17 Effects of Grazing on Biodiversity, Productivity, and Soil Erosion of Alpine Pastures in Tajik Mountains

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INTRODUCTION

Tajikistan is a typical mountainous country. Mountains make up 93% of its territory. The highest mountain systems of Central Asia are the Tyan-Shan and the Pamir-Alai. The maximum elevation is 7495 masl. More than 60% of the territory of Tajikistan is located at or above 2500 masl. This region is mostly used as summer pastures. In the Pamir-Alai mountain system, it consists of Darvaz, Academy Sciences, Peter the First, Alai, Zaalai, Karategin, Hissar, Zerafshan, and Turkestan mountain ranges.

The high-mountain areas (subalpine and alpine zone) exhibit a strong continental climate. The severe long winter is followed by a rather short and cool summer. The average annual temperature is about 0.2 to 1.6°C. The warmest months are July to August (maximum temperature: 22°C). The coldest month is January (absolute minimum: −36°°C). The annual period without frosts lasts about 88 to 101 d. The annual precipitation is very varied: in the East Pamir it is only about 72 to 200 mm, in the West Pamir it can reach more than 500 mm, and in central Tajikistan (Hissar Mountains) it is about 600 to 1200 mm (Narzikulova, 1982). About 50% of the precipitation falls during the spring months. In the other seasons of the year, the scarce precipitation is distributed rather equally. Precipitation in autumn, winter, and, partially in spring is as snowfall; snow cover can last until early summer. The climatic conditions are demonstrated by climatic diagrams (see Breckle and Wucherer, this volume; Walter and Breckle, 1986a, 1986b, 1994; Breckle and Agakhanjanz, 2004).

PASTURES AND GRAZING AREAS

The conservation of biodiversity in the high mountains that have been used intensively as summer pastures has become an important problem. Until 1992, high pasturelands were used for 2 to 3 months, and in the autumn–winter period the cattle were moved to winter pastures. The exploitation of the summer pastures had decreased, and this had presented an opportunity for the restoration of pasturelands. However, high pasturelands are now used all year round, and the grazing intensity has increased manyfold, with the result that severe erosion processes and degradation of grassy vegetation have taken place. Therefore, there are two problems in the biodiversity conservation of high pasturelands: (1) protection of the unique highland grassy vegetation, which has many species that are included in the Red Book of NIS and Tajikistan (e.g. *Taraxacum*, *Rosularia*, *Desideria*, and *Tulipa*) and (2) conservation of different types of vegetation formations through protection of pastures from weeds that can turn land into marginal deserts.

Natural pastures and the haymaking areas of Tajikistan occupy more than 3.5 million ha

and are major sources of high-grade and other forages for the livestock sector. The stock of forages on pastures, according to expert data, is more than 1.6 million t of dry mass per year. The livestock sector is economically profitable — it has the lowest production costs, much below the cost of production of the stalls necessary for the maintenance of cattle in the winter period. The present conditions of pastures in the republic are characterized by an accelerated decrease in their fodder efficiency due to anthropogenous factors. The productivity of the pastures has changed greatly over the years, and the animal population is rarely provided with a steady supply of forage. For the maintenance of stable livestock populations during periods with very low fodder availability (winter), additional feeding of animals is required. Therefore, the strategy for the use of pastures and keeping cattle should reflect the specific conditions of the region.

DEGRADATION OF PASTURES AND BIODIVERSITY CHANGES

Extensive use of pastures and periods of drought have caused severe degradation in many parts of the subalpine and alpine zone. The basic indicator of such degradation is the change in vegetation. Under excessive grazing, there is a significant change in the species composition in the bluegrass–sedge pastures. Poisonous, harmful, and unpalatable plant species (e.g. *Hordeum leporinum*, *Centaurea squarrosa*, and *Alyssum desertorum*) start to develop; production of herbage decreases five to tenfold; and biodiversity changes from highly varied vegetation patches to monotonous overgrazed areas. The large number of species (Ikonnikov, 1979; Agakhanjanz and Breckle, 1995, 2002) is threatened by the spread of toxic and unpalatable weeds. The effects differ in the various pasture types, but in all types, a reduction of 20 to 60% in the number of species can be postulated. In addition, the replacement of long-term fodder plants (with strong taproots) by fast-growing annuals (with a superficial root system) has resulted in increased water and wind erosion on pastures.

