and 0.942, respectively). Fe and Al were as always negatively correlated to calsium (Ca), though this correlation was poor; r = -0.609 and -0.688, respectively.

The major oxide elements presented in Fig. 5.1 were followed in abundance by titanium (Ti), manganese (Mn), phosphorous (P), and barium (Ba) (Tab. 5.3). Ti and lanthanum (La) were strongly correlated (r = 0.927) and both elements were negatively correlated to % Ctot (r = -0.464 and -0.560), and as usual positively correlated to Al (r = 0.795 and 0.736) and Fe (0.794 and 0.609), in addition to the trace elements Scandium (Sc; r=0.935 and 0.831) and Yttrium (Y; r = 0.957 and 0.868). Total phosphorous (P) was correlated to LOI (r = 0.843) and %Ctot (r = 0.787), as well as Tot. N (r = 0.870). Mn was strongly positively correlated to Fe (r = 0.819) and Ti (r = 0.721), and other several trace elements (Co, Cr, Cu, Sc, V, Y, Zn and Ti). Ba was only found to be strongly correlated to beryllium (Be; r = 0.735) and Zirconium (Zr; r = 0.709).

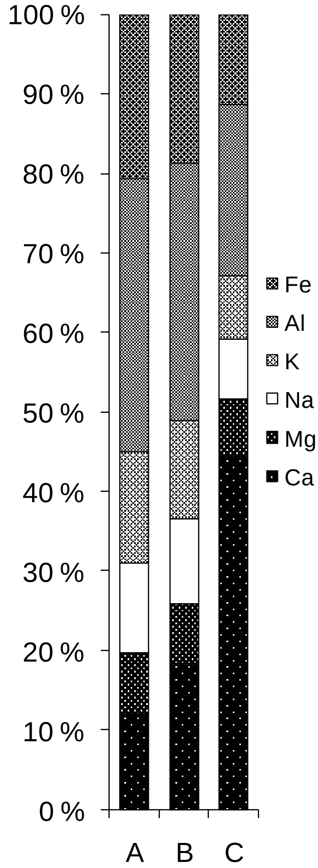

Fig. 5.1. Main (avg. value > 3.5 mg/g) oxide composition of the mineral soils.

Tab. 5.3. Average and quartile range of soil content of less abundant oxide elements in 50 A and B horizon and 35 C horizon samples from Gauyan.

Horizon	P	Mn	Ti	Ba
	mg/kg			
A	724	905	2812	691
	549 – 866	832 – 1006	2639 – 3028	558 – 827
B	556	791	3196	764
	512 - 605	636 - 946	2710 - 3621	631 – 873
C	504	551	2409	606
	466 - 545	446 - 565	2037 - 2502	523 - 678

Soil composition of measured trace elements along with the composition of continental crust (Taylor & McLennan 1985) and selected heavy metal contamination norms (Lacatusu 1998) are presented in Tab. 5.4. The bedrocks in the studied sites are generally secondary sedimentary minerals. The contents of hard (type A) trace elements (i.e. Sr, Cr, V, Sc, Y, Zr and Be) are therefore generally depleted compared to continental crust as found in all the TEMP sites. Nevertheless, the heavy metal (Cd, Cu, Cr, Zn, Ni and Co) 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). The exception is Pb which is found within the normal range. The levels of Zn are especially high.

Tab.5.4. Average soil content of measured trace elements in 50 A and B horizon and 35 C horizon samples from Gauyan.

Site	Hor	As	Ba	Sr	Pb	Cd	Cu	Cr	Zn	Ni	Co	V	Sc	Y	Zr	Be	Mo
									mg/kg								
Earth crust[1]		1.0	250	260	8.0	0.1	75	185	80	105	29	230	30	20	100	1.5	1.0
Normal Min[2]					0.1	0.1	1	2	3	2	1						
Normal Max[2]					20	1.0	20	50	50	5	10						
World mean[3]		6		300	10	0.06	20	100	50	40	8						
M.A.L. (Pl) [2]					100	3	100	100	300	100	50						
Gauyan	A	14.2	691	201	11	2.1	40	79	142	40	17	86	10	15	68	2.4	2.8
	B	18.8	764	241	9.8	1.9	37	76	116	44	20	99	11	17	81	2.8	2.8
	C	12.5	606	313	6.7	1.5	29	56	81	34	14	69	8.0	12	69	2.0	2.8

[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)

The Al and Fe content were strongly correlated to 7 and 10, respectively, of the 18 measured trace elements (Fig. 5.2), as found at most TEMP sites. Important exceptions are as usual the soft (or type B) metals lead (Pb), cadmium (Cd) and arsenic (As) and the hard (type A) elements barium (Ba) and strontium (Sr). Soft metals (high covalent index) were often found to be negatively correlated to hard (Type A) metals (e.g. Ca, Mg, and Sr). The variation in the content of hard element strontium (Sr) follow type A elements, such as Ca (r = 0.718). This is also found at other TEMP sites. Molybdenum (Mo) gave no significant correlations because a majority of samples were below the detection limit.

