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

Establishment of monitoring reference area in Sogot, Jalal-abad oblast, the Kyrgyz Republic, 2005. TEMP-CA monitoring site No.2.

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

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

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

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

  The Sogot monitoring site in Osh oblast in the Kyrgyz Republic was the second of ten monitoring sites established in forests in Central Asia:

1: "Kara-Koi" in the Osch oblast, the Kyrgyz Republic.
2: "Sogot in the Jalal-Abad oblast, the Kyrgyz Republic.
3: "Dugoba" in Batken oblast, the Kyrgyz Republic.
4: "Besh-Tash" Talass oblast, the Kyrgyz Republic.
5: "Sary-Chelek", in Jalal-Abad oblast, the Kyrgyz Republic.
6: "Navobod" in Sogdi oblast, the Republic of Tajikistan.
7: "Gauyan" in Batken oblast, the Kyrgyz Republic.
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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 five plots of 1-m^2 were randomly placed.

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

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

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

  The soils at Sogot had a circumneutral pH with a relatively high base saturation on the cation exchanger. Soil chemical characteristics are in the middle of the range found among the TEMP-CA sites. Spatial variation in soil chemistry was mainly governed by the soil organic content. The soil contents of titanium (Ti) were relatively high (615 mg/kg in the B horizon). The contents of a majority of the 16 measured trace elements were strongly correlated to the iron (Fe) content, which again was strongly correlated to the aluminium (Al) and Ti content. A Principal Component Analysis (PCA) of the metal content and chemical characteristics of the A- and B-horizons gave a main principal component (PC1), explaining a staggering 72 and 68%, of the variation in the A and B horizons, respectively, that was mainly explained by the Al and Fe content relative to calsium (Ca) and total carbon (C) content. The parameter loadings along the PC2 were to a certain extent correlated to the Covalent index (CI = X^2 r) of the elements (r = 0.424 and 0.445 in the A and B horizons, respectively).

Ansvarlig signatur

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

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NFG
NORWEGIAN FORESTRY GROUP

Cover Photo: Sogot, Photo: Tonje Økland

ABSTRACT

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

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PREFACE

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

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

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

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

My very special thanks to Halvor Solheim (leader of the Forest Health Section at NFLI), who supported me and helped me, especially in the last phase of the work with completing the TEMP-CA reports. I also want to give special thanks to Dan Aamlid (head of the Department for Biology and Environment at NFLI), Arne Bardalen (Director General at NFLI), Karl Thunes (project leader after Odd Eilertsen of the Ahangaran Forest Damage Project at NFLI) and Øystein Aasaaren (Managing Director of Norwegian Forestry Group), all of whom have, in different ways, given me support in the difficult situation that occurred when Odd died. Odd Eilertsen was the initiator and project leader of TEMP-CA, but he was also my friend and colleague.

Ås, 22 November 2010

Tonje Økland

Project leader

CONTENT

INTRODUCTION

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

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

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

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

The situation is more or less similar for the neighbouring countries around the Fergana Valley. Besides this, the main land degradation processes include salinization, swamping, chemical pollution, and destructive changes in vegetation cover.

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

The institutional co-operation between Norway and the Kyrgyz Republic provides the opportunity for education and training of numerous environmental field workers and scientists, laboratory engineers, forest and environmental experts and managers from the Central Asian region. The TEMP-CA project contributes to better understanding of environmental problems, as a first step to promoting a sustainable use of the forests in Central Asia. Thus, increased expertise in environmental monitoring methods and in environmental management as well as institutional development in general is the most important output from the 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 second monitoring site established in the TEMP-CA project, Sogot in the Jalal-Abad oblast, the Kyrgyz Republic. This monitoring site was established in 2004, but the first analyses of the plots were performed in 2005. Measurements of a lot of variables for forest tree condition, forest growth, soil chemistry, and soil classification, ground vegetation, and environmental factors were performed in 2005 according to manuals based on ICP Forests, ICP Integrated Monitoring and the monitoring concept used in Norway since 1988 (Økland 1996, Lawesson et al. 2000).

1. DESCRIPTION OF THE SOGOT REFERENCE MONITORING AREA

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

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

1.1   Geographical position of the reference monitoring area

The Sogot monitoring site is located on the south-western macro-slope of the Fergana mountain range. This area, which belongs to the Tien-Shan province, is part of the Central Asian Mountain Area.
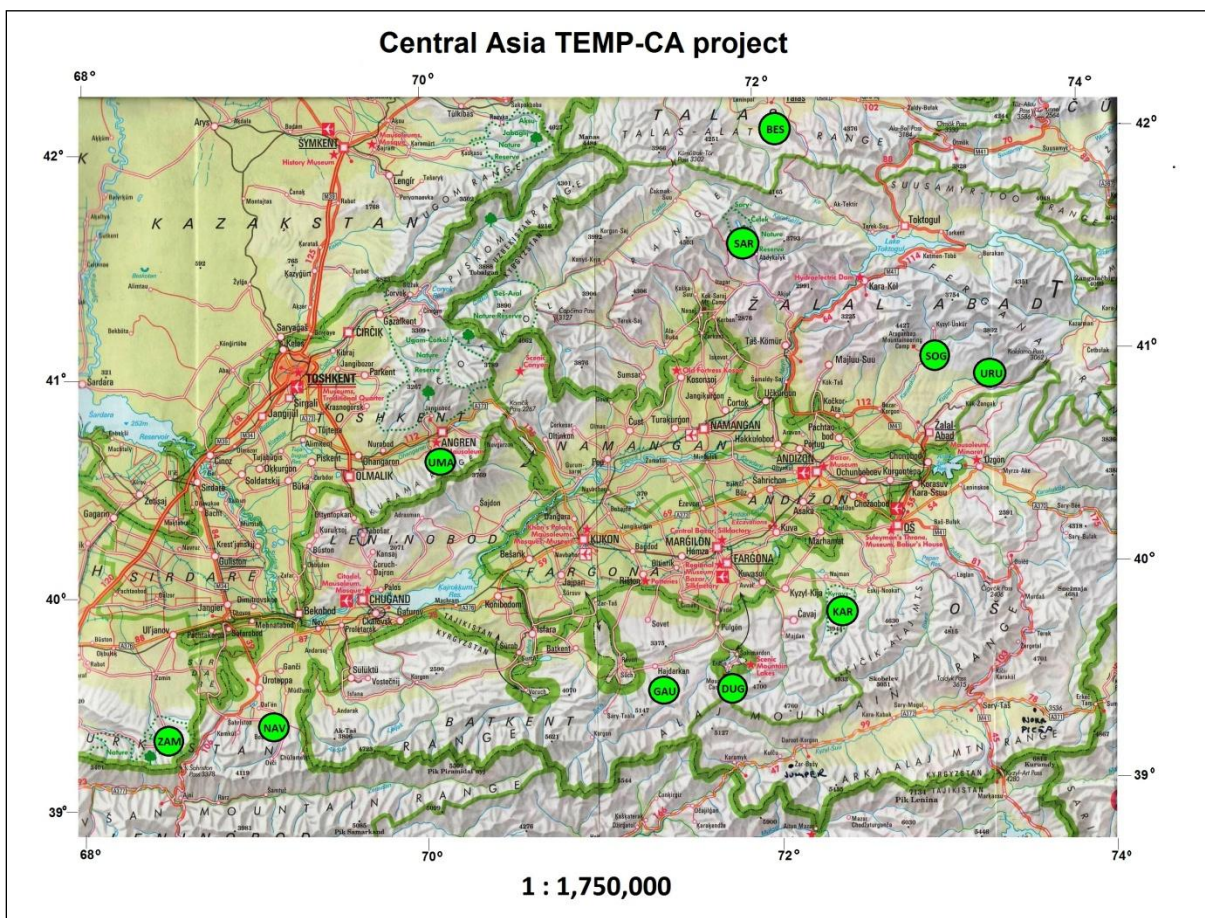
Fig. 1.1. Map of the Sogot (SOG) area and the nine other TEMP-CA monitoring reference areas.

The south-western Tien-Shan province covers the whole of Northern Fergana and the Chatkal river basin. Administratively, the Sogot investigation area belongs to the Bazarkorgon district of Jalal-Abad oblast, the Kyrgyz Republic.
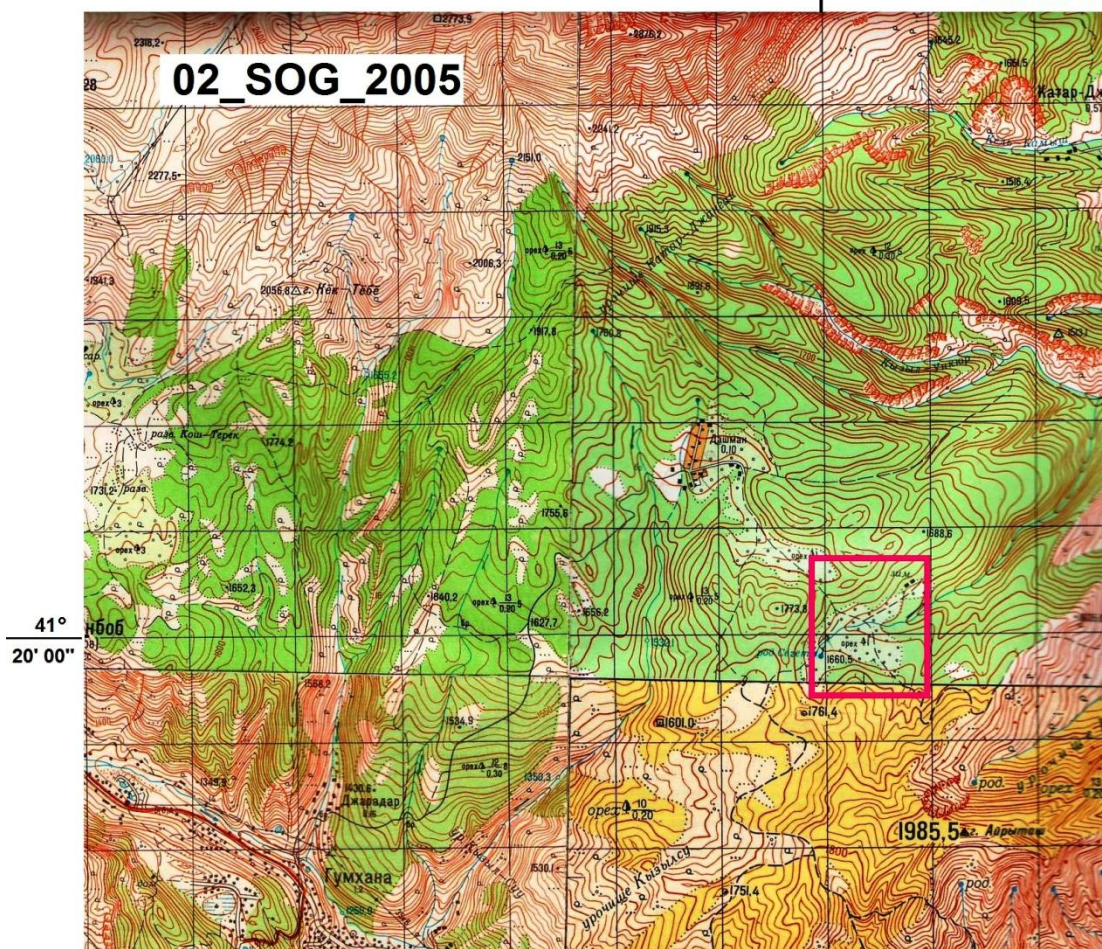
Fig. 1.2. Geographical position of the Sogot monitoring reference area.