During recent years, the grazing pressure on the winter–spring pastures has increased considerably. All-year-round grazing of cattle has become common. Not only overgrazing of vegetation and pastures but also the felling of trees and cutting of bushes and semishrubs for fuel has had very negative effects. Production of herbage has decreased, and pastures have become seasonally narrow. This has resulted in a significantly higher seasonal and annual variability in available fodder. Unlimited grazing has not only influenced the plant composition of the pasture but also appreciably changed ecological conditions, especially in localities in which the forest vegetation was destroyed and the area then was transformed into pastures. A marked reduction of vegetation density and destruction of the soil cover can be observed, as well as the formation of numerous sheep paths (Table 17.1). Water permeability of the soil is reduced by overgrazing, leading to enhanced erosion and drought. The herbaceous vegetation significantly lost soil stability because of loss of protective vegetation cover. Overgrazing of a meadow coenosis with *Alopecurus seravschanicus* develops by pasture degradation to an open vegetation dominated by *Adonis turkestanicus* or with *Scorzonera acanthoclada* and *Lagotis korolkovii*. Additionally, a weedy, tall herbaceous vegetation develops with *Artemisia dracunculus*, *Cousinia franchetii*, *C. splendida*, and other unpalatable short-grass meadow species (Akhmadov, 2003a). In general, desertification of the various pastures lead to an invasion by considerable numbers of toxic and harmful species and a great loss of biodiversity due to the disappearance of many high grasses (cereals), sedges, legumes, valuable forbs, and associates (as described in the following text).

SURVEY OF PASTURE TYPES

In the subalpine and alpine zones of the Pamir-Alai, the following types of pastures can be distinguished (Ovchinikova, 1977): (1) summer cryophilic (alpine) pastures and heath; (2) prickly-grass (tragacanth) summer pastures; (3) summer steppe (mountain and high-mountain); (4) swamps and meadow summer pastures; (5) long-grass mountain steppe; (6) autumn–winter

TABLE 17.1
Density of sheep paths, soil washout, and steep slopes in Tajikistan

Inclination of Slope (in Degrees)	Quantity of the "Sheep Paths" (1000 Units.km^{-2})	Soil Washout (t.ha^{-1})	Density of Gullies (Units.km^{-2})	Length of Gullies (km.km^{-2})
5–7	less than 1.0	1.2–21.1	0.1–0.2	1–2
10–12	1.4–3.2	35–72	0.5–0.7	5–7
15–17	2.3–6.8	64–400	0.9–2.4	7–20
20–22	4.5–8.7	250–1200	1.4–3.2	16–32
25–27	6.7–9.6	470–1800	1.7–4.7	24–47
30–32	9.1–11.2	800–2700	2.4–7.4	36–62
35–37	12.5–14.7	1300–3800	1.7–6.2	16–74
More than 40	14.2–17.4	2700–5200	1.9–8.2	20–84

Source: From Akhmadov (1997).

desert pastures (with *Artemisia* and *Ceratoides*); and, in the lower areas; (7) short-grass mountain steppe as winter pastures; and (8) winter–spring pastures.

Some basic characteristics, such as the yield, the degree of erosion, and area subjected to desertification of these different types of high-mountain pastures, are given in Table 17.2. Table 17.3 gives estimates of the biodiversity of the different pasture types.

Summer Cryophilic (Alpine) Pastures and Heath

Summer cryophilic or heath pastures are often called *alpine meadows*. They are located below the nival zone, at an altitude above 3300 to 3500 masl. Heterogeneous climatic, geomorphological, and botanical characteristics do not allow an overall characteristic to be given. Thus, in the valleys of the West Pamir, more hygrophilous pastures with short-grass heaths, high meadows, and steppes are prevalent. The alpine formations on the West Pamirs have the characteristics of deserts. Xerophilous vegetation is widespread in the alpine zone but does not have a continuous distribution because of various mounds, glaciers, and snow patches. Thus, it is very often represented only by many small separate fragments. The common trait of all heath vegetation is their suitability to a short and cold vegetative season and the adaptation of the vegetative organs and buds (which are very close to the soil surface) to a long harsh winter, as well as their ability to endure considerable frosts during the summer. Xerophilous species are very unequally distributed in pastures, depending on their specific structure and on the grass cover density.

