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• *Forest degradation – Shifting species composition – Post-Soviet transformation – Central Asia*

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Vegetation Patterns in Kyrgyzstan's Walnut-Fruit Forests Under the Impact of Changing Forest Use in Post-Soviet Transformation

Vegetationsdifferenzierung in Kirgistans Walnuss-Wildobst-Wäldern unter dem Einfluss veränderter Waldnutzung während der postsowjetischen Transformation

With 5 Figures, 4 Tables and 3 Photos

The walnut-fruit forests of Kyrgyzstan are the most extensive walnut forests worldwide and of global significance for biodiversity conservation, in particular owing to their high diversity of trees and shrubs. At the same time, the forests are of considerable importance for sustaining the livelihoods of over 50,000 people living in the forest area. A wide range of valuable resources (wood, nuts, fruits, hay) has caused intensive forest use since pre-Soviet times. Present institutional settings, external demands for specific products and the economic constraints of the local population lead to the exploitation of these forests. To assess the effects of human impacts on vegetation patterns, we conducted detailed vegetation analyses covering a complete utilisation gradient. Classification resulted in four forest communities, differentiated primarily by form and intensity of forest use. Ordination analyses showed that anthropogenic site factors exert a greater influence on variation in vegetation patterns compared to natural site factors. Impoverished stand structures, regressive successions and insufficient regeneration point to considerable changes in the walnut-fruit forests and to their uncertain future.

1. Introduction

Mountains and uplands are essential resource regions for the surrounding lowlands with regard to water, biodiversity, forest and grazing resources, mineral resources and tourism. Mountain forests often play a crucial role in this context due to their multiple social, economic and environmental functions. For example, forests are important reservoirs in the water cycle and diminish soil erosion and sediment loads as well as the risk of natural hazards (avalanches, rockfalls, landslides). Other intrinsic values of mountain forests include their role as carbon sinks, their rich biodiversity, their potential for recreation and tourism, and their supply of timber, wood products and other non-

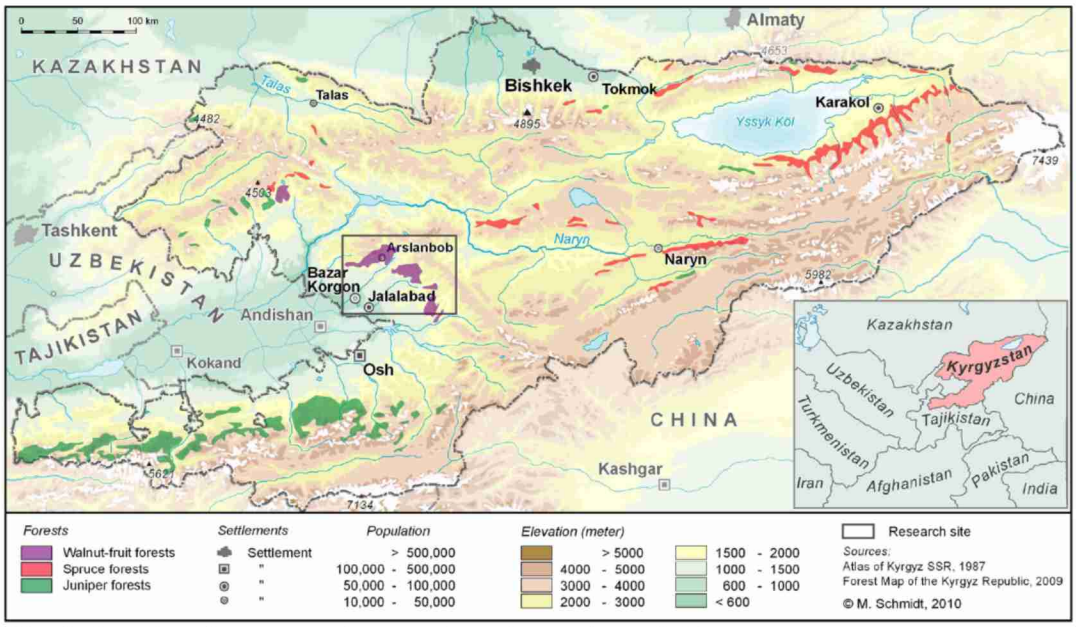

Fig. 1 Location of contiguous forest stands and research area in Kyrgyzstan
Lage der Waldbestände und des Forschungsgebietes in Kirgistan

timber forest products. However, rapid rates of decline in the cover and intensified uses of mountain forests limit the goods and services provided. Forest degradation and deforestation are widespread phenomena in the world's developing regions (*Schickhoff* 2004).

Among the Central Asian states, which belong to the least forested countries in the world, there has been a recent trend towards slightly increasing forest cover. In Kyrgyzstan, forest cover increased from 836,000 ha in 1990 to 869,000 ha in 2005, so that forests now account for 4.5 % of the country's total area (FAO 2007). Kyrgyzstan's forests are predominantly mountain forests and can be differentiated into four main forest types: the walnut-fruit forests (*Juglans regia*) at the south-western ranges of the Tian Shan mountains, the juniper forests (*Juniperus* spp.) found mainly at higher elevations in the Pamir-Alai region, the spruce forests (*Picea schrenkiana*) in the central part of the Tien Shan mountains, and the riverside forests (*Salix* spp.) (*Fig. 1*). However, despite slightly increasing total forest cover, the state of the forests and wooded lands is expected to deteriorate in many regions owing to the legacy of silviculture practiced in the Soviet period and to intensified, sometimes unregulated forest utilisation at present.

Utilisation pressure during the Soviet era and thereafter has especially affected the walnut-fruit forests, which are unique in several respects. These forests are characterised by a particular species composition with a high diversity of trees and shrubs, including around 180 woody species. They represent the most extensive contiguous walnut-fruit forest stands in the world, and at the same time they are of high economic value and of essential importance for sustaining the livelihoods of a large population living in the forest area. Accordingly, the forests have attracted many

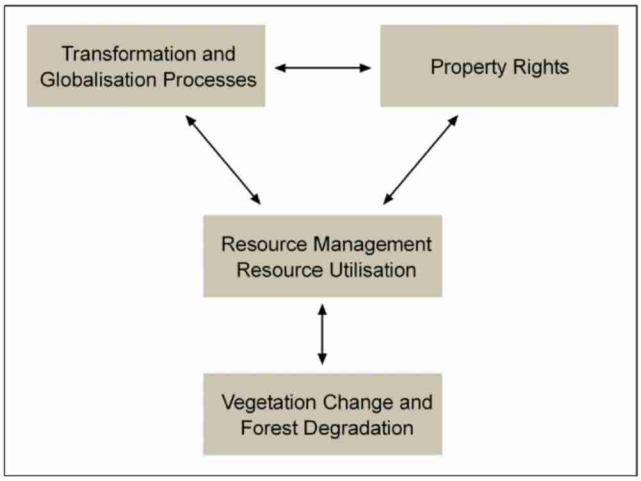

Fig. 2 Model of interrelations between transformation and globalisation processes, property rights, resource management and vegetation patterns (design: *M. Schmidt*) / *Modell der Wechselwirkungen zwischen Transformations- und Globalisierungsprozessen, Eigentumsrechten, Ressourcenmanagement und Vegetationsmustern (Entwurf: M. Schmidt*)

scientists over the last decades (e.g., *Sukacev* 1949; *Usolin* 1984; *Gan* 1992; *Kolov* 1997; *Blaser* et al. 1998; *Toktoraliev* 1998; *Scheuber* et al. 2000; *Epple* 2001; *Sorg* et al. 2003; *Gottschling* et al. 2005; *Ashimov* et al. 2007; *Mamadjanov* 2005; *Eastwood* et al. 2009; *Winter* et al. 2009).