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

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

Plot #	Name of plots	Elevation	N	E
1	SOG 1	1709 m	41°19.988′	073°01.722′
2	SOG 2	1744 m	41°19.947′	073°01.802′
3	SOG 3	1731 m	41°20.189′	073°01.457′
4	SOG 4	1566 m	41°20.428′	073°02.532′
5	SOG 5	1584 m	41°20.410′	073°02.558′
6	SOG 6	1558 m	41°20.417′	073°02.713′
7	SOG 7	1561 m	41°20.411′	073°02.742′
8	SOG 8	1558 m	41°20.430′	073°02.777′
9	SOG 9	1521 m	41°20.762′	073°02.762′
10	SOG 10	1561 m	41°20.499′	073°02.470′

1.2 Forest type, ownership, and conservation status

The main forest forming species is *Juglans regia*, while *Fraxinus sogdiana* and *Acer turkestanica* are rarer. Other trees and bushes in the area, up to 4-5 m high, include *Prunus sogdiana*, *Crataegus turkestanica*, *Malus kirghisorum*, *Malus sieversiana*, *Cerasus mahaleb*, *Acer semenovii* and *Ramnus cathartica*. Due to cuttings and other damages, older *Prunus* and *Crataegus* trees often have a deliquescent form.

The Arstanbap-Ata leskhoz, which is a structural subdivision of the State Agency on Forestry and Environmental Protection, is part of the Bazar-Korgon Administrative region in Jalal-Abad oblast. The territory of Arstanbap-Ata leskhoz is divided on 3 forest departments (Tab. 1.2). The Sogot monitoring site is established on the territory of Dashman forest department.

Tab. 1.2. Leskhoz's administrative and economical structure.

Forestry name	Area		Forestry office location	Distance to the leskhoz's office, km
	Total, hectares	% of the area		
1. Kosh-Terek	9211,5	57	Arstanbap v.	6
2. Gumhana	4023,4	25	Gumhana v.	
3. Dashman	3031,1	18	Dashman v.	12
Total in leskhoz	16266,0	100		

As a state organization the Arstanbap-Ata leskhoz follows the policy of the Forest Code, which has the following purposes:

1. Forest resources protection.
2. Forest regeneration and cultivation measures.
3. Increase the living standard of the human population.

Due to the importance of the walnut and fruit forests, including their ability to protect vulnerable mountain nature (e.g. against soil erosion), these forests are subjected to protection, with special strict use.

1.3   Geology, topography, and Quaternary deposits

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

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

Geo-morphologically the Sogot site belongs to the West Tien Shan group (Fergana, Chatkal, Pskem and Kuramin ranges). The relief is worked out primarily in Palaeozoic and Proterozoic rocks, more rarely in Mesozoic-Cainozoic rocks. The type of relief is caused by tectonic-denudation and mainly erosion. The characteristic feature are deep and thick partitions (from 500 m up to 1000-1500 m, and even up to 2000 m thick). Deep V-formed canyons with large amounts of debris and landslides at the bottom are widely distributed. Relics of the ancient surface can often be found on slopes and in watersheds of the mountain ranges.

The presence of subsurface water combined with a continental climate cause fragmentation of the rocks.

The age for the formation of the mountain ranges and mountains is predominantly Pliocene and, more rarely, early Quaternary.

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1.4 Climate

The climate at the Sogot monitoring site is Mediterranean with moderate conditions of humidity. High mountain ranges as Chatkal, Fergana, Talas and Atoinok weaken the influence of cold air masses from Siberia and the anticyclone from South and East. In winter, autumn and spring this territory is under the influence of the South cyclones and intrusion of air masses of the temperate zone from West and North-West. Days with precipitation are frequent in winter and spring.

1.4.1 TEMPERATURE

The average annual temperature in the lower zone is 11 to 13 °C, in the middle mountain zone 8 to 10 °C, and 0 to 2 °C in the zone from 2500 to 3000 m a.s.l (Tab. 1.3). The duration of the cold period with a mean daily temperature below 0 °C is 60 to 70 days at 600 to 1000 m a.s.l., increasing to 100 to135 days at 2000 to 2200 m a.s.l.

Tab. 1.3. The average temperature in the region (°C).

Nearest meteorological station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	Year
Ak-Terek	-2.2	-1.7	2.6	9.5	13.2	17.7	20.5	19.9	15.9	9.7	4.6	0.6	9.2

1.4.2 PRECIPITATION

The annual precipitation on slopes of the territory is 900 to 1050 mm (Tab. 1.4). In the lower and middle part of the territory 50-70% of the total precipitation fall during the cold period of year while in the upper zone precipitation is highest during the warm period. The highest amount of precipitation falls in the period from October to May, while August and September usually are quite dry.

Tab. 1.4. The average precipitation in the region (mm).

Nearest meteorological station	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Des	year
Ak-Terek	78	81	111	157	142	87	47	25	33	92	96	81	1030

1.5 Vegetation zones

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

The vegetation cover of the Sogot investigation area belongs to the North-Fergana type of vertical zones. The diverse physical and geographical features result in a diverse vegetation cover. The most prevalent forest types of the investigated area are nut and fruit forests of *Juglans regia* and *Prunus sogdiana*, low and light forests of *Acer turkestanica*. The most of the area is occupied by *Rosa kokanica*. The forests are generally complex and multi-layered (multi-storied). The presence of considerable areas of tall grass meadows, rocks and stony – rubbly slopes is typical for this region.

1.6 Forest history, forest structure, and external influence

1.6.1 HUMAN IMPACT

According to information from the Arstanbap-Ata Leskhoz's staff more that 1650 people currently resides the territory of the leskhoz.

The human activity in the walnut and fruit forests is higher than in other forest types. Several types of activities have impact on the forest, as grazing, illegal cutting of trees or parts of trees and other kinds of human activity, including harvesting of wild walnuts, apples, cherry plums, pears, pistachios and other non-arboreal forest products as medicinal herbs. The local population also cut the grass for haymaking, and they sometimes plough up parts of the forest lands for agriculture

Fig. 1.3. During the harvesting season local people live in huts made of material found in the forest area.

and bee-keeping. The natural forest regeneration is difficult due to the human impact. However, every year leskhoz's workers plant nurslings for forest area expansion.

Irrational forest plantations may have illegal cuttings for sale. The condition of walnut and fruit forests on the leskhoz's territory becomes worse year after year due to damages caused by the local population during harvesting season and irregular grazing.

1.6.2 FOREST HISTORY

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

From 1933 up to 1947 walnut and fruit sectors were under the authority of different ministries and departments, repeatedly turned from one ministry to another, which affected the conditions of the walnut forests. Following a 1944 USSR Governmental Order to investigate the production forces of the USSR, the Academy of Sciences of sent an expedition under the general direction of

Vladimir N. Sukachev to the forests of South Kirgizia. After inspecting materials from this expedition, especially with regards to the importance of walnut and fruit forests, the SNK of the USSR by its Resolution of April 30, 1945, declared walnut and fruit forests of southern Kyrgyzstan as closed fruit wood with special use conditions. In 1948 all leskhozs of southern Kyrgyzstan were passed to the Ministry of Forestry of Kirgiz SSR.

Currently, the local forest department (leskhoz) let the local population rent the walnut plantations on short-term basis (one season) for walnut harvesting. Initially the area passed for communal forest tenure for one year was 140 hectares. This area will expand year after year. In addition to contracts with the leaseholders a map of the rented areas are drawn where borders and internal situation of the different site are indicated.

1.6.3   GRAZING

Degradation of pastures due to overgrazing has very negative impact on the walnut forests. Productivity has decreased with c. 50% over the last 10 years. Pastures occupies 2679 ha of the total leskhoz's area, ploughed fields 449 ha. There are more than 5050 cattle, 2900 small cattle and 490 horses on this territory. The most intensive grazing on the leskhoz's territory falls on spring-autumn period before pasturing in high-mountain pastures (April-May) and their return (October-November).

Intensive grazing in summer time is not observed in the area where the monitoring sites are established.

1.6.4   OTHER BACKGROUND INFORMATION

Very intensive anthropogenic impact is observed on leskhoz's lands and in walnut forests in general. The timber of walnut including wood-knobs are very valuable and are also used as fire-wood so people are tempted to break laws (illegal felling, smuggling). During harvesting, the underbrush and young trees are damaged, which affects negatively the natural regeneration of the walnut forests.

2 FOREST STAUS AND TREE CONDITION

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2.1 Methods

2.1.1 SAMPLING DESIGN

The establishment of monitoring plots and field assessments where done in accordance with the ICP-Forest manual (ICP Forests 2006), revised for Kyrgyz conditions. Briefly, at each site ten 30x30 m plots were established in which the spatial coordinates for all trees > 5 cm DBH (vitality trees) were assessed. The individual trees were numbered consecutively at breast height within each plot for later reassessments.

Within each of the plots a central macro-plot of 10x10 m is defined, in which more intensive assessments were done, such as measurement of tree heights, crown projections, and crown heights.