Intensive grazing has caused a lack of regeneration of the grasses. Shoots are completely absent, morphological structure has changed, plants have become stocky, the aboveground system of shoots exhibits a partially rosettic shape, leaf size has decreased 2 to 3 times, the height of the grass stands has been reduced drastically (from 40–50 cm to 3–5 cm in low-herb meadow pastures), and aboveground mass of plants is concentrated in the lowermost layer. Valuable fodder and grass species have disappeared, the first to go being *Poa alpina*, *P. bucharica*, *P. litvinovii*, *Alopecurus himalaicus*, *Festuca alaica*, and *Allium fedtschenkoanum*. Numerous field experiments carried out by Akhmadov and coworkers in the basic types of pastures and hayfields have shown that intensive grazing leads to a decrease in soil fertility and a sharp decrease in productivity, resulting in deterioration of the quantitative structure of herbage on those pastures.

Overgrazing of cryophilic pastures in summer favors the growth of *Cousinia franchetii*, *C. pannosa*, *Scorzonera acanthoclada*, and *Lagotis korolkovii*. Consequently, these pastures further lose their economic value, becoming unsuitable for grazing. Observations (Akhmadov, 1999) have shown that the soil

TABLE 17.2
Area, yield, and degree of desertification of high-mountain pasturelands in Tajikistan

Type of Pasture	Area (x1000 ha)	Altitude (masl)	Yield of Dry Mass ($t.ha^{-1}$)	Total Grazed ($t.ha^{-1}$)	Degree of Land Erosion (Percentage of Total Area)	Area Subjected to Desertification (Percentage of Total Area)
Summer cryophilic pastures	100	3300–4800	0.05–0.63	0.03–0.56	78–96	97
Prickly-grass pastures	400	2400–3200 (3800)	0.05–2.5	0.03–0.57	90–95	100
Summer steppe pastures	420	1800–3500	0.35–1.3	0.32–0.62	78–91	96
Swamps and meadow pastures	170	1500–2900 (3200)	0.48–3.2	0.30–3.0	57.4–72	80
Long-grass mountain steppe	600	1000–3300	0.36–3.6	0.25–3.2	88.4–92	95
Autumn–winter desert pastures	700	400–800 (1200) and 3000–4700	0.005–1.0	0.002–0.8	96–100	100
Short-grass mountain steppe and winter–spring pastures	500	300–700 (1100)	0.15–2.0	0.06–1.7	86–94	95

Source: From Akhmadov and Gulmakhmadov (1999).

protection provided by a covering of 60 to 80% by *Carex* and *Kobresia* is lost when the cover percentage reaches less than 35 to 55%.

Prickly-Grass Summer Pastures

Prickly-grass (tragacanth) summer pastures are very common in many mountain regions of Tajikistan. They are constituted by nonpalatable grasses, prickly subshrubs, and undershrubs. The tragacanth growth form is common in *Astragalus*, *Onobrychis*, and some other genera. With few exceptions, they are unpalatable, woody, and prickly plants, with a somewhat hedgehog shape. Only some *Cousinia* species can be grazed, mainly very late in the season, after its germination. Prickly and spiny species increasingly persist on the pastures and, thus, gradually replace valuable fodder plants. Among the prickly grasses important for pastures there are different Gramineae, such as the meadow species; *Poa bucharica* and *P. zaprjagajevii*, and the steppe species; *Poa relaxa*, *Festuca sulcata*, *Stipa*, *Leucopoa karatavica*, and others. This zone often suffers from intensive erosion processes because the vegetation here does not have a good density of sward (large intertussock space).

Summer Steppe (Mountain and High-Mountain Pastures)

The summer steppe, mountain, and high-mountain pastures are the most common types of summer pastures. The prevailing constituent grasses are *Festuca sulcata*, *Poa relaxa*, *Leucopoa olgae*, *L. karatavica*, and a few others. Additionally, there are very palatable cereals: *Piptatherum sogdianum*, *P. pamiroalaicum*, *Zerna angrenica*, *Alopecurus seravschanicus*,

TABLE 17.3
Plant species richness of different high-mountain pasturelands in Tajikistan (approximate number of species)