After a short glimpse into the Soviet forest use system, we will assess how the most recent political transformation processes have influenced land and forest use, and analyse the subsequent effects on forest vegetation patterns. Our goal is to show in which way recent political and socioeconomic transformation and globalisation processes, initialised on the supranational level, are intertwined with impoverishment and human-environmental interactions on the local level. This includes analyses of the changed underlying property rights, including access, usufruct and land use rights, and how these changes influence recent resource management and utilisation practices and thus current vegetation patterns (*Fig. 2*). We hypothesise that political and socioeconomic processes and circumstances in the area have led to an increased and unsustainable forest utilisation, causing the degradation of the forests.

2. Study Area

The walnut-fruit forests (*Photo 1*) are located at altitudes between 1200 and 2000 m a.s.l. on the south-facing, windward slopes of the Ferghana and Chatkal Ranges of western Tian Shan (*Fig. 1*). The major tree species are walnut (*Juglans regia*), maple (*Acer turkestanicum*) and various fruit-bearing species in their wild form, such as apple (*Malus sieversii*), pear (*Pyrus korshinskyi*), plum (*Prunus sogdiana*), barberry (*Berberis integerrima*), rosehip (*Rosa kokanica*) and sea buckthorn (*Hippophae rhamnoides*). The species-rich shrub layer consists of many species of the genera *Rosa* spp., *Crataegus* spp., *Lonicera* spp. and *Cotoneaster* spp. Among the woody species, the rose family is of particular importance. More than 20 species of *Rosaceae* occur in the walnut-fruit forest (cf. *Gottschling* et al. 2005). Herb layer species with high constancy include common Eurasian taxa such as *Bromopsis ramosa*, *Brachypodium sylvaticum*, *Geum urbanum,* and *Impatiens parviflora*.

Until recently, these stands of walnut, maple and other tree species were considered to be an impoverished relic of mesophyllic forests of the Tertiary period, and even an evolutionary centre of

Photo 1 Walnut-fruit forests near Arslanbob village (Kyrgyzstan) *(Photo: P. Borchardt)*
Walnuss-Wildobst-Wälder bei Arslanbob (Kirgistan) (Photo: P. Borchardt)

Juglans regia by some scientists (*Ashimov* 1998; *Kolov* 1998). However, new palynological results show that the forests in their present species abundance and dominance are far younger (date back to 800-1200 years BP), and that they had very likely been established as a consequence of human land use (*Beer* et al. 2008; own unpublished data). Regardless of their natural or anthropogenic origin, it is noteworthy that these relatively small forest patches could survive over time, considering that they offer valuable resources such as timber, firewood, nuts, fruits and herbs while located in the vicinity of the densely populated Ferghana Valley. Undoubtedly, there must have been, and still is, an enormous human impact on these forests, which influenced vegetation and forest patterns significantly.

Formalised forestry began at the end of the 19th century when the area became part of the Russian Empire and the first forest farms were established (*Lisnewsky* 1884; *Navrockii* 1900). Gradually, land and forest utilisation intensified owing to the forcible settling of Kyrgyz nomads that culminated in the collectivisation processes under Stalin's rule in the 1930s and the establishment of state farms in the area. Over decades, the forests were used in accordance with the Soviet socialist system resulting in a specific footprint on the environment. The collapse of the Soviet Union and the independence of the Kyrgyz Republic in 1991, interlinked with tremendous economic and social ruptures, have brought about new fundamental changes in the management of land and forest resources and in their utilisation intensity.

3. Methods

Empirical fieldwork was carried out between 2003 and 2009. Information on historical and present forms of forest management and utilisation practices was garnered by qualitative and reconstructive forms of empirical social research, including participatory observation and focused interviews. We conducted semi-standardised interviews with local residents, either in their homes, or at work in the forest or on the pasture. Thematically focused interviews with members of the state forest farms, village administrators (*ayl oekmoet*) and other experts provided more in-depth information on specific aspects. Oral statements from *aksakal* (respected elders) gave a deeper understanding of the historical and current problems of the people affected, as well as their living reality. During fieldwork, Kyrgyz colleagues and various locals assisted as interpreters and contact persons. Documents related to forest policy and measurements as well as administrative proceedings were collected and analysed in archives of Jalalabad, Osh and Bishkek. The state forest enterprises themselves provided recent documents and statistics.

To examine the effects of altered forest use and recent resource utilisation practices on vegetation patterns, and to assess how the transition to market economy is finally reflected in changing structure and species composition of forest floor vegetation, we conducted detailed vegetation analyses including phytosociological sampling and classification, environmental data sampling, and multivariate statistical procedures (cluster and ordination analyses). A random sampling design was used to select sample plots (500 m²), with three altitudinal belts and all four exposures as strata. In total, 78 sample plots were selected to cover a complete utilisation gradient from near-natural to highly disturbed stands.

Vegetation sampling followed the relevé method (*Braun-Blanquet* 1964; *Dierschke* 1994). Relevé analyses included the listing of all vascular plant species and the assessment of species cover according to the traditional Braun-Blanquet cover-abundance scale (7 classes). A voucher specimen of each species was collected for final identification in the herbarium of the Kyrgyz Academy of Sciences, Bishkek. The nomenclature of vascular plant species follows *Czerepanov* (1995). Field sampling was complemented by a detailed characterisation of habitat conditions with emphasis on utilisation intensity and physical and chemical soil parameters. Furthermore, the intensity of utilisation was recorded for each relevé, subdivided into the categories felling, mowing and grazing. Estimates were carried out in decimal scales (1-4) in order to ease the intended transfer of data to the ordination matrix. Soil samples (each 100 cm³) were collected from the uppermost mineral soil horizon (10-20 cm depth) at each relevé site. Laboratory soil analyses comprised grain size distribution, soil pH, EC (electroconductivity), calcium carbonate content, organic matter content, carbon content (C_{org}, C_{anorg}, C_{total}/N ratio, C_{org}/N ratio) and nutrient content (N, P, K, Mg).

Vegetation was classified according to the Braun-Blanquet sorted table method, i.e. the relevés were arranged in phytosociological tables to differentiate and characterise vegetation types (*Dierschke* 1994). Species of differentiated communities were divided into four categories according to their disturbance tolerance ('ruderal', 'grazing-tolerant', 'mowing-tolerant', 'indifferent'), mainly based on *Gottschling* et al. (2005) and *Vykhodtsev* (1956). To analsze relationships between variation in vegetation and environmental variation, Canonical Correspondence Analysis (CCA) ordinations were carried out using the PC-ORD (5.2 for Windows) programme (*McCune* and *Mefford* 1999). Cover-abundance values of species were given in actual percent cover in the main matrix. Only '+' was converted to a value of 0.5 % (*Dierschke* 1994); 'r' was transformed to 0.01. The direct ordination method CCA was applied to test the

hypothesis that utilisation-dependent parameters are the most critical environmental variables for variation in the vegetation data.