2.1.2 TREE PARAMETERS

At each site standard crown condition parameters, such as social status, defoliation, and discoloration were recorded. The classification of the defoliation follows ICP-Forest: Class 0 shows healthy trees, with ≤ 10% defoliation; class 1, "warning stage", > 10 up to 25%; class 2, "moderately damaged", > 25-60%; class 3, "severely damaged", > 60% defoliation; and class 4, dead trees.

Diameter at breast height was recorded on all trees > 5 cm DBH, whereas tree height was only recorded within the central 10x10 m macro-plot (cf. ICP Forests 2006). To take into account possible non-circular stem circumference, the diameter at breast height of all vitality trees was assessed in two directions, north-south and east-west.

In addition, regeneration (< 5 cm DBH) of all tree species were recorded as a part of the ground vegetation analysis in the five 1-m^2 plot in each of the 10x10 m macro plots, making a total of 50 m^2 for the each site.

2.2 Results

2.2.1 TREE COMPOSITION

The Sogot site consisted exclusively of deciduous species. The most abundant species were *Juglans regia* (39.2%) and *Malus kirghisorum* (33.2%) (Fig. 2.1), whereas *Crataegus turkestanica* (11.6%), *Prunus sogdiana* (9.7%) and *Acer semenovee* (5.6%) had modest occurrence. There were only a few individuals of *Malus sieversiana* (0.3%) and *Populus tianschanica* (0.3%) at the site.
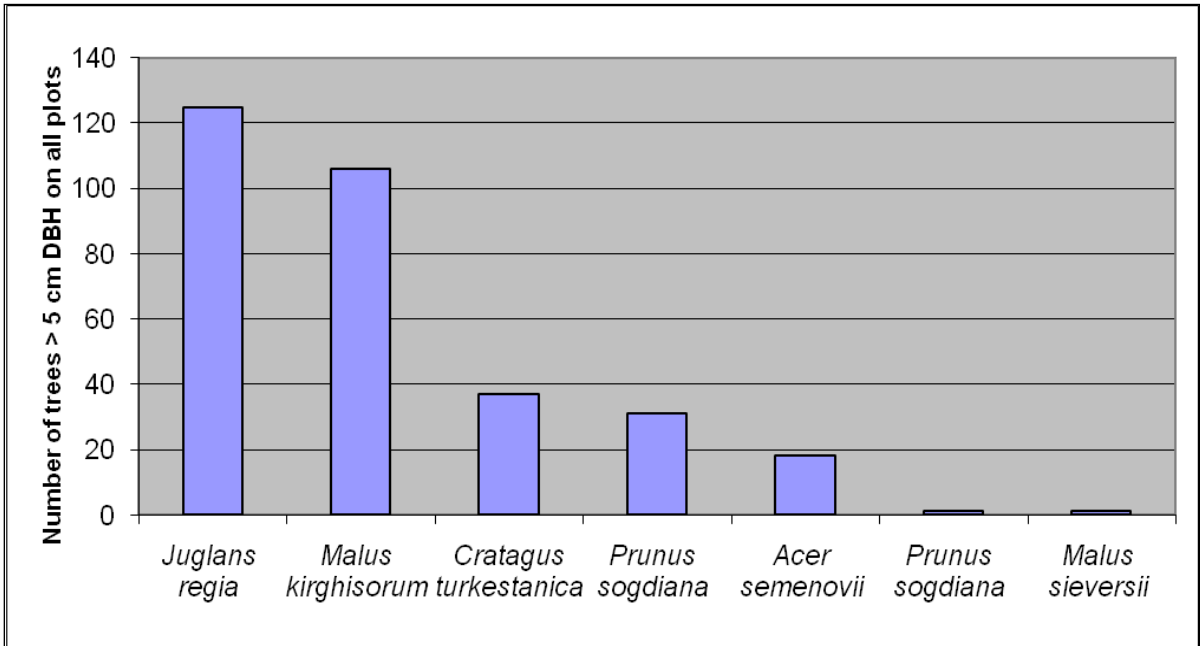
Fig. 2.1. Total number of trees of the different species > 5 cm DBH in all plots.

2.2.2 TREE CONDTION

Tree condition is presented for the main species, for which there are sufficient numbers to draw conclusions. Defoliation for *J. regia* and *M. kirghisorum* was both in the moderate range, although highest for *M. kirghisorum* (Fig.2). However, the proportion of discolorated trees was at about 1% for both species.
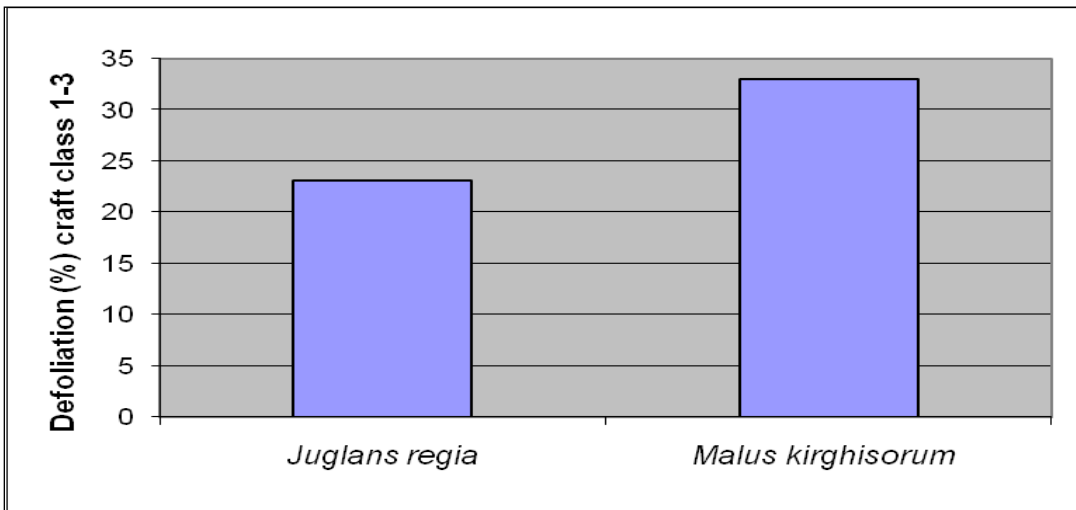
Fig. 2.2. Defoliation for the main species.

2.2.3   DEMOGRAPHY AND REGENERATION OF MAIN SPECIES

Size distributions of *J. regia* and *M. kirghisorum* at the SOG site showed significant differences. *J. regia* showed an increase in the number of individuals with increasing DBH up to 35 cm. The two smallest size classes (DBH < 25 cm) made up only 19.3% of the trees (Fig.3), and the smallest class (DBH 5-15 cm) constituted only 6.4%.

For *M. kirghisorum* there was a slight decrease in the number of trees with increasing DBH. The two smallest size classes (DBH > 15 cm) made up 68% of the trees, which indicated an adequate level of regeneration for this species. The frequency of trees with DBH > 20 cm was 14.5%.
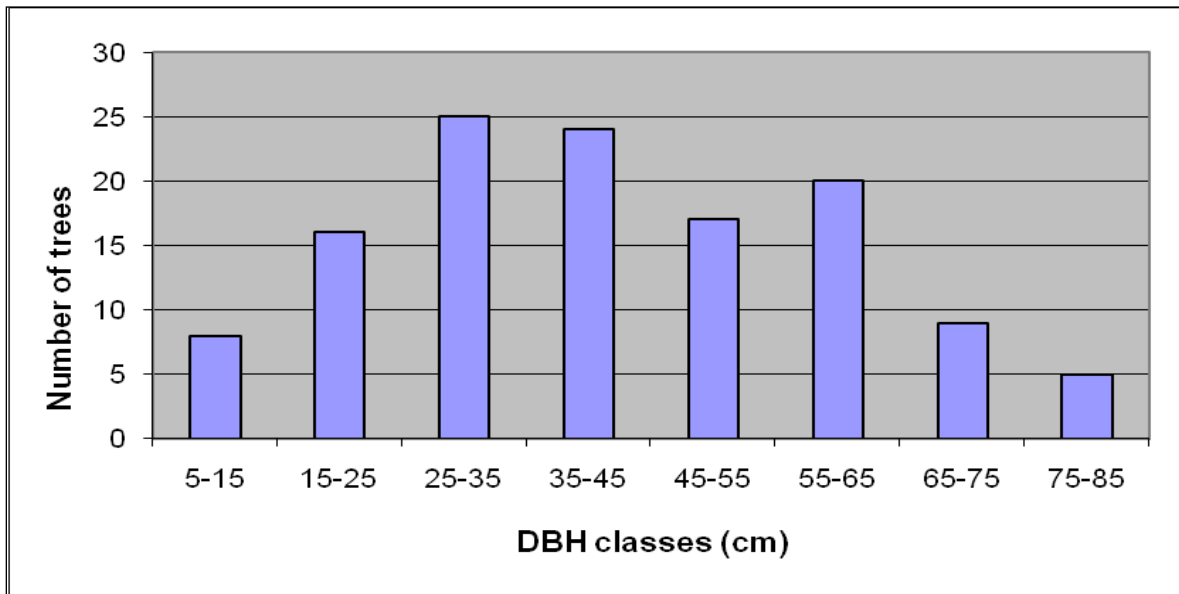
Fig. 2.3. Size distribution (DBH) for *J. regia* (all plots).
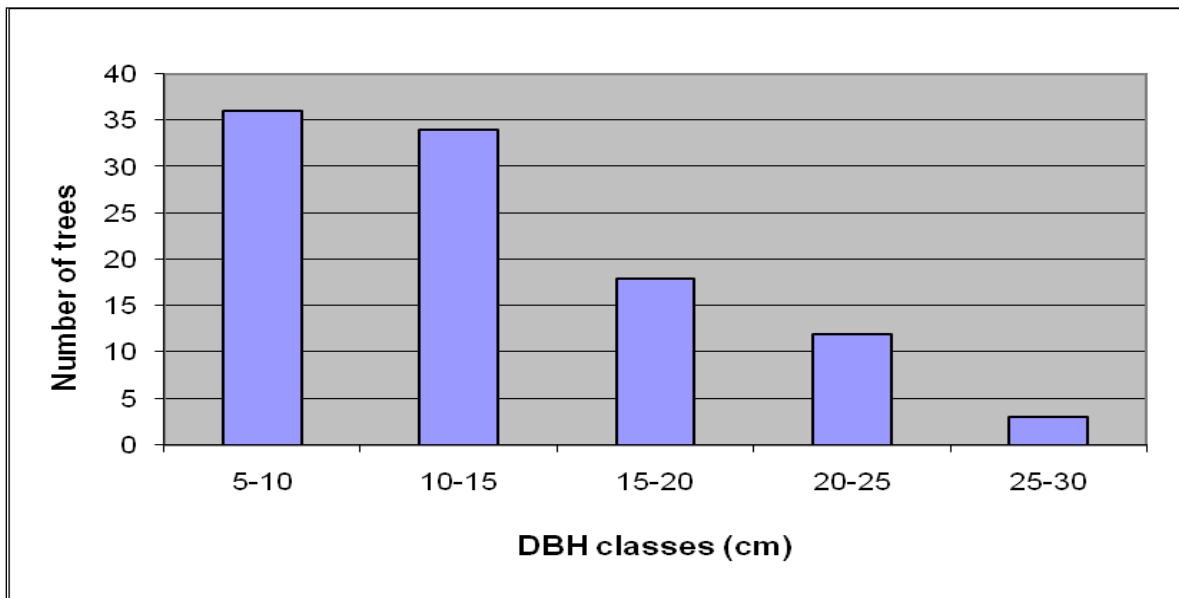
Fig. 2.4. Size distribution (DBH) of *M. kirghisorum* (all plots).