Type of Pasture	Total Species	Gramineae	Cyperaceae	Leguminoseae	Forbs Grazed	Associated Species	Toxic and Harmful
Summer cryophilic pastures	58	12	5	2	15	20	4
Prickly-grass pastures	88	25	3	5	10	41	4
Summer steppe pastures	145	36	1	12	23	63	10
Swamps and meadow pastures	54	17	8	6	8	11	4
Long-grass mountain steppe	82	23	4	10	12	27	6
Autumn pastures	86	13	2	4	27	35	5
Short-grass mountain steppe and winter–spring pastures	108	25	1	9	33	34	6

and *Roegneria ugamica*. This vegetation is the best grazing area for sheep and, to some extent, for domestic cattle and horses. Because of overgrazing and prolonged unsystematic use, steppe pastures are greatly degraded, and on trampled pastures, there has been a sharp decrease of productivity. Because of overgrazing, many valuable grasses have disappeared and *Artemisia*, Polygonaceae, *Scorzonera*, and *Cousinia* have taken over. The steppes of the Pamir-Alai extend from the zone of the thermophilic juniper slopes in the valleys up to the subalpine region. The most complete steppes are found on high-mountain plateaus (dashts) and in dry valleys. Everywhere in the Pamir, the main belt of their distribution is the subalpine zone, normally above the timberline. Usually the subalpine zone is characterized by short dry summers and long, inclement, snowy winters. Therefore, winter grazing is not possible. The intensive grazing of the mountain steppe summer pastures by cattle results in the loss of many valuable plants. Trampled pastures are subject to erosion and degradation of the soil. The productivity can reach up to 3 $t.ha^{-1}$ of dry mass; the palatable parts, on average, reach only 0.2 $t.ha^{-1}$. But, taking into account that up to 90% of plant dry mass is concentrated in the region of 0 to 2 cm above the surface of soil (below the level of grazing by sheep), it means that fodder amounts to only about 0.04 $t.ha^{-1}$. Thus, the actual used plant dry mass on sites with extensive pasture grazing is only about 5 to 8 % compared with the total herbage mass.

Swamp and Meadow Summer Pastures

Swamps (habitats with a high and permanent water table; also called *saza*) and meadow summer pastures are not widespread. By the character of the dominant plant functional types, they can be subdivided into two groups: forbs and meadow grasses. On meadow summer pastures with prolonged overgrazing, there is a change from productive and palatable plants to low and unpalatable grasses. These pastures additionally become weedy with harmful, poisonous plants, e.g. *Thermopsis*, *Trichodesma*, *Heliotropium*, and others. Meadow summer pastures are rather widespread, mainly in montane (with moderate and tall herbs) and in alpine mountain zones (with low herbs). On montane meadows, cereal grasses (*Zerna turkestanica*,

Dactylis glomerata, *Roegneria ugamica*, *Poa bucharica*, *Hordeum turkestanicum*, *Alopecurus seravschanicus*, and *Agrostis alba*) and some leguminous species (e.g. *Vicia tenuifolia*) are dominant. These meadows are used for haymaking. The productivity is high, with 1.5 to 2.5 t.ha^{-1} of dry mass. As a result of the prolonged uncontrolled use of the tall-grass meadows of the subalpine zone for grazing, most areas are degraded and contain many weeds, as well as unpalatable prickly grasses. Controlled areas with natural borders (Ziddy region, Hissar mountain range), which are isolated from pastures and are only used for haymaking, give 2.0 to 2.5 t.ha^{-1} of high-quality hay, whereas in intensively grazed sites, the edible part of herbage only makes up 0.25 to 0.3 t.ha^{-1}, with 50 to 70% being unpalatable, mostly prickly *Cousinia*. The percentage of the area of these degraded (and now prickly-grass pastures) is more than 30% of the entire summer pastures of Tajikistan. The percentage of palatable fodder on some sites does not exceed 10%.