4. Results

4.1 Transformation of property rights and forest management

During the Soviet period, control, management and utilisation of the walnut-fruit forests had been the affair of state institutions. After the collectivisation of land, forests and livestock in the 1930s, various state farms (*sovkhoze*) were established in the region. At the end of the 1940s some of these farms were reorganised and transformed into state forest farms, the so-called *leskhozes*. Under the authority of the State Forest Service, these farms were the main acting institutions at the local level, organising and carrying out all forestry operations such as forest farming, conservation, timber felling and processing as well as the collection of nuts, fruits and herbs. The walnut-fruit forests were prized for their valuable forest products. On the other hand, their unique ecological status and their important landscape-ecological functions were also recognized. As a result, the forests were declared a Fruit-Tree Forest Reserve per decree of the People's Commissariat of the USSR in 1945 (*Lupinovich* 1949; *Musuraliev* 1998).

In accordance with this declaration a strict use regime was implemented. The local population was not allowed to use the forest resources freely. Actually, they had not much intention of doing so since the villagers were employed by the state forest farms or in other state-run institutions and thus received regular incomes. The *leskhozes* offered employment as foresters, forest labourers, joiners, or in the administration. The supply of foodstuffs and fuel was also organised and heavily subsidised by the state, so that all people could easily make their living with income from regular employment. Additionally, all households in rural areas practiced farming on a small scale by growing vegetables and potatoes in their kitchen gardens and keeping some livestock. To feed their privately owned animals – each household was allowed to keep not more than one horse, one cow, one calf and five sheep – the households were given the right to cut grass on specific plots within the forest territory, while grazing of livestock within the forests was strictly forbidden. During the summer season, private flocks as well as herds of various state farms were pastured on high-altitude grounds. For cooking and heating purposes, the local people were supplied with firewood by the *leskhoze* which alone held the right to cut wood. Additionally, to a minor degree, the locals had been able to purchase coal and gas containers, which had reduced the pressure on the forest resources.

In other words, the state forest farms controlled the whole territory of the forests and managed the harvest of their most valuable products (nuts, fruits, timber, firewood and herbs) in accordance with plans drawn by superior forest institutions. The local population was given only the right to cut grass; other forest resources were the sole property of the state and could not be marketed or consumed by the local population. For example, all nuts had to be delivered to the state farms; private houses were even searched for hidden nuts when households did not fulfill the harvesting plans that were given to them by the *leskhoze* (*Schmidt* 2005a).

Today, the territories of the walnut-fruit forests are still state property, and the forests are officially managed by the *leskhozes*. With limited financial and personnel means the *leskhozes* are no longer able to fulfill all forestry tasks. The harvesting of grass, nuts and fruits is placed in the hands of the local population; however, there exist complex rules as to what kinds of resources on which lands may be used by whom. The right to cut grass on specific plots given in the Soviet period still prevails, whereas rights to harvest nuts are given to local households on a yearly basis only.

Photo 2 Rows of walnut trees planted during Soviet times *(Photo: P. Borchardt) / Reihen in der Sowjet-Zeit gepflanzter Walnuss-Bäume (Photo: P. Borchardt)*

Disputes and irregularities are common when usufruct rights for nut collection are allocated. Especially in places with many inhabitants and limited forest resources, people quarrel about the available walnut trees. In one village, for example, each household is given not more than eight to ten walnut trees which are not necessarily located on the plot on which the household can cut grass. The nuts on a specific territory in the forest can thus be harvested by one household, while members of another household cut grass and again others collect morels or apples; the *leskhoz* takes timber and firewood out of the same plot. Currently, the forestry sector of Kyrgyzstan is still in the process of reorganisation. A Kyrgyz-Swiss Forestry Support Programme is introducing a form of collaborative forest management in the walnut-fruit forests (*Carter* et al. 2003; *Fisher* et al. 2004).

4.2 Utilisation of local land and forest resources

Soviet forest policy and forest management implemented by the local *leskhozes* resulted in a significant impact on the forest stands: Although wood cutting was only permitted in the form of sanitary felling, complex and extensive felling was also conducted with the aim of transforming the over-matured walnut stands into more productive forests to increase the nut yield (*Musuraliev*

Photo 3 Forest clearings are used as hay meadow and grazing ground *(Photo: P. Borchardt)*
Als Mähwiesen und Weideflächen genutzte Waldlichtungen (Photo: P. Borchardt)

1998). Today, rows of planted trees can be found at several locations within the forests (*Photo 2*). Thus, substantial anthropogenic transformation of these forests into intensively used forests has occurred in recent years.

The political and economic transformation after the dissolution of the Soviet Union on the national level is connected with various economic and social constraints for the population on the local level. Unemployment is prevalent in rural Kyrgyzstan. Employment of most households is now reduced to farming on a very small scale, which is in most cases not adequate to sustain the livelihood of the household. Alternatives are limited, so many people seek their fortune in labour migration. More than 500,000 of Kyrgyzstan's total population of 5.1 mill. have temporarily migrated to Russia and Kazakhstan in search of employment (*Toralieva* 2006).

This is also true for the local population in the vicinity of the walnut-fruit forests. In 60 % of all households, there is at least one person absent for economic reasons (*Schmidt* and *Sagynbekova* 2008). However, the local forest resources are an important pillar in local livelihood strategies (*Schmidt* 2006): People collect nuts, apples, morels and herbs and sell them in the market. Furthermore, they cut grass for their livestock and collect firewood for cooking and heating purposes. And finally, the forests serve as grazing grounds for their livestock in spring and autumn (*Photo 3*). Although this is still prohibited, the *leskhozes* are

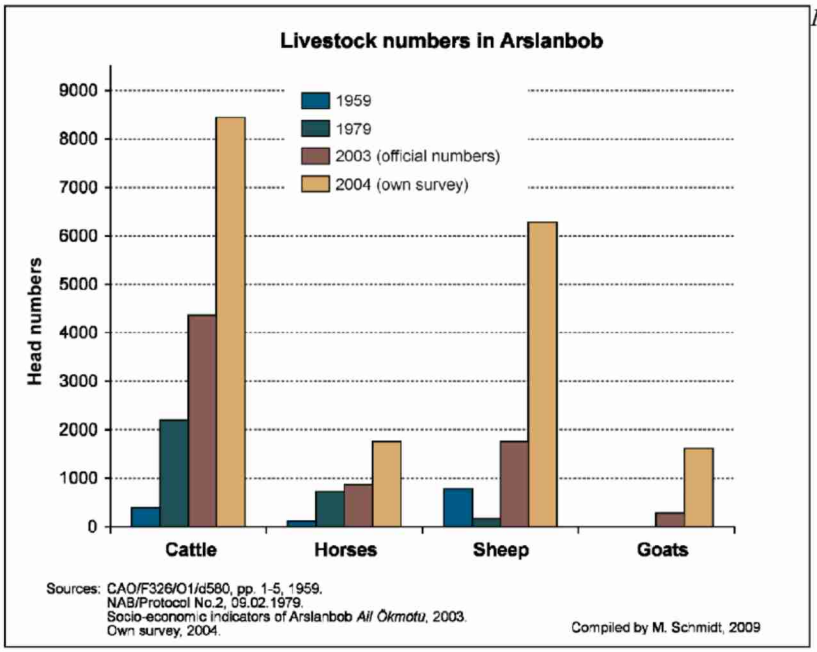

Fig. 3 Livestock numbers in the village of Arslanbob
Viehzahlen in der Siedlung Arslanbob

not able to control their territory anymore. The grazing pressure is further tightened due to the sharp increase in livestock numbers, as can be seen by the example of the village of Arslanbob (*Fig. 3*).