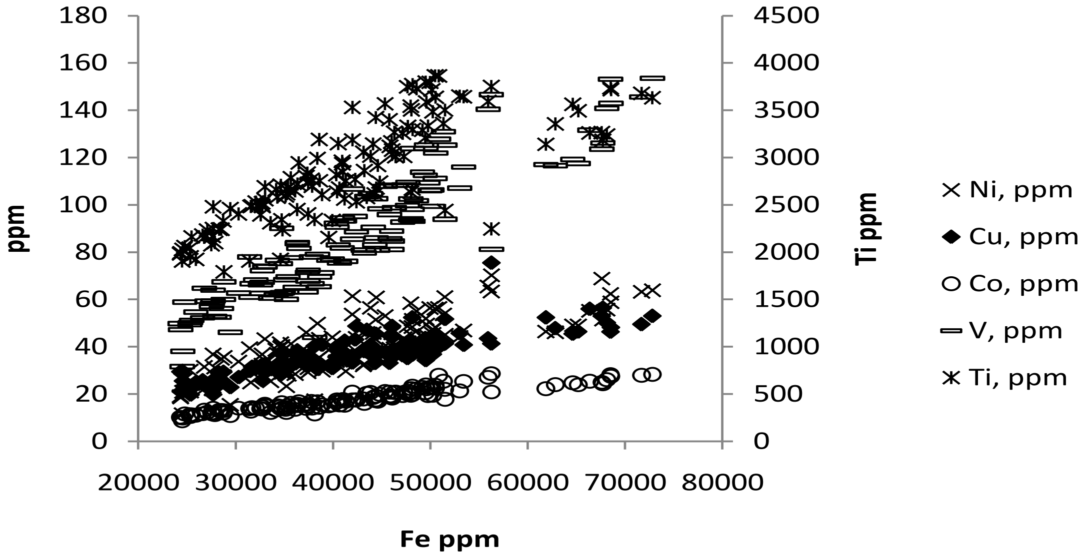

Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements; nickel (Ni), copper (Cu), cobolt (Co) and vanadium (V).

A large number (30) of strong correlations were found between the 18 measured trace elements (Tab. 5.5). As usual the typical borderline elements Co, Ni and Vanadium (V) showed the largest number of strong correlations. The more typical soft (or type B) elements (Pb, Mo, Cd and As) and the hard (or type A) elements (Ba, Sr) were the poorest correlated to the other trace elements.

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

Tab. 5.5. The strongest sets of correlations (i.e. r > 0.7) found for each of the measured 18 trace elements in 50 A- and B horizon and 32 C horizon samples from Gauyan. The elements are sorted in the order of decreasing covalent index with type B elements on the top and type A elements in the bottom. - Indicates no strong correlations (r < 0.7).

	# of corr.	Vs.	r
Pb	0	-	-
Mo	-	-	-
Cd	0	-	-
As	0	-	-
Cu	2	Co	0.742
Co	8	V	0.968
Ni	5	Co	0.861
Zn	0	-	-
V	8	Co	0.968
Ti	6	Y	0.957
Cr	2	Co	0.786
Sc	7	Ti	0.937
Y	7	Ti	0.957
La	4	Ti	0.927
Zr	1	Ba	0.709
Ba	2	Be	0.735
Sr	0	-	-
Be	7	Ti	0.888

5.3 Discussion

The role of Fe content as a governing factor for the soil chemical content of trace elements can be illustrated by a Principal Component Analysis (PCA) (Minitab®).

In the A horizon the PCA 1 and PCA 2 explains only 35.1 and 27.3% of the variation in the data set, respectively. In the B horizon the PCA 1 and PCA 2 axes explains 58.8 and 13.3% of the variation in the data set, respectively. In the plane of the first two principal components (PCA 1 and PCA 2) in the A and B horizons the Fe is clustered together with Al and most trace elements (except Pb, Mo, Cd, As and Ba, Sr) (Fig. 5.3). Negatively loaded to this cluster along the PCA 1 axis we find Ca and Sr, together with % C_{tot}. The PCA 1 axis is therefore mainly explained by a strong loading of Fe and Al on the one side and Ca on the other.