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2.3   Discussion

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

At this site the defoliation was rather high, in average 23% for *J. regia* and 33% for *M. kirghisorum.* By contrast, the discoloration was insignificant in both species. The trees may be attacked by fungi and insects, which could affect tree vitality negatively. Thus, wood and needle samples should be collected for plant pathological investigations when the disease or injury cannot be assessed with certainty in the field.

Sufficient regeneration is fundamental for sustainable forests. The *size distribution* of *J. regia* shows that the greatest number of individuals was found among the intermediate size classes (DBH 25-45 cm), rather than in the smallest classes. Although we have no information about the abundance of the seed plants, our results suggest insufficient regeneration of this species. With adequate regeneration over time we would expect a much larger proportion of individuals in the smallest size classes (DBH 5-10 cm and 10-15 cm) than in the larger size classes, i.e. a size distribution that would fit to a reversed J-shaped distribution.

In comparison, the size distribution of *M. kirghisorum* with a relatively high proportion of individuals in the smallest size classes possibly reflects that regeneration is sufficient. The project does not, however, have an objective of monitoring natural regeneration as such. To draw firm conclusions on this matter, more specific investigations are needed.

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

3   BIODIVERSITY AND GROUND VEGETATION

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3.1   Methods

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

The key principles are summarised below:

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

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

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

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

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

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

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

3.1.1   SAMPLING DESIGN

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

As far as possible, sites that were not visibly affected by external impacts were preferably chosen for placement of macro plots. Sample plot positions were rejected according to a predefined set of criteria. Positions for 1-m^2 plots were rejected if they (1) had a joint corner or side edge with another plot; (2) included trees and shrubs or other plants that physically prevented placement of

the aluminium frame used for vegetation analysis of the plot; (3) were physically disturbed by man (by soil scarification, extensive trampling or crossed by a path, digging of pits, etc.); (4) were disturbed by earth slides; (5) were covered by stones for more than 20% of their area; or (6) when a vertical wall of 25 cm or more would be included or situated close to the corresponding plot. In case of rejection, a new position for the 1-m^2 plot was selected according to a predefined set of criteria. All plots were permanently marked by subterranean aluminium tubes as well as with visible plastic sticks.

3.1.2   VEGETATION PARAMETERS

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

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

The number of vascular plant species within macro plots was calculated as: (a) the cumulative number of species recorded within the five 1-m^2 plots in each

10x10 m macro plot, (b) the total number of species recorded in each 10x10 m macro plot, and (c) the total number of species in each 30x30 m extended macro plot. The ratio a/b and a/c was calculated for each macro plot.

3.1.3   EXPLANATORY VARIABLES

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

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

(1)   Topographical variables include:

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

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

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

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

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

Indices of *concavity/convexity* in each 1-m² 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-m² plot in centre. Derived indices were calculated for both the 1-m² 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-m² 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 m² (5x5 m) plot around each 1-m² plot (the 1-m² plot placed in the centre of the 25 m² plot):

CC = $\sum$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-m² 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-m² 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:

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

The litter index for each 1-m² plot was calculated as:

Litterl = $\sum$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:

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

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

Litterl = ∑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; **Litterl = 0**

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

Litterli = cci × cai × (hi - chi)

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

Litterl = ∑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.

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3.1.4 ORDINATION METHODS

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

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

3.1.5 INTERPRETATION OF GROUND VEGETATION GRADIENTS

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

3.2 Results

3.2.1 GROUND VEGETATION BIODIVERSITY

The number of species, α-diversity, is reported in this chapter, while β-diversity (variation in species composition along gradients) will be reported in chapter 3.2.2. The total species list for the 50 1-m^2 plots is given in Appendix 3.1. The number of species within macro plots was calculated as: (a) the sum of species recorded within the five 1-m^2 plots in each 10x10 m macro plot, (b) the total number of species recorded in each 10x10 m macro plot included the species in the 1-m^2 plots, and (c) the total number of species in each 30x30 m extended macro plot included the species recorded in the 1-m^2 plots (c), Tab. 3.1. The ratio a/b and a/c was calculated for each macro plot.

Alltogether 24 species were recorded in the 50 1-m^2 plots. Of these species five are endemic to Central Asia: *Rubus caesius, Acer turkestanicum, Crataegus songorica, Malus sieversiana* and *Prunus sogdiana. Malus sieversiana* is listed in the Red book of the Kyrgyz Republic.

The main dominating tree species in the monitoring site Sogot was *Juglans regia.* Typical for the *J. regia* forest is a low α-diversity, i.e. low number of species in total and per plot. The tree layer also sporadically consisted of *Malus sieversiana, Prunus sogdiana* and *Crataegus songorica.*

The shrub layer included *Berberis sphaerocarpa, Rosa beggeriana* and *Spireae lasiocarpa.*

The grass and herb layer in the plots was dominated by *Bromopsis ramosa and Impatiens brachycentra*, but in some sites other species dominated, as e.g. *Galium aparina* Other species were*, Conioselinum tataricum, Geranium collinum, Geum urbanum, Lamium album, Phlomoides speciosa, Urtica urens, Vicia cracca, Galium aparina* and *Ligularia thompsonii.*

The herbaceous plants consisted mainly of shade tolerant species, often tall (50-60 cm). and with low percentage cover. Bryophytes were almost absent due to the thick layer of litter (fallen leaves) from *J. regia.* Most of the vascular plants were herbs. In total, 16 out of the 24 species recorded in the 50 1-m^2 plots were herbs.

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The maximum number of species recorded in any 1-m^2 plot was 19, while the minimum number was 3. The average number of species recorded in the 1-m^2 plots was 9.7.

The total number of species recorded within the 50 1-m^2 plots + ten 10x10m^2 plots was 29, while the total number of species in the in the 50 1-m^2 plots + ten 30x30m^2 plots was 35. The maximum total number of species recorded in the five 1-m^2 plots in any 10x10 m macro plot was 15, while the minimum number was 6. The maximum total number of species recorded in any of the 10x10 m macro plots (the five 1-m^2 plots included) was 17, and the minimum number was 10. The average number of species in the 10x10 m macro plots (the five 1-m^2 plots included) was 13. The ratio a/b varied between 0.50 and 0.92 (Tab. 3.1). The ratio a/c varied between 0.56 and 0.86 in the macro plots.

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

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

Plot number	a Five 1-m^2 plots	b Five 1-m^2 plots + 10x10 m plot	c Five 1-m^2 plots + 10x10 m plot + 30x30 m plot	The ratio a/b	The ratio a/c
1	8	10	11	0.80	0.73
2	8	12	13	0.67	0.62
3	15	17	18	0.88	0.83
4	12	13	14	0.92	0.86
5	8	10	14	0.80	0.57
6	10	13	15	0.77	0.67
7	6	12	16	0.50	0.38
8	9	12	14	0.75	0.64
9	14	16	20	0.88	0.70
10	9	15	18	0.67	0.56
Total number	**24**	**29**	**35**	**0.86**	**0.71**

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

Plot number	Tree species	Shrubs	Herbs	Ferns	Graminoids
1	1	0	5	0	1
2	0	0	5	0	2
3	2	0	10	0	2
4	2	1	7	0	2
5	1	1	4	0	2
6	1	0	6	0	2
7	0	0	3	0	2
8	0	0	6	0	2
9	3	1	7	0	2
10	2	1	5	0	2
Total number	**5**	**2**	**16**	**0**	**2**

3.2.2   MAIN GROUND VEGETATION GRADIENTS

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

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

	DCA 1	DCA 2	DCA 3	DCA 4
Eigenvalues	0.347	0.273	0.191	0.116
Gradient lengths	2.580	1.888	1.779	1.577