Cattle and sheep are a very popular investment for three reasons: First, livestock keeping is profitable, since the costs for pasturage on summer pastures is relatively low while dairy products can be sold at good prices. Second, it is flexible because animals can easily be transformed into cash when needed. Third, there is a lack of investment alternatives as the land market is rather restricted.

Apart from the increased need for the local population to use local forest and land resources, external actors also put pressure on the resources: foreign wood companies are interested in the timber of nut trees, especially burl and root wood. Many old trees were cut during the last 16 years, and the valuable wood, which is used for exquisite furniture such as chessboards or for the interior of luxury cars, is exported to foreign countries, a business that is officially prohibited but of which officials at all levels of the administration get their share (*Schmidt* 2005a, 2005b).

The pressing economic needs of the local population have led to an uncontrolled and intensified land and forest use. The present institutions are weak and cannot guarantee a proper forest management. People are alienated from the resources and have no trust in official institutions in which corruption and nepotism prevails.

4.3 Human impact and vegetation of the walnut-fruit forest

Species composition, species abundance and dominance, and structural configuration of walnut-fruit forests reflect a long-lasting human impact. Vegetation classification resulted in four forest communities differentiated primarily by

Tab. 1 Indicator species groups and indicator species constancy of differentiated walnut-fruit forest communities / *Indikatorartengruppen und Stetigkeit der Indikatorarten der differenzierten Walnuss-Wildobst-Waldgesellschaften*

	Indicator species groups			
	Aegopodium-Juglans	**Milium-Juglans**	**Ranunculus-Juglans**	**Alliaria-Juglans**
Constant companion species	*Juglans regia V* *Prunus sogdiana V* *Geum urbanum V* *Impatiens parviflora V* *Brachypodium sylvaticum V*	*Juglans regia V* *Prunus sogdiana V* *Geum urbanum V* *Impatiens parviflora V* *Brachypodium sylvaticum V*	*Juglans regia V* *Geum urbanum V* *Impatiens parviflora V* *Brachypodium sylvaticum V* *Bromopsis ramosa V*	*Juglans regia V* *Geum urbanum V* *Impatiens parviflora V* *Brachypodium sylvaticum V* *Bromopsis ramosa IV*
Diagnostic species	*Acer turkestanicum III* *Galium aparine IV* *Silene fedschenkoana IV* *Aegopodium tadshikorum V* *Euonymus semenovii V*	*Acer turkestanicum III* *Galium aparine V* *Milium effusum V* *Silene fedschenkoana IV* *Nepeta formosa IV*	*Crataegus turkestanica V* *Rosa corymbifera V* *Galium aparine V* *Poa pratensis III* *Ranunculus polyanthemos IV*	*Arum korolkowii IV* *Euonymus semenovii IV* *Clinopodium integerrimum IV* *Alliaria petiolata V* *Melissa officinalis IV*
Ruderal species	*Rumex paulsenianus II*	*Rumex paulsenianus II*	*Convolvulus arvensis II* *Plantago lanceolata I* *Rumex paulsenianus III*	*Potentilla reptans III* *Plantago major III* *Poa annua II* *Stellaria media III*
Grazing-tolerant species	*Ligularia thomsonii V* *Pyrethrum parthenifolium II* *Rumex paulsenianus II*	*Ligularia thomsonii V* *Ranunculus polyanthemos II* *Rumex paulsenianus II*	*Ligularia thomsonii IV* *Pyrethrum parthenifolium IV* *Ranunculus polyanthemos IV* *Rumex paulsenianus III*	*Ligularia thomsonii III* *Pyrethrum parthenifolium V* *Ranunculus polyanthemos I*
Mowing-tolerant species	*Dactylus glomerata II* *Geranium collinum II* *Stachys betoniciflora III*	*Geranium collinum II* *Vicia tenuifolia II*	*Dactylus glomerata IV* *Ranunculus polyanthemos IV* *Pimpinella peregrina IV* *Trifolium pratense IV* *Vicia tenuifolia V*	*Hypericum perforatum II* *Stachys betoniciflora II* *Trifolium repens II* *Trifolium pratense II* *Vicia tenuifolia III*

Constancy classes after *Mueller-Dombois* and *Ellenberg* 1974: I = 1-20 %; II = 21-40 %; III = 41-60 %; IV = 61-80 %; V = 81-100 %

form and intensity of forest use. Subdividing the species set of each community into indicator species groups with regard to disturbances, it becomes obvious that a large number of species is positively selected by mowing, grazing, thinning and other forms of human interferences (*Tab. 1*).

Although utilisation pressure on the forests is virtually ubiquitous, it is possible to arrange the differentiated communities along a disturbance gradient. The *Aegopodium-Juglans* community, which occurs at sites difficult to access and in remote side valleys with lower utilisation pressure, shows comparatively low human impact. An exceptionally high diversity of shrubs and trees characterises the stands of this community. Lower use intensity is further indicated by the highest numbers of seedlings and saplings of trees and shrubs, including rare taxa such as *Padellus mahaleb*, *Sorbus persica*, *Celtis caucasica* and *Louiseania ulmifolia*. Walnut (*Juglans regia*) is present in all age classes. This community has a comparatively lower percentage of species indicating disturbances (*Fig. 4*). Only 6 % can be termed ruderal, 18 % belong to the grazing-, and 29 % to the mowing-tolerant species group, whereas nearly half of all species can be classified as indifferent to human impact. Because of the less disturbed appearance that corresponds to our extensive field observations, this vegetation type can be used as reference community for disturbance-related changes in species composition and structural parameters.