The PCA 2 axis at these sites may partly be explained by the Covalent index ($CI = X^2r$) of the elements. Elements with low CI, commonly referred to as hard or type A elements, prefer to bind to carbonates, while elements with high CI, commonly referred to as soft or type B elements, forming more stable complexes, e.g. with sulphides. Type A elements (Ca, Mg, Na, K, Ba and Sr) have generally opposite loading to more Type B elements (Pb, Mo, Cd, As). Borderline metals have generally low loading along the PCA 2 axis. Instead they are strongly clustered with Fe and Al. In the A and B horizons PCA 2 axis is therefore correlated to the Covalent index with an r = 0.540 and 0.533, respectively.

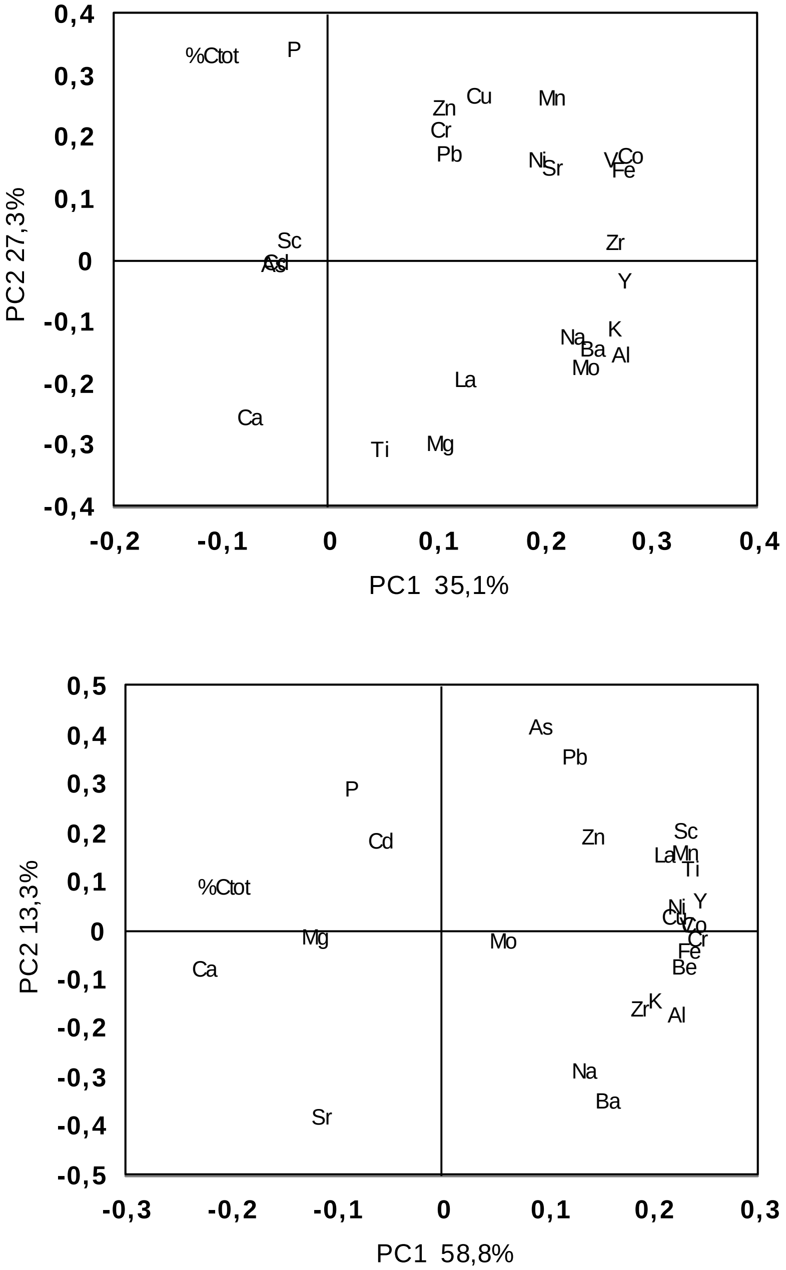

Figure 5.3. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 62.4 and 71.8% of the variation in soil elemental composition, respectively.

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