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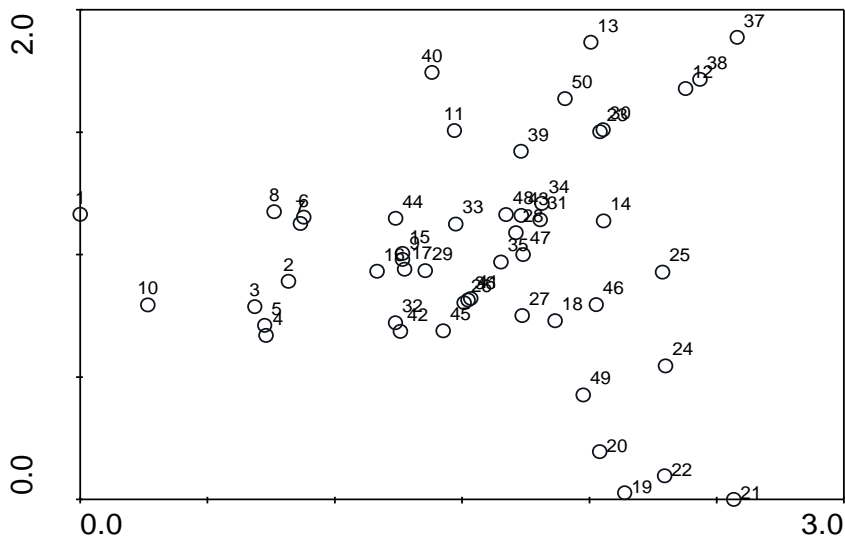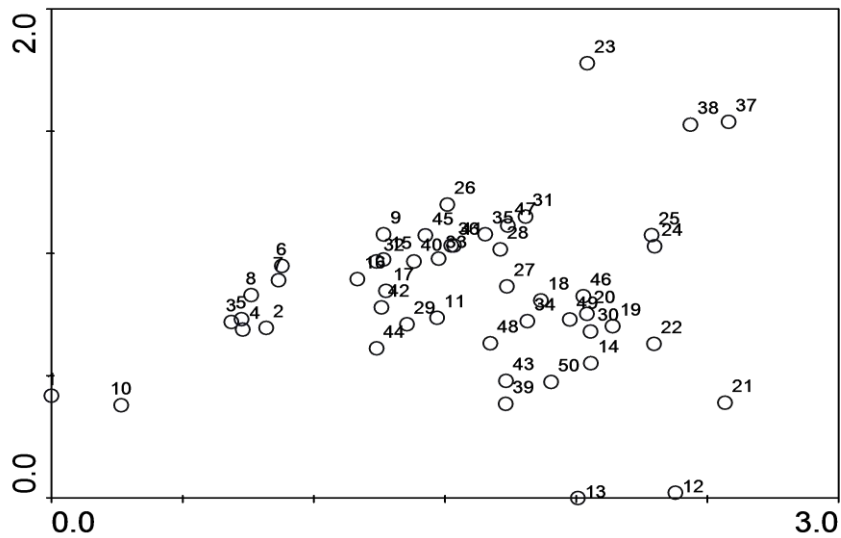

Fig. 3.2. DCA ordination of 50 1-m^2 plots, axes 1 (horizontal) and 3 (vertical). Plot numbers for the 50 1-m^2 plots are plotted onto the sample plot positions. Scaling of axes in S.D. units.
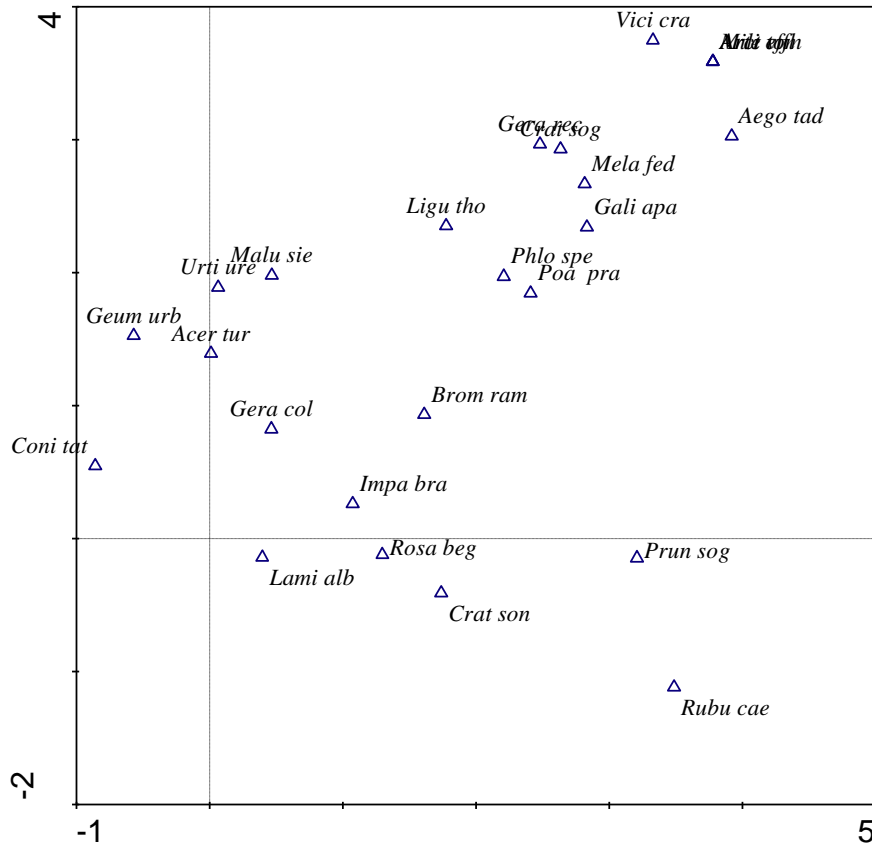
Fig. 3.3. DCA ordination of species in the 50 1-m^2 plots.

3.2.3 CORRELATION ANALYSES BETWEEN EXPLANATORY VARIABLES AND DCA ORDINATION AXES

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

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

	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
DCA 1	1.000	0.000	0.072	0.462	0.070	0.472	0.100	0.304
DCA 2	0.072	0.462	1.000	0.000	0.004	0.967	-0.145	0.136
DCA 3	0.070	0.472	0.004	0.967	1.000	0.000	-0.010	0.920
DCA 4	0.100	0.304	-0.145	0.136	-0.010	0.920	1.000	0.000
Soil moisture	-0.203*	0.038	-0.068	0.488	-0.035	0.719	-0.193*	0.048
Inclination	-0.019	0.847	-0.145	0.145	-0.010	0.920	0.019	0.847
Aspect	**-0.327****	**0.001**	0.082	0.403	-0.088	0.366	-0.083	0.398
Aspect favour.	-0.045	0.645	**0.299****	**0.002**	-0.117	0.235	-0.081	0.407
Heat index	-0.041	0.676	**0.259****	**0.008**	-0.032	0.744	-0.002	0.987
Max. inclination	0.010	0.920	-0.089	0.370	-0.074	0.456	0.010	0.920
Sum. conc. 1x1 m	0.066	0.545	**0.291****	**0.008**	-0.054	0.618	0.006	0.953
Var. conc1x1 m	-0.079	0.470	-0.262*	0.016	-0.044	0.689	0.171	0.118
Abs.sum.conc.1x1m	-0.082	0.452	-0.276*	0.012	-0.049	0.653	0.170	0.120

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

	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
Sum conc 3x3 m	-0.124	0.261	0.143	0.196	-0.110	0.319	0.008	0.944
Var. conc 3x3 m	0.057	0.600	-0.198	0.068	0.009	0.933	0.240*	0.027
Abs.sum.conc.3x3m	0.070	0.524	-0.189	0.083	0.021	0.844	0.242*	0.027
Rel. decid. trees	-0.161	0.107	-0.118	0.237	0.038	0.706	0.062	0.534
Crown cover index	0.003	0.973	0.001	0.993	-0.022	0.821	0.080	0.412
Litter index sum	0.041	0.686	0.053	0.605	-0.062	0.546	0.087	0.394
Mean grass height	0.016	0.878	-0.113	0.272	0.010	0.925	0.084	0.414
Max soil depth	**-0.256****	**0.010**	-0.107	0.276	-0.033	0.738	-0.107	0.280
Min soil depth	**-0.338****	**0.001**	-0.116	0.246	0.086	0.391	-0.178	0.076
Med soil depth	**-0.346****	**0.000**	-0.105	0.288	0.118	0.231	-0.176	0.073
Max. org. layer	**-0.376****	**0.000**	-0.085	0.411	0.233*	0.031	-0.170	0.100
Min. org. layer	**-0.388****	**0.000**	-0.002	0.987	0.147	0.151	-0.181	0.077
Med. org. layer	**-0.392****	**0.000**	-0.065	0.518	0.176	0.079	-0.192	0.055
Med. org. layer	**-0.392****	**0.000**	-0.065	0.518	0.176	0.079	-0.192	0.055
Max. litte depthr	0.168	0.104	-0.092	0.373	0.128	0.213	-0.023	0.826
Min. litter depth	0.163	0.136	-0.015	0.893	0.050	0.647	0.266*	0.015
Med. litter depth	0.100	0.324	-0.135	0.183	0.167	0.099	-0.083	0.414
Altitude	-0.100	0.330	0.105	0.309	-0.131	0.204	-0.256*	0.013
pH	0.197*	0.048	-0.155	0.122	0.179	0.073	0.212*	0.034
H+	-0.197*	0.048	0.155	0.122	-0.179	0.073	-0.212*	0.034
LOI, %	-0.057	0.569	-0.092	0.355	0.174	0.081	0.129	0.197
C total, %	0.039	0.696	-0.025	0.803	0.092	0.355	0.184	0.066
Ca	-0.112	0.263	-0.012	0.901	0.227*	0.023	-0.008	0.936
Mg	-0.020	0.845	0.101	0.311	0.233*	0.025	-0.022	0.824
K	-0.090	0.365	.250*	0.012	0.110	0.270	-0.111	0.267
CEC	-0.158	0.114	-0.069	0.488	0.055	0.582	-0.139	0.163
Total N, mug/g	0.034	0.736	-0.016	0.873	0.037	0.709	-0.097	0.333
Ca, ppm	**0.277****	**0.006**	-0.110	0.270	0.152	0.126	0.164	0.100
Mg, ppm	0.004	0.972	0.067	0.499	-0.121	0.227	-0.185	0.063
Na, ppm	-0.130	0.191	0.024	0.810	-0.153	0.124	-0.044	0.657
K, ppm	-0.197*	0.048	0.190	0.057	-0.144	0.150	-0.191	0.056
Al, ppm	-0.204*	0.041	0.158	0.114	-0.122	0.220	-0.226*	0.023
Fe, ppm	-0.132	0.185	0.153	0.124	-0.157	0.116	-0.234*	0.019
Mn, ppm	-0.199*	0.046	0.188	0.060	-0.131	0.188	-0.235*	0.019
P, ppm	-0.250*	0.012	0.128	0.201	-0.087	0.384	-0.106	0.290
Zn, ppm	**-0.266****	**0.008**	0.181	0.070	-0.131	0.188	-0.217*	0.029
Ntot/LOI*100	0.035	0.722	0.021	0.831	-0.035	0.722	-0.166	0.096
Ca/LOI*100	-0.053	0.594	0.021	0.831	0.014	0.887	-0.205*	0.040
Mg/LOI*100	-0.028	0.776	0.121	0.227	-0.053	0.594	-0.159	0.112
K/LOI*100	-0.066	0.511	0.172	0.085	-0.115	0.248	-0.175	0.080
CEC/LOI*100	-0.122	0.220	-0.020	0.845	0.009	0.929	-0.168	0.093
Total N/LOI*100	0.035	0.722	0.021	0.831	-0.035	0.722	-0.166	0.096
Ca, ppm/LOI*100	**0.305****	**0.002**	-0.078	0.434	0.046	0.644	0.043	0.663
Mg, ppm/LOI*100	0.016	0.873	0.108	0.278	-0.204*	0.041	-0.178	0.074
Na, ppm/LOI*100	-0.041	0.683	0.080	0.424	-0.232*	0.020	-0.141	0.158
K, ppm/LOI*100	-0.101	0.311	0.168	0.091	-0.207*	0.038	-0.221*	0.027