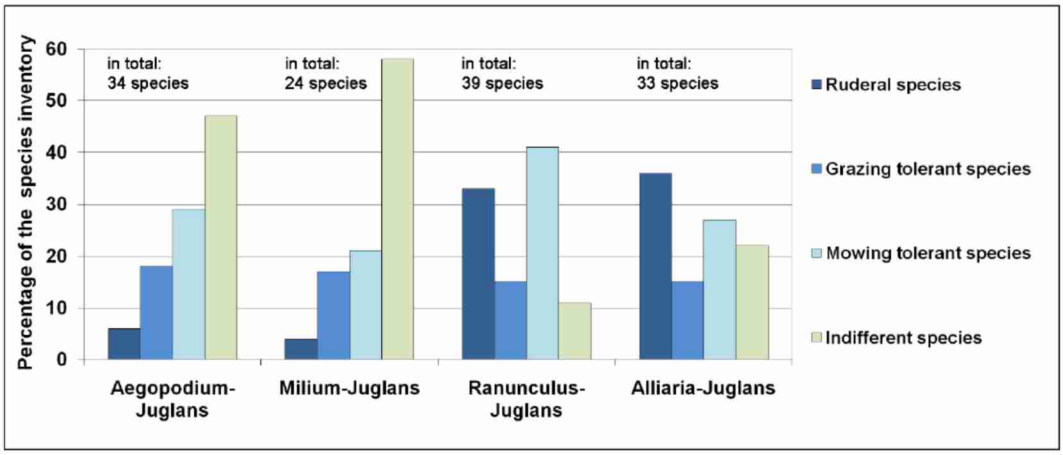

Fig. 4 Average percentage of disturbance indicators and of species indifferent to disturbances in differentiated communities / *Mittlerer Prozentanteil von Störungsindikatoren und von störungsindifferenten Arten in den differenzierten Gesellschaften*

The *Milium-Juglans* community also occurs in more remote forest areas. Sites of this community are used for hay-making; however, mowing is conducted late in the year. A large amount of deadwood impedes the common utilisation of the understory and of forest floor vegetation in these open forest areas. Below the walnut canopy, *Acer turkestanicum* is usually prevalent in the second tree layer. The dense herb layer is largely composed of species which are indifferent to utilisation (58 %). Analogous to the *Aegopodium-Juglans* community, the percentages of ruderal and other species indicating disturbances are rather low (cf. *Fig. 4*; *Tab. 1*). Although the *Milium-Juglans* stands are used for haymaking, merely five mowing-tolerant species are present on average.

The *Ranunculus-Juglans* community is distributed over vast forest areas where mowing is the dominant form of utilisation. Moreover, a considerable amount of firewood is extracted from these forest stands, resulting in less canopy cover and a more open, park-like character. The upper tree layer consists almost solely of *Juglans regia*, complemented by some fruit tree species (*Malus sieversii*, *Prunus sogdiana*, *Crataegus turkestanica*) in the second tree layer. A shrub layer is only rudimentarily developed despite favourable light conditions. Natural regeneration of trees and shrubs is insufficient. The dense and well-developed herb layer is characterised by the frequent occurrence of disturbance indicators and the lowest percentage of indifferent species (cf. *Fig. 4*). Nearly half of all species (41 %) belong to the mowing-tolerant species group. Some of these typical meadow species occur with high constancy. Likewise, the high percentage of ruderal species (33 %) points to the massive human impact to which this community is subjected.

The *Alliaria-Juglans* community represents a vegetation type which is common in forest areas used as pastures. Seedlings and saplings are severely damaged or destroyed by cattle and sheep, so generative regeneration is almost absent on these forest pastures. *Alliaria-Juglans* stands are further adversely affected by cutting of firewood and timber leading to decreased stand density and very open conditions. The tree layer is species-poor. Apart from walnut trees,

Tab. 2 Average cover of stand layers of differentiated communities
Mittlerer Deckungsgrad der Bestandsschichten der differenzierten Gesellschaften

	Average cover (%)			
Community	1st tree layer	2nd tree layer	Shrub layer	Herb layer
Aegopodium-Juglans	54	26	16	57
Ranunculus-Juglans	52	19	7	83
Milium-Juglans	57	8	6	72
Alliaria-Juglans	45	13	7	39

otherwise common species such as *Malus sieversii* and *Prunus sogdiana* can be found only occasionally. The herb layer is characterised by the highest percentage of ruderals (36 %), and a high percentage of grazing- and mowing-tolerant species (15 % and 27 % resp.; cf. *Fig. 4*).

Human interferences, such as wood-cutting, grazing and mowing, cause stand structural changes that are reflected inter alia in the cover of different stand layers (*Tab. 2*). The *Aegopodium-Juglans* community shows significantly higher cover of tree and shrub layers – another indication of comparatively less human impact. More adversely affected stands of the other communities are characterised by impoverished tree and shrub layers. Regarding the cover of the herb layer, it is obvious that intensive grazing (*Alliaria-Juglans* community) prevents a well-developed herb layer, whereas mowing (*Ranunculus-Juglans* community) seems to favour dense forest floor vegetation.

4.4 Vegetation patterns: natural versus anthropogenic site factors

Considering the long-lasting human impact on walnut forest vegetation, the question arises to what extent natural site factors play a role in the differentiation of vegetation and whether the variation in vegetation patterns is really largely governed by anthropogenic site factors. If the distribution of differentiated walnut forest communities is correlated with recorded ecological site factors, it becomes obvious that the communities are associated with rather diverse habitat conditions. Each vegetation type occurs in different altitudinal belts, at different aspects and slope inclinations, and over varied edaphic conditions, suggesting that human impact might have an overriding influence on vegetation patterns.

To test this hypothesis, we performed CCA, using both the floristic dataset and recorded environmental variables (*Tab. 3; Fig. 5*). The ordination diagram shows a clear separation of the differentiated communities and thus corroborates the results of the classification. Moreover, the diagram indicates that variables such as mowing and grazing are the most important environmental variables. Ecological site factors explain the variance in and between the vegetation types only to a limited extent. As the correlation coefficients of environmental variables with main axes (*Tab. 4*) clearly show, anthropogenic interferences dominate the loadings at the first three main axes. Among natural site factors, only the variable 'altitude' has a higher loading at one of the axes (Axis 1, not shown in *Fig. 5*). To an even lesser extent, soil nutrients such as

Tab. 3 Axis summary statistics for CCA ordination
Zusammenfassende Achsenstatistik der CCA-Ordination

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.263	0.198	0.143
Variance in species data **% of variance in species data explained**	5.7	4.3	3.1
Cumulative % of variance in species data explained	5.7	10	13.1
Pearson Correlation Spp-Envt	0.872	0.828	0.807
Kendall (rank) Correlation Spp-Envt	0.684	0.634	0.614

Number of canonical axes: 3; Total variance ("inertia") in the species data: 4.6158