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

	DCA 1	P	DCA 2	P	DCA 3	P	DCA 4	P
Al, ppm/LOI*100	-0.099	0.320	0.131	0.188	-0.202*	0.043	-0.202*	0.019
Fe, ppm/LOI*100	-0.080	0.424	0.129	0.194	-0.197*	0.048	-0.197*	0.011
Mn, ppm/LOI*100	-0.128	0.201	0.156	0.118	-0.191	0.055	-0.251*	0.012
P, ppm/LOI*100	-0.200*	0.045	0.158	0.114	-0.236*	0.018	-0.233*	0.026
Zn, ppm/LOI*100	-0.179	0.073	0.168	0.091	-0.243*	0.015	-0.265*	0.008

3.3   Discussion

3.3.1   GENERAL DESCRIPTION OF VEGETATION AND GROUND VEGETATION BIODIVERSITY

The monitoring site Sogot is dominated by the relict walnut forest in the West Tian-Shan. The territory has a rich biodiversity of trees and bushes but with poor grass and herb coverage under the walnut forest. Both the average number of species per 1-m^2 plot (bryophytes and lichens not included) as well as the total number of species recorded in the 50 plots is low. This is probably mainly due to the great influence of litter from the walnut trees, covering most of the forest ground. Thus the α-diversity per area unit is in general relatively low, and the litter prevents many species to occur, especially bryophyte species.

3.3.2   INTERPRETATION OF GROUND VEGETATION GRADIENTS

The variables most strongly (negatively) correlated with DCA 1 are *minimum*, *median* and *maximum depth of the organic layer*, all with significant negative correlations. Also, the *soil depth* variables and *aspect* are more or less strongly negatively correlated with DCA 1. Thus the plots with low scores along DCA 1 typically have a species composition favoured by sites with a deeper soil and organic layer as compared to plots with high DCA 1 scores, and differ in aspects.

The variables most strongly (positively) correlated with DCA 2 are *aspect favourability*, the micro topography variable *sum concavity/convexity 1-m^2*, and the *heat index*. All these variables show significant positive correlations with DCA 2. The plots with high DCA 2 scores, therefore, have a species composition reflecting higher heat index, more favourable aspects, and more micro topographical variation.

The relationships between species composition and environmental variables described above are, however, difficult to understand in more detail. As described in 3.1.1 the litter from walnut trees has an obvious influence on ground vegetation and is preventing many species from establishing. Because this is more or less the case for all plots in the monitoring site only *minimum litter depth* is significantly correlated with one of the ordination axis (DCA 4), but this axis has a low eigenvalue. Some soil chemical variables are significantly correlated, for example is exchangeable Mg significantly correlated with DCA 3. However, a clear nutrient gradient is not observed.

The very low average species number per plot and in total may have influence on the DCA ordination diagram. Further statistical analyses including parallel use of two or three ordination methods (Økland 1996, Økland & Eilertsen 1996 among others) are thus recommended in order to clarify the vegetation-environment relationships in more detail.

Human activities probably have considerable influence on the species composition. However, the influence of grazing, harvesting of walnuts, and cutting of trees etc. was not clearly expressed by the measured environmental variables (i.e. the grazing parameters). This is partly due to the fact that the plots in Sogot was analysed the first year (2005), when the Kyrgyz field staff was less experienced. The grazing of vegetation by domestic animals is reflected in the high dominance of *Bromopsis ramosa.*

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
Acer turkestanicum	Түркстан зараны	Клен туркестанский
Aegopodium tadshicorum	Тажик элик балтырканы	Сныть таджикская
Arctium tomentosum	Тытыш түктүү угак	Лопух войлочный
Artemisia vulgaris	Кадимки шыбак	Полынь обыкновенная
Bromopsis ramosa	Бутактанган түбү бош	Костер ветвистый
Conioselinum tataricum	Татар гирчовниги	Гирчовник татарский
Crataegus songorica	Жунгар долоносу	Боярышник джунгарский
Galium aparina	Жабышчак галиуму	Подмаренник цепкий
Geranium collinum	Шалбаа каз таманы	Герань холмовая
Geranium rectum	Түз каз таманы	Герань прямая
Geum urbanum	Шаар геуму	Гравилат городской
Impatiens brachycentra	Кыска текөөрлүү кына	Недотрога короткошпорцевая
Lamium album	Ак дүлөй чалкан	Яснотка белая
Ligularia thomsonii	Томсон кой жалбырагы	Бузульник Томсона
Malus sieversiana	Сиверс алмасы	Яблоня Сиверса
Silene fedtschenkoana	Федченко дремасы	Дрема Федченко
Milium effusum	Барпагай бор	Бор развесистый
Phlomoides speciosa	Кооз шимүүрчөк	Фломоидес красивый
Poa pratensis	Шалбаа жылганы	Мятлик луговой
Prunus sogdiana	Согдия алчасы	Слива согдийская
Rosa beggeriana	Беггер ит муруну	Роза Беггера
Rubus caesius	Көгүлтүр кара бүлдүркөн	Ежевика сизая
Urtica urens	Чагычуу чалкан	Крапива жгучая
Vicia cracca	Жапайы жер буурчак	Вика мышиная

4   SOIL CLASSIFICATION AND SOIL DESCRIPTION

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4.1   Methods

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

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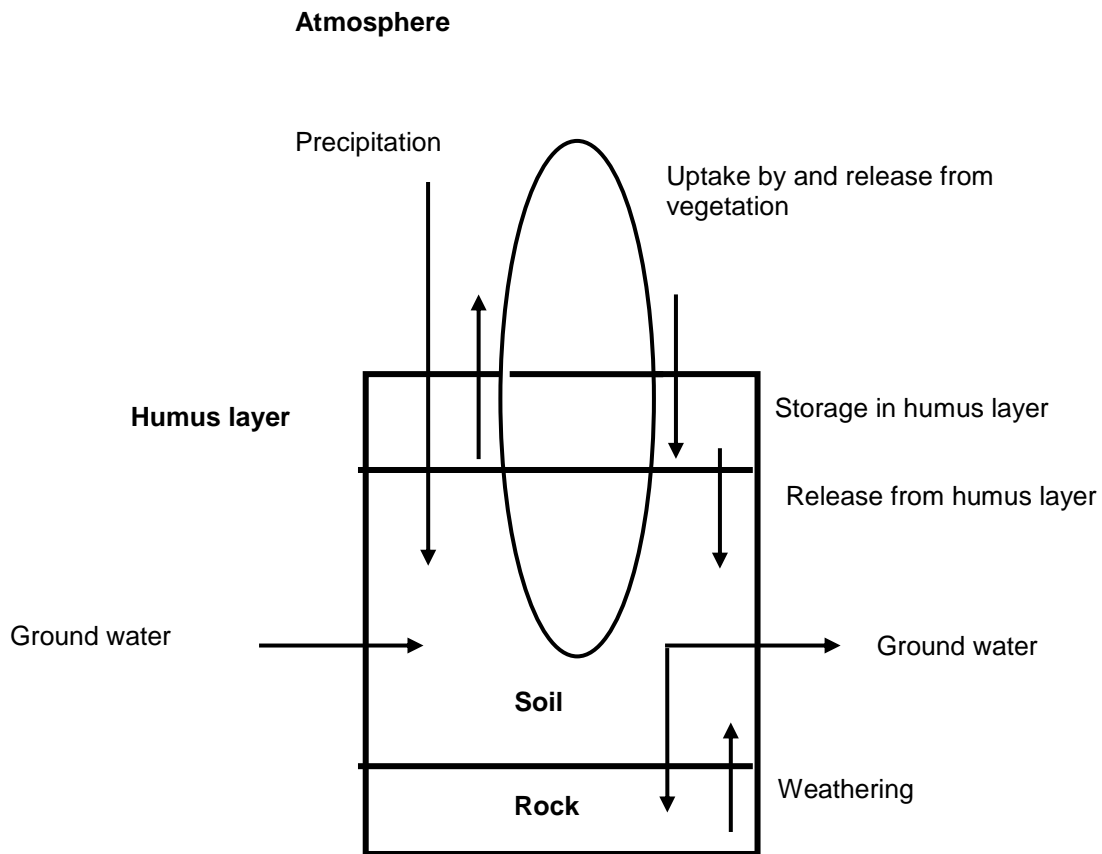- Soil moisture content of the top soil.

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. Soil samples were taken from each 1-m^2 plot during the 24th – 26th of October 2004. The weather before the sampling was sunny, but during the sampling procedure the weather conditions got worse, with periods of rain and fast decreasing temperatures. 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

The macro plots were situated in a broad watershed dominated by walnut forests. The walnut forest was developed on a deep loess deposition. In a narrower part of the valley, where the loess deposition was shallower, a small stream has carved so red sandstone was visible. In plots situated here the loess deposition was shallower and weathered red stone was reachable within sampling depth.

All soil profiles were generally deep and well developed with deep developed organic layers. Secondary chalk could often be identified lower in the profile, indicating that the soil type could be a Chernozem. However, identifying Chernozems with certainty requires special laboratory equipment, and therefore falls outside the scope of this project.

Local farmers are allowed to graze their cattle in the forest and signs of intensive grazing were visible. In some parts the vegetation indicated eutrofication (manure - *Urtica urens)*.

Generally the whole area had a good drainage. Near the stream some macro plots were established under more damp conditions and in the last macro plot seepage was signalised. Near the stream Umbrisols, Cambisols and Regosols were identified.

The altitude of the macro plots varied from 1521 m to 1749 m a.s.l.

The walnut forest, in which the macro plots were situated, differed in degree of development and composition. The first three macro plots were under well developed open walnut forest. The other plots had less well developed walnut trees and other tree- and shrub species were mixed with the walnuts.

A varying number of soil samples were taken per 1-m^2 plot. The number of soil horizons per 1-m^2 plot per varied from 2 to 4. In some cases the humus layer was present to such an extent that sampling was possible. In the well grown walnut forest both A and B layers were present and sampled. In the plots near the stream the C layer could be reached and in a few cases the B layer was not developed at all (A-C profile).

The soil texture varied from silt to clay soils. Often the soil textures in B and C layer were more clayey and difficult to auger in case of dry soils.

In general the macro plots can be characterised as follows:

Macro plots 1, 2 and 3: well developed soil profile in loess.

Macro plots 4 and 5: more damp, positioned in the surroundings of the stream. Profiles developed in loess. Secondary chalk was sometimes present in both B and C layer.

Macro plots 6, 7, 8, 9 and 10: profiles developed in loess overlying weathered red sandstone or in weathered red stone.

Macro plot 7: soil conditions in the 1-m^2 plots varied. Due to trampling of cattle the top soil was often transported away, and as consequence depth to the red sandstone subsoil was less.

Macro plot 10: established on an old landslide. The stream had earlier gravelled in the loess deposits. The seepage cause unstable soil conditions with a landslide as a result. The site is still wet and characterised by seeping groundwater.

The soil moisture is in generally around 25%. The macro plots 8 and 10 are drier. The soil pH of the topsoil is around pH 7. The subsoil has a higher pH. The total carbon (C) content is around 2% in the A layer.

The arsenic (As) levels are not high, the same is for cadmium (Cd), mercury (Hg), lead (Pb) and antimony (Sb). Strontium (Sr) shows in general low levels, but some macro plots show higher levels in the subsoil. Zinc (Zn) shows in general lower levels than in Kara Koi. Also here there is little difference between the levels in top- and subsoil.

4.3   Discussion

The macro plots 1, 2 and 3 are placed under well developed walnut forest. Grazing activities are quite intensive in periods of the year resulting in manuring of the soil. The influence of the surplus of nitrogen on the vegetation is visible (*Urtica urens*). Due to the good soil conditions it is expected that the soil has a high resilience against disturbances.

In the other macro plots the conditions for walnut are suboptimal. Hydrological conditions are different and the depth of the A and B layer in the loess is less. It is expected that these ecosystems are more vulnerable for changes in land use (overgrazing) and/or pollution. Negative aspects of grazing are already visible in the field and the grazing intensity should be kept in balance with the soil and terrain capacities.

Due to the higher amount of other tree- and shrub species in macro plots 4 – 10, the effects of (illegal) wood cutting may have an influence on the ecological conditions.

The heavy metals in the environment originate from the local geological substrate.

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 determinaion 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 Sogot were analyzed at Alex Steward Laboratories, Kara Balta, the Kyrgyz Republic.

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

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

5.1.3.3. Total and organic carbon (C)

Total C includes both inorganic and organic C. Inorganic C is principally found in carbonate minerals, whereas most organic C is present in the soil organic matter fraction.

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

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

5.1.3.4 Total nitrogen (N)

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

5.1.3.5 Effective CEC

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

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

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

5.1.3.6 Loss on ignition (LOI)

Procedure from Krogstad (1992):

Weigh a porcelain crucible using an analytical balance (m_1). Approx. 3 to 5 g air-dried soil passed through a 2.00 mm aperture sieve is weighted accurately using an analytical balance in the crucible (m_2) and glowed in a furnace at 550 ± 25 °C using a Carbolyte Muffle furnace for more than 3 hours. The crucible with dried soil must cool down for more than 30 minutes in an exicator before weighing (m_4).

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

Calculations:

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

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

5.1.3.7 Available phosphate (P)

Principle:

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

The Mehlich's method uses a mixture of sulphuric and hydrochloric acid to de-sorb the phosphate according to the method described by Olsen & Sommers (1982). This method is effective in extracting Ca-P, Fe-P and Al-P in acid and neutral soils.

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

Reagents:

1. Extracting solution, Mehlich's :
Add 12 mL of conc. sulphuric acid (H_2SO_4) and 73 mL of conc. hydrochloric acid (HCl) to 15 litres of ion exchanged water. Dilute the solution to 18 litres with Milli-Q or double distilled ion exchanged water. This extracting solution is approximately 0.05N HCl and 0.025N H_2SO_4.

Extracting solution, Olsen's :
Dissolve 84.008 g dry $NaHCO_3$ with approx. 1.8 L of Milli-Q or double distilled ion exchanged water. Titrate the solution with NaOH to pH 8.5. Dilute the solution to 2 L in a volumetric flask. This extracting solution is approximately 0.5 M $NaHCO_3$.

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

3. Standard phosphate solution:
Dissolve 0.1098 g of potassium dihydrogen phosphate (KH_2PO_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:

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

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 an 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:

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

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

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

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

5.1.3.9. ICP-AES metal scan

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

5.1.3.10 Extractable sulphate

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

5.2   Results

Average soil chemical data are presented in Tab. 5.2. Circum neutral pH conditions prevailed at all the sampling plots and all horizons at Sogot. As commonly found, the pH increases with depth along with decreasing organic content. Studying all samples (across horizons) we found that the organic content, measured as loss on ignition (LOI), was strongly correlated to total Carbon content (% C_{tot}; r = 0.886), implying that the soils content of inorganic Carbon was less important at this site. Studying only the mineral soils we also found that the total N was in fact strongly related to the % C_{tot} content. The % C_{tot} was negatively correlated to acid cations as aluminium (Al; r = -0.871) and iron (Fe; r =-0.792) and several trace elements (Cr, Co, V, La, Be, Sc, Y, Zr), and positively correlated to the total phosphorous (P) content (r = 0.536). Adsorbed sulphate (Ads. SO_4^{2-}) were, with a few exceptions, below the detection limit (0.01 g kg^{-1}). Adsorbed phosphate was not analyzed.

Tab. 5.2. Average and quartiles of soil chemical characteristics in each horizon at Sogot. LOI denotes Loss on Ignition.

Horizon	Samples #	pH$_{H2O}$	LOI	C total	Total N
			w/w%		µg/g
O	12	6.76	N/A	29.1	3144
		6.7-7.1	N/A	26-32	1799-3331
A	49	6.98	17.8	6.0	2720
		6.9-7.4	15-20	5-7	1486-3823
B	39	6.96	8,5	1.9	787
		6.8-7.6	7-9	1-2	476-895
C	34	7.79	6,8	2.1	880
		7.8-8.0	6-8	2-2	356-856

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) was made up by iron (Fe) and calsium (Ca), followed by aluminium (Al) and magnesium (Mg). The base cations (Ca, Mg, Na and K) constituted 42, 37 and 56% of the oxide composition in the A, B and C horizons, respectively. This illustrates a typical acidified soil profile with depletion of base cations in the top horizons. The values are somewhat misleading as samples with an elemental content greater than a maximum analytical value, e.g. 50 mg g^{-1} for Ca, are set to this analytical maximum value. This was the case for 32% of the Ca data in the C horizon.

The content of Fe and Al were strongly correlated (r = 0.976). The Fe content was also commonly found to be correlated with both Mg (r = 0.903) and potassium (K) (0.761). Al was always negatively correlated to Ca, though this correlation was poor (r < -0.515).

The major oxide elements presented in Fig. 1 were followed in abundance by phosphorous (P), manganese (Mn) and titanium (Ti) (Tab. 5.3). The variation in P was closely correlated to the levels of sodium (Na; r = 0.734) and the trace elements copper (Cu; r = 0.722) and zinc (Zn; r = 0.780). The amount of Ti was relatively high compared to e.g. Na. Ti was correlated with Al (r = 0.908), Fe (0.933) and several trace elements (Cu, Cr, Ni, Co, V, Y, Zr) in addition to Mg (r = 0.888) and K (r = 0.767). The variation in La was correlated to Mg (r = 0.903) and Fe (0.920). Contrary to what was found at the other TEMP sites, Mn at this site showed strong correlations with a large number of elements (Mg, K, Al, Fe, Cu, Zn, Ni, Co, V, La, Sc, Ti, Y, Zr). In addition to P, Na was correlated to Cu (r = 0.713).

Fig. 5.1. Main (avg. value > 3.5 mg/g) oxide composition of the mineral soils.
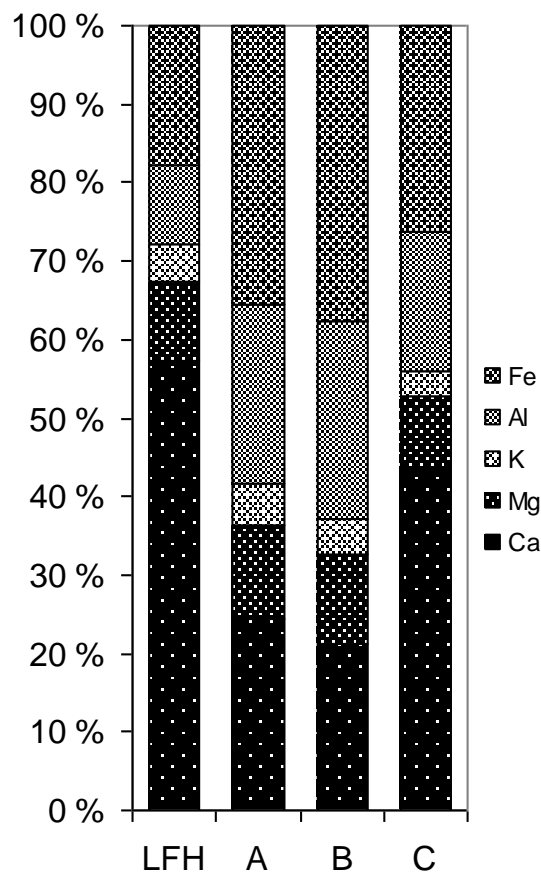
Tab. 5.3. Soil average and quartile content of less abundant oxide elements in 12 O-, 49 A-, 39 B- and 34 C horizon samples from Sogot.