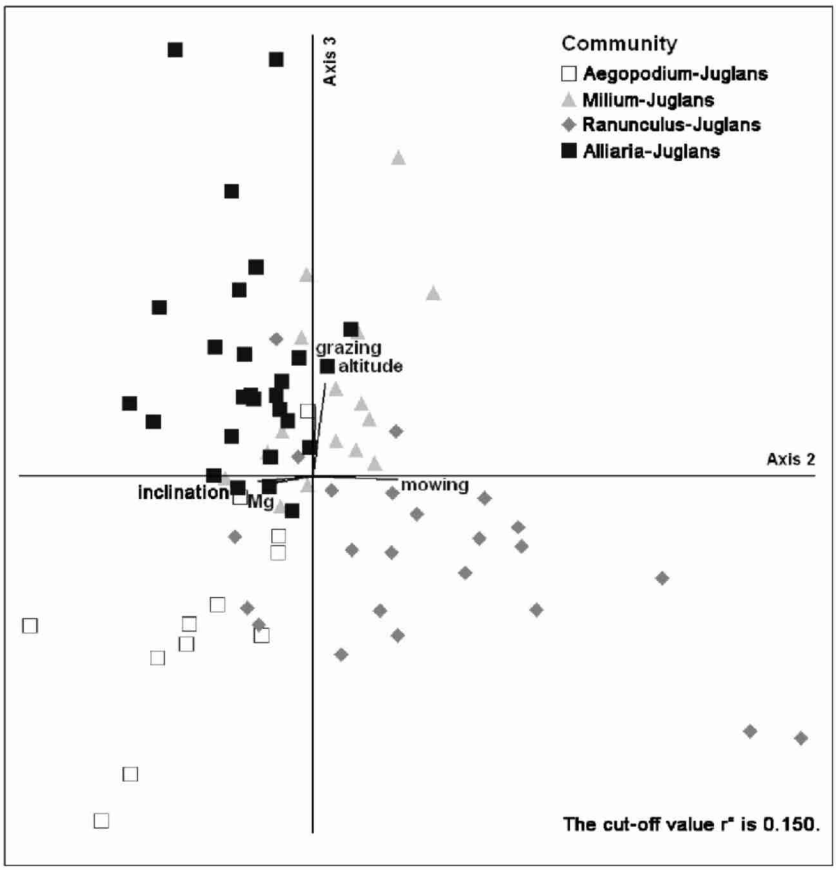

Fig. 5 CCA ordination with floristic and environmental datasets
CCA-Ordination mit floristischem und standörtlichem Datensatz

Tab. 4 Intraset correlations for environmental variables used in CCA ordination
Intraset-Korrelationen der in der CCA-Ordination genutzten standörtlichen Variablen

Variables	Axis 1	Variables	Axis 2	Variables	Axis 3
Altitude	0.405	Mowing	0.806	Grazing	0.803
N	0.317	P	0.43	Altitude	0.603
K	0.308	Felling	0.305	Felling	0.391
C_{org}	0.288	Silt	0.178	Clay	0.227
Silt	0.261	Grazing	0.117	Silt	0.216
Mg	0.25	Altitude	0.027	Bulk density	0.032
Mowing	0.21	Clay	0.004	Water content	-0.008
Electroconductivity	0.161	Bulk density	-0.035	Mowing	-0.029
Water content	0.106	Water content	-0.077	Mg	-0.048
Inclination	0.034	pH	-0.233	Inclination	-0.08
P	-0.061	Electroconductivity	-0.256	N	-0.081
Bulk density	-0.067	K	-0.289	P	-0.089
pH	-0.202	N	-0.371	Sand	-0.09
Sand	-0.26	C_{org}	-0.401	C_{org}	-0.121
Clay	-0.277	Sand	-0.427	Electroconductivity	-0.244
Felling	-0.295	Inclination	-0.489	pH	-0.322
Grazing	-0.36	Mg	-0.523	K	-0.424

potassium, nitrogen and magnesium exert a certain influence on the variation in the vegetation data set. The second and third main axes which are depicted in the diagram (*Fig. 5*) correspond to complex gradients primarily representing mowing (Axis 2) and grazing (Axis 3). Accordingly, relevés of the *Ranunculus-Juglans* community are located in the lower right side of the diagram and those of the *Alliaria-Juglans* community in the upper left. Relatively low eigenvalues of main axes must be attributed to rather homogeneous habitat conditions within the surveyed forest areas lacking steep environmental gradients. To sum up, distinct relationships between natural site factors and vegetation differentiation could not be ascertained. Instead, the results of the CCA corroborate the overriding influence of human impacts that already became obvious during vegetation classification.

5. Discussion

Our study generally confirms the results of other studies regarding the massive human impact to which the walnut-fruit forests in southern Kyrgyzstan have been subjected during recent decades, in particular after the collapse of the Soviet Union. From their establishment till the end of the Soviet Union, all forestry matters were officially organised by state forest farms. The great interest of the state in the forests must be attributed mainly to the economic value of the forest but also to its ecological functions. Soviet forest policy caused the transformation into intensively used forests. The actual property rights do not guarantee long-term usufruct rights for the stakeholders, resulting in short-sighted resource exploitation instead of a long-term resource management. The right to cut grass is

based on vague agreements and only in some cases on written contracts from the Soviet period; it seems that it could be revoked by the *leskhozes* at any time. Even vaguer is the right to collect nuts, which is allocated only for one season. These facts mean that local people do not feel responsible for the resources they utilise. External interests in timber and burls by international wood companies tighten the pressure on the forests. Proper working institutions and clear usufruct rights are needed to preserve the forests and ensure their sustainable utilisation without undermining the needs of the local population.

The effects of increased utilisation pressure on forest ecology and biodiversity have caused much debate after the independence of the Kyrgyz Republic in 1991. The critical condition of the walnut-fruit forests from a forestry point of view was discussed in terms of sustainable use and management during an international seminar in Arslanbob in 1995 (*Blaser* et al. 1998). At this workshop, *Sherbinina* (1998) already pointed out that most of the forests had become secondary vegetation, consisting mainly of unpalatable shrub species, with a high percentage of inedible herbs – in accordance with our findings pertaining to the abundance of disturbance indicators. She did not, however, give any details on shifting species composition.

From detailed phytosociological studies in walnut-fruit forests located some distance away from our study area, *Epple* (2001) also inferred a far-reaching impact of grazing on species composition. She differentiated a *Pyrethrum parthenifolium* variant with grazing indicators as diagnostic species and a species composition similar to the *Alliaria-Juglans* community of the present study, and concluded that the influence of grazing was clearly reflected in the species composition of the walnut-fruit forests. *Gottschling* et al. (2005) described effects of intensified forest use in terms of stand structural changes, lack of regeneration and loss of multi-functionality of the forests. They did not go into shifts in species composition, but provided a species list subdivided into indicator groups for certain site conditions that points to considerable anthropogenic modifications of species spectra.

On the basis of our vegetation sampling alone, it is not possible to exactly date successional changes in the herb layer and to exactly answer the question whether shifts in species composition were reinforced as a concomitant of the intensification of forest use after independence. However, combining our socioeconomic and ecological data shows that the massive occurrence of disturbance indicators and the low cover of the herb layer in grazed forest areas are connected to recent changes in utilisation intensity and grazing pressure in particular. Grazing within walnut-fruit forests was strictly forbidden during Soviet times and is still prohibited, but the ban on forest grazing is no longer effectively controlled. The problem of grazing pressure has been further aggravated by the sharp increase of livestock numbers in the walnut-fruit forest region in recent years. Unfortunately, vegetation relevés from Soviet times that are directly comparable to recent relevés regarding cover and abundance of species do not exist. However, comparisons with lists of typical species, e.g., with the description of walnut forest types by *Lavrenko* and *Sokolov* (1949), point to a lesser percentage of grazing indicators during Soviet vegetation surveys. Thus, changing utilisation intensity and comparisons with older data suggest that changes in species composition caused by anthropogenic interferences have accelerated since 1991.