Horizon	P	Mn	Ti	Na	La
	mg/kg				
O	1095	438	195	271	6,2
	947 - 1215	393 - 500	146 - 244	224 - 303	5 - 8
A	874	700	470	218	19,3
	709 - 1000	643 - 810	409 - 582	191 - 244	18 - 21
B	704	752	615	212	24,9
	644 - 802	658 - 846	514 - 730	191 - 233	23 - 27
C	490	561	418	178	21,1
	349 - 643	410 - 677	207 - 565	140 - 212	17 - 24

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Soil composition of measured trace elements along with the composition of continental crust (Taylor and McLennan, 1985) and selected heavy metal contamination norms (Lacatusu, 1998) are presented in Tab. 5.4. The bedrocks in the studied sites were generally secondary minerals (sandstone, clay and limestone) that were apparently partly transformed to shale and marble by metamorphosis. The contents of trace elements were elements arsenic (As), lead (Pb) and cadmium (Cd). The heavy metal contents were 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. Measured trace elements in Sogot soil samples along with reference values.

Site	Hor	As	Ba	Sr	Pb	Cd	Cu	Cr	Zn mg/kg	Ni	Co	V	Sc	Y	Zr	Be	Mo
Earth crust[1]		1.0	25	260	8.0	0.1	75	185	80	105	29	230	30	20	100	1.5	1.0
Normal Min[2]					0.1	0.1	1	2	3	2	1						
World mean[3]		6		300	10	0.06	20	100	50	40	8						
M.A.L. (Pl) [2]					100	3	100	100	300	100	50						
Sogot	O	3.9	156	113	22	0.7	29	16	84	15	4.6	16	1.3	3.7	1.3	0.5	0.8
	A	13	175	52	15	0.5	29	37	78	35	12	42	3.9	10	3.8	0.8	0.8
	B	16	185	45	15	0.5	30	46	82	43	15	52	5.3	13	4.6	1,0	0.8
	C	12	160	69	11	0.4	21	33	55	30	10	39	4,0	10	3.7	0.8	0.6

[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 Fe content was strongly correlated to the abundance of a majority of the 16 measured trace elements (Fig. 5.2). Important exceptions were the soft (or type B) metals Pb, molybdenum (Mo) and Cd and the hard (type A) elements barium (Ba) and strontium (Sr). Soft metals (high covalent index) were instead generally found to be correlated only to each other (Tab. 5.5) and somewhat negatively correlated to hard (Type A) metals. Copper data at Sogot deviating from the relationship with Fe (see Fig. 5.4) were from the organic LFH horizon. Variation in Sr content followed the Ca levels (r = 0.703).
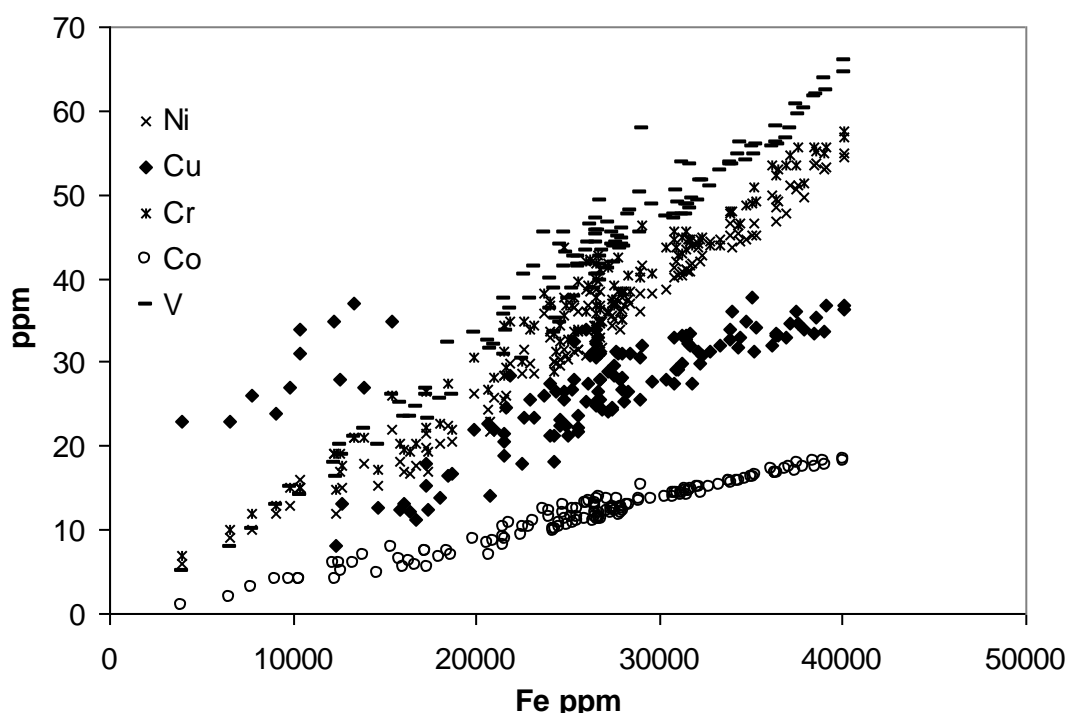

Fig. 5.2. Correlation between soil content of iron (Fe) and borderline trace elements nickel (Ni), copper (Cu), chrome (Cr)

cobolt (Co) and vanadium (V).

The levels of most of the trace elements co-varied in the soils at Sogot; a total of 26 strong correlations were found between the 16 measured trace elements (Tab. 5.5).

The borderline elements cobolt (Co), nickel (Ni), Vanadium (V) and chromium (Cr) showed the largest number of strong correlations, whereof V also possessed the strongest set of correlations. Type B elements (Pb, Mo, Cd, As) and type A elements (Ba, Sr) showed few or no strong correlations. As commonly found there were few strong correlations with zinc (Zn). Considering the lack of correlation and that the Zn concentration was higher in the top horizon than deeper in the soil profile (Tab. 5.4) we may speculate that there may be an anthropogenic deposition of zinc at this site.

Tab. 5.5. The strongest sets of correlations (i.e. r > 0.700) found for each of the measured 16 trace elements in 134 samples from Sogot. The elements are sorted in the order of their covalent index with type B elements on the top and type A elements in the bottom. "-" Indicates no strong (r>0.7) correlations.

| Elements	# of corr.	Vs.	r
Pb	2	Zn	0.706
Mo	0	-	-
Cd	2	Zn	0.749
As	0	-	-
Cu	3	Zn	0.930
Co	7	Ni	0.990
Ni	8	Co	0.990
Zn	3	Cu	0.930
V	7	Co	0.984
Be	2	Y	0.710
Cr	7	Ni	0.990
Sc	4	V	0.960
Y	6	V	0.964
Zr	6	V	0.888
Ba	0	-	-
Sr	0	-	-

5.3 Discussion

The role of Fe content as a governing factor for the soil chemical content of trace elements can clearly be illustrated by a Principal Component Analysis (PCA). The same pattern was found in all the studied sites. In the plane of the first two principal components (PCA 1 and PCA 2 axes) in both the A- and B horizons the Fe was clustered together with Al and most trace elements (except the hard and soft elements Sr, Mo, As, Cd and Pb) (Fig. 3). Negatively loaded to this cluster along the PCA 1 axis we find a cluster of Ca and Sr, often together with % C_{tot}. The first principal component (PCA 1 axis) in the PCA explains a staggering 72 and 68%, of the variation in the A and B horizons, respectively. Fe was as usual clustered with borderline trace elements.

The PCA 2 axis at these sites may partly be explained by the Covalent index (CI = X^2r) of the elements. Elements with low CI, commonly referred to as hard or type A elements, prefer to bind to carbonates, while elements with high CI, commonly referred to as soft or type B elements, forming more stable complexes, e.g. with sulphides. Type A elements (Ca, Mg, Na, K) have generally opposite loading to more Type B elements (Pb, Cd, As). Borderline metals have generally low loading along the PCA 2 axis. Instead they are strongly clustered with Fe. At Sogot the PCA 2 axis in the A and B horizons was correlated to the Covalent index with an r = 0.424 and 0.445, respectively.

Fig. 5.3. Parameter loading along the two first principal components in a PCA analysis of soil data from the A horizon (top graph) and B horizon (bottom graph), explaining 78.6 and 77.4% of the variation in soil elemental composition, respectively.
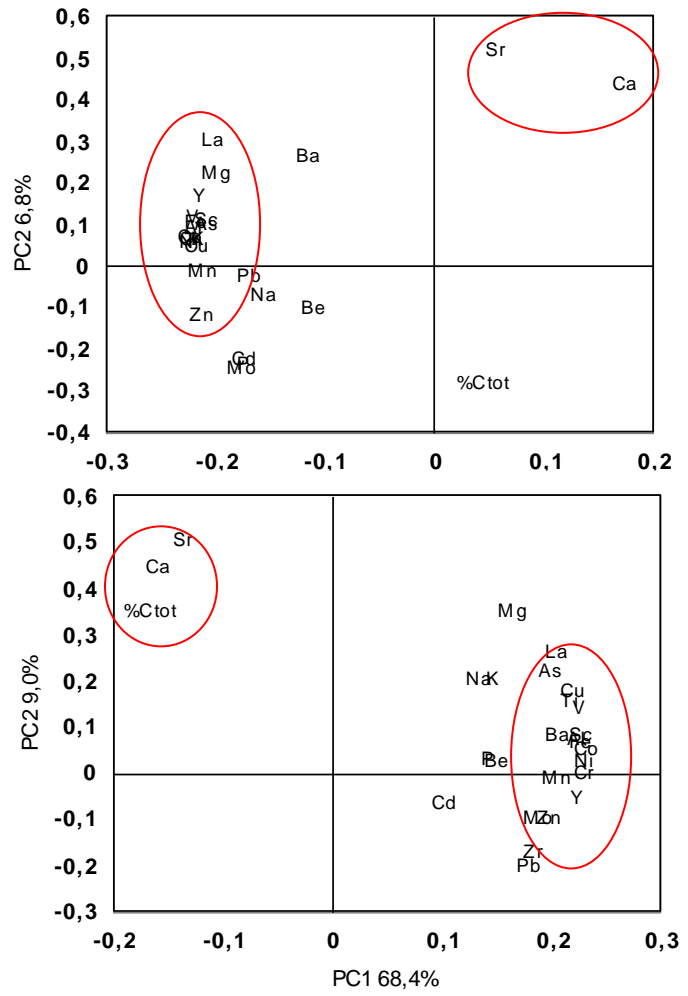
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