The classification of walnut forest types by *Lavrenko* and *Sokolov* (1949) gives further evidence of recently reinforced anthropogenic modifications since it is still based solely on natural site factors. According to their classification, walnut forest types (*Juglandetum brachypodiosum*, *Juglandetum fruticosum*, *Juglandetum crataegosum* etc.) are differentiated primarily along a gradient of decreasing soil moisture. Likewise, *Epple*

(2001) considers soil water supply to be the most important site factor for the differentiation of walnut forest communities, without, however, presenting measurements or giving statistical evidence. The present results of the first CCA ordination in walnut-fruit forests including natural and anthropogenic environmental variables make it clear that the role of soil moisture has to be qualified (cf. *Tab. 4*). According to our data and in contrast to the above-cited studies, the importance of soil moisture is much more limited; soil moisture does not vary significantly within areas presently covered by walnut forest, regardless of exposure. As an explanation of variation in the vegetation data, soil moisture is subordinate to anthropogenic disturbances. However, an exact evaluation of the role of soil moisture depends on long-term measurements and detailed descriptions of soil morphology. Further investigations of the effects of soil moisture on vegetation differentiation are badly needed.

Other existing classifications of Kyrgyzstan's walnut forests from Soviet times (*Tuychiev* 1959; *Prutenskiy* and *Nikitinskiy* 1962; *Golovkova* 1990) follow the floristic dominance principle, i.e., units of classification result primarily from prevalent tree and occasionally also shrub species. Because of fundamental differences compared to the *Braun-Blanquet* approach or other recently used approaches, in which the entire species composition is the basis for classification, traditional Soviet classification units do not correspond to recent units and cannot be compared. Original relevés no longer exist or are not accessible. If previous classification attempts had considered composition, cover and abundance of the herb layer to a greater extent, it would be much easier today to elaborate successional changes caused by anthropogenic interferences. Favouring disturbance-tolerant species means at the same time reducing cover and abundance of some diagnostic species or constant companions of walnut forests. In the long term, such species could be replaced by more competitive ruderals (cf. *Borchardt* 2007). Changes of the herb layer include the decreasing abundance of seedlings and saplings of trees and shrubs. Detailed regeneration analyses (*Gend* 2005) showed a considerably increasing failure of regeneration along utilisation gradients, mainly caused by grazing, hay-making and the virtually hundred percent harvesting of nuts each year. In some 90 % of the surveyed *Juglans regia* stands generative regeneration is completely insufficient. Vast forest areas around the village of Arslanbob show no regeneration at all (cf. *Messerli* 2002; *Gottschling* et al. 2005). Even vegetative regeneration by sprouting was only observed at less disturbed sites, e.g., in *Aegopodium-Juglans* stands, to a greater extent.

6. Conclusion

The present state of the walnut-fruit forests is the result of a long history of human impact. The most recent transformation processes in connection with the collapse of the Soviet Union have led to an increasing pressure on forest resources. Unemployment and a lack of alternatives for income generation force people to use and, in face of the limited resource base, overuse the locally available land and forest resources. The distinct increase of livestock numbers is followed by an increasing demand for grazing lands and hay to provide constant supplies for the domestic animals in wintertime. With the growing local population and the lack of alternatives, the demand for fuel wood increases.

Effects of grazing, hay making, intense nut harvesting, cutting of fuel wood and exploitation for timber have shaped the forests' present-day appearance. In the walnut-fruit forests, man-made patterns of species composition, floristic differentiation and stand structures as well as the failure of regeneration point to considerable changes that have accelerated after 1991. The maintenance of manifold functions of the forests is

threatened, and even their existence is at risk. Great importance must be continuously attached to sustainable, multi-purpose management and protection of these forests and their biodiversity. The establishment of a new national forest management strategy as a result of the reformulated Kyrgyz forest policy (cf. *Carter* et al. 2003; *Kouplevatskaya* 2006) is an important step in this respect that has to be followed by consequent implementation.

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Summary: Vegetation Patterns in Kyrgyzstan's Walnut-Fruit Forests under the Impact of Changing Forest Use during Post-Soviet Transformation

The world's largest continuous walnut-fruit forests are located in the south of the Central Asian Republic of Kyrgyzstan. Because of the exceptional species richness of trees and shrubs and the high genetic diversity of the walnut (*Juglans regia*), these forests are of global importance for maintaining biodiversity and have been the focus of scientific studies and conservation efforts since the end of the 19th century. At the same time the walnut-fruit forests are an important resource for the local population. Many different forest products such as timber and fuelwood, walnuts, grasses, wild herbs, crab apples and other wild fruit species have always helped to secure livelihoods and were also systematically used and exploited by the state under Russian tsarist rule and later under the Soviet regime. Our study focuses on how far the political and socioeconomic transformation processes associated with the collapse of the Soviet Union influence the use of land and forest resources and how this affects forest vegetation. This research approach is based on the hypothesis that economic privatisation and liberalisation measures and the local population's present economic difficulties are leading to more intensive forest use and hence to the degradation of the walnut-fruit forests. On the basis of extensive empirical field studies using qualitative and quantitative social research methods and detailed vegetation studies along utilisation gradients, we obtained data on past and present forms of forest management and utilisation practices and on current vegetation structures. Multivariate vegetation analyses provide evidence that the forest vegetation pattern is influenced more strongly by human impact than by natural site factors; this is due especially to the recent increase in fuelwood felling and the intensified use of the forests as pastures as a result of rapidly growing livestock numbers. Degraded stand structures, regressive successions and, above all, insufficient regeneration point to fundamental, human-induced changes in the forests. Progressive degradation of the walnut-fruit forests will be impossible to halt in view of the current institutional weaknesses of forest management, unsecured rights of access and land use, outside demand for selected forest products such as burls, and the economic difficulties of the local population.

Zusammenfassung: Vegetationsdifferenzierung in Kirgistans Walnuss-Wildobst-Wäldern unter dem Einfluss veränderter Waldnutzung während der postsowjetischen Transformation

Im Süden der zentralasiatischen Republik Kirgistan befinden sich die weltweit größten zusammenhängenden Vorkommen von Walnuss-Wildobst-Wäldern. Aufgrund ihres außergewöhnlichen Reichtums an Gehölzarten und der hohen genetischen Diversität der Walnuss (*Juglans regia*) sind diese Wälder für den Erhalt von Biodiversität von globaler Bedeutung und stehen bereits seit Ende des 19. Jahrhunderts im Fokus wissenschaftlicher Studien und Schutzbemühungen. Gleichzeitig sind die Walnuss-Wildobst-Wälder eine wichtige Ressourcengrundlage für die in der Region lebende Bevölkerung. Verschiedenste Waldprodukte wie Nutz- und Brennholz, Walnüsse, Gräser, Wildkräuter, Wildäpfel und weitere Wildfrüchte stellten immer schon einen Beitrag zur Sicherung des Lebensunterhalts dar und wurden zudem bereits unter russisch-zaristischem und später sowjetischem Regime von staatlicher Seite aus gezielt genutzt und ausgebeutet. Im Mittelpunkt der Studie steht die Frage, inwieweit die mit dem Ende der Sowjetunion verbundenen politischen und sozioökonomischen Transformationsprozesse die Nutzung von Land- und Waldressourcen beeinflussen und wie sich dies auf die Vegetation der Wälder auswirkt. Dem Forschungsansatz lag die Hypothese zugrunde, dass ökonomische Privatisierungs- und Liberalisierungsmaß-

nahmen sowie die gegenwärtigen wirtschaftlichen Nöte der lokalen Bevölkerung zu intensivierter Waldnutzung und damit zur Degradation der Walnuss-Wildobst-Wälder führen. Auf der Basis umfangreicher empirischer Feldstudien unter Anwendung qualitativer und quantitativer Formen der Sozialforschung sowie detaillierter Vegetationsstudien entlang von Nutzungsgradienten konnten Daten zu vergangenen und gegenwärtigen Formen des Waldmanagements und der Nutzungspraktiken sowie zu aktuellen Vegetationsstrukturen gewonnen werden. Multivariate Vegetationsanalysen belegen, dass insbesondere der sich in jüngerer Zeit verstärkende Brennholzeinschlag und die aufgrund des stark gestiegenen Viehbestands intensivierte Nutzung der Wälder als Viehweide dazu führen, dass die Vegetationsdifferenzierung in den Wäldern stärker von anthropogenen Einflussfaktoren als von natürlichen Standortfaktoren geprägt wird. Degradierte Bestandsstrukturen, regressive Sukzessionen und vor allem eine unzureichende Verjüngung weisen auf tiefgreifende anthropogene Veränderungen in den Wäldern hin. Eine fortschreitende Degradierung der Walnuss-Wildobst-Wälder wird sich angesichts der gegenwärtigen institutionellen Schwächen im forstlichen Management, ungesicherter Zugangs- und Nutzungsrechte, der externen Nachfrage nach ausgewählten Waldprodukten wie Maserknollen sowie der ökonomischen Nöte der lokalen Bevölkerung nicht aufhalten lassen.

Résumé: La différenciation de la végétation dans les forêts de noyers et de fruitiers du Kirghizstan à la suite de la modification de l'exploitation forestière durant la période de mutation postsoviétique

Au sud de la République Kirghiz, en Asie centrale, se trouvent les plus grandes réserves forestières mondiales en un seul tenant de noyers et de fruitiers. En raison de leur extraordinaire richesse en variétés de bois et de l'importante diversité génétique du noyer *(Juglans regia)*, ces forêts sont d'une importance capitale pour la préservation de la biodiversité à l'échelle globale. Dès la fin du 19ème siècle, elles étaient au cœur des études scientifiques et des efforts de protection. Par ailleurs, les forêts de noyers et de fruitiers constituent une ressource fondamentale essentielle pour la population vivant dans la région. Les produits forestiers les plus variés comme le bois de consommation et le bois de chauffage, les noix, les graminées, les herbes sauvages, les pommes et autres fruits sauvages représentent depuis toujours une contribution à la garantie de leur subsistance, et furent en outre, déjà sous le régime tsariste russe et plus tard sous le régime soviétique, exploités et utilisés à des fins propres au pouvoir étatique. La question centrale de l'étude est de savoir jusqu'à quel point les processus de mutation politique et socio-économique liés à la fin de l'Union soviétique influencent l'exploitation des ressources agricoles et forestières et comment cela se répercute sur la végétation des forêts. L'hypothèse qui sous-tendait le début de la recherche était que les mesures de privatisation et de libéralisation ainsi que les besoins économiques actuels de la population locale mènent à une intensification de l'exploitation forestière et par là à la dégradation des forêts de noyers et de fruitiers. Sur la base d'études de terrain empiriques menées sur un vaste territoire par l'emploi des formes qualitatives et quantitatives de la recherche sociale ainsi que sur celle d'études détaillées de la végétation à partir de gradients d'exploitation, des données sur les formes passées et présentes de la gestion forestière et des pratiques d'exploitation ainsi que sur les structures actuelles de la végétation ont pu être recueillies. Les analyses multivariées de la végétation prouvent que c'est en particulier le volume d'exploitation de bois de chauffage, plus récemment renforcé, et l'exploitation intensifiée des forêts comme pâturage en raison de la croissance drastique du bétail, qui amènent à ce que les facteurs d'influence anthropogènes déterminent davantage le phénomène de différenciation de la végétation dans les forêts que les facteurs stationnaires naturels. Les structures dégradées de peuplement, les successions régressives et surtout un rajeunissement insuffisant indiquent de profondes mutations dans les forêts. Vu des faiblesses institutionnelles actuelles de la gestion forestière, des droits d'accès et d'utilisation non protégés, des demandes externes de produits forestiers sélectionnés comme le crosne veiné ainsi que des besoins économiques de la population locale, la dégradation croissante des forêts de noyers et de fruitiers ne peut pas être enrayée.

Резюме: Дифференциация растительности в орехо-плодовых лесах Кыргызстана под влиянием изменившегося лесопользования во время постсоветской трансформации

На юге центрально-азиатской Кыргызской Республики расположены самые обширные орехоплодовые леса мира. Вследствие их чрезвычайного богатства древесной растительности и генетического разнообразия грецкого ореха (*Juglans regia*) эти леса имеют всемирное значение для сохранения биологического многообразия и уже с конца 19ого века находятся в фокусе научных исследований и под охраной. Одновременно орехо-плодовые леса являются важной ресурсной основой местного населения. Уже давно различные лесные продукты, такие как дрова и деловая древесина, орехи, травы и зелень, дикие яблоки и другие плоды имели доходное значение для жизнеобеспечения населения и целенаправленно эксплуатировались государством в царское и советское времена. В центре этого исследования стоит вопрос, насколько политические и социоэкономические трансформационные процессы вследствии расформирования Советского Союза влияют на эксплуатацию земельных и лесных ресурсов и как эти формы эксплуатации влияют на растительность лесов. Основой исследования является гипотеза, что мероприятия приватизации и либерализации, но и теперешние экономические потребности местного населения ведут к более интенсивному лесопользованию и таким образом к деградации орехо-плодовых лесов. На основе обширных качественных и количественных эмпирических исследований и подробного изучения вегетации вдоль градиентов лесопастбищного пользования стало возможно определить не только прежние и современные формы лесоустройства и лесопользования, а также получить данные о структуре растительности в настоящее время. Мультивариационные анализы растительности показывают, что особенно в последнее время усиленная вырубка леса, а также более интенсивное испольсование лесов для пастбищ в результате сильного прибавления домашнего скота привели к тому, что на дифференциацию вегетации лесов антропогенные факторы влияют сильнее чем естественные. Деградированные структуры древозапасов, регрессивные сукцессии и особенно недостаточное возобновление древостоя указывают на радикальные антропогенные изменения в лесах. Деградация орехо-плодовых лесов будет продолжаться ввиду таких обстоятельств, как организационное бессилие лесохозяйственного управления, отсутствие гарантированных прав на доступ и пользование естественными ресурсами, внешний спрос на изысканные лесо-продукты, такие как ореховые наплывы, и экономические потребности местного населения.

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Supporting Information:

Additional information is provided in the online version of this article:

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The appendix contains:

1. Species-relevé data
2. Summary statistics of variables implemented in the gradient analysis

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