Long-Grass Mountain Steppe: Summer Pastures

These are tall-herb and long-grass mountain steppes used as summer pastures, which are characterized by *Ferula ovina*, *F. jaeschkeana*, *F. karatavica*, *F. kokanica*, *Prangos pabularia*, *Alcea nudiflora*, *Crambe kotschyana*, *Inula grandis*, and other large herbs. These large or giant herb vegetation types are very conspicuous in the different mountain zones; they belong to many different vegetation types and are always different in each site. The main dominants are ephemeroids. The various species of *Ferula* are not only characterized by their adaptation to a short vegetation period but also by their monocarpic (hapaxanthic) behavior. Such dominant species as *Ferula* and *Inula grandis* differ not only in their size and the roughness of their tissue but also in their vegetation mosaic. Tall-herb and long-grass steppe summer pastures are located from 1000 to 3300 masl. The vegetation is basically made up by tall cereal grasses: *Hordeum bulbosum*, *Elytrigia trichophora*, and many ephemers and ephemeroids. The productivity of *Hordeum bulbosum* and *Elytrigia trichophora* used for haymaking can reach, in some rangelands, up to 2.16 t.ha^{-1} of hay. Fluctuations of crop productivity from year to year are between 1.4 and 3.51 t.ha^{-1}. The cereal grasses *Piptatherum sogdianum* and *Roegneria ugamica* deliver the basic fodder value. In overgrazed areas, there is a change to unpalatable small grasses and an invasion by harmful, poisonous weeds, such as species of *Thermopsis*, *Trichodesma*, *Heliotropium*, *Cousinia*, and *Origanum tyttanthum*, etc. Additionally, overgrazing results in higher proportions of *Artemisia*, indicating a shift to semidesert-like conditions (Akhmadov, 2003b). One of the widespread tall-herb formations is characterized by *Prangos pabularia*, which reaches as high as 3200 masl, the subalpine zone. This characteristic association with *Prangos pabularia* contains many ephemers (up to 1500 masl), many forbs (between 1500 and 2200 masl), mainly *Polygonum coriarium* (between 2500 and 3200 masl) and *Ferula jaeschkeana* (between 1600 and 3200 masl). Common species in all associations are *Hypericum scabrum*, *Artemisia persica*, *Ziziphora pamiroalaica*, and *Dactylis glomerata*, etc. The widespread *Ferula jaeschkeana* and *Prangos pabularia* sometimes displace other vegetation types and depreciate the pastures. *Ferula jaeschkeana* and *Prangos pabularia* contain essential oils and strong rough fibers, forming a hard straw, and therefore they are not eaten by cattle.

Autumn–Winter Desert Pastures with *Artemisia* and *Ceratoides* in High Mountains

Autumn–winter desert pastures develop in peneplain and low-mountain zones and, especially, in the high mountains of the East Pamirs. The insignificant snow cover and a relatively dependable availability of dry stems and some leaves and fruits make the alpine deserts suitable for winter grazing. The prevailing plants here are almost unpalatable in spring or in summer during their vegetative conditions. They become edible only in the dry conditions in winter or in late autumn. In the autumn–winter period, this grazing is synchronous in the river valleys with partly halophilous vegetation and on saline meadows. Jungles, which develop on the sands of creeks, also are included in the winter pasture cycle.

Teresken or *Eurotia* (*Krascheninnikovia ceratoides* syn. *Eurotia ceratoides*, now called *Ceratoides papposa*) is the most common species in the East Pamir (see Breckle and Wucherer, Chapter 17). The teresken high-mountain autumn–winter desert pastures prevail in the West Pamirs only in the wide subalpine zone (3500 to 4200 masl, and rarely, up to 4500 masl). They prevail along wide and straight valley bottoms, on gentle slopes, on debris cones, and on the smoothed hills of ancient moraines. In the lower parts, the bigger *Ceratoides ewersmanniana* is also present. All soils in which teresken is found are slightly salty. They are pastures of very low productivity (0.05 to 0.2 $t.ha^{-1}$). Vegetation cover is only 5 to 15%. In recent years, because of shortage or lack of fuel, widespread uprooting of bushes and half-bushes took place and, thus, teresken became the basic fodder source, as well as fuel, in winter pastures.

High-mountain autumn–winter desert pastures with *Artemisia* are also widely distributed in the lower mountains, in middle mountains, and in the high-mountain zones of Tajikistan up to an altitude of 4300 masl. The productivity of these pastures reaches 1.45$t.ha^{-1}$, and the palatable mass makes up 0.9 $t.ha^{-1}$. The plant cover is 15 to 40%.

Alpine high-mountain autumn–winter desert pastures are distributed widely but in small patches in the alpine zone of the East Pamirs between the heights of 4300 to 4700 masl. They are represented by formations of the xerophytic dwarf semishrub *Ajania tibetica*. They are found along gentle slopes with low snow cover and on debris cones with desert skeletal soils. The productivity of these pastures reaches up to 0.18 to 0.25 $t.ha^{-1}$, and the palatable portion amounts to 0.9 $t.ha^{-1}$. Plant cover is 10 to 15%, and rarely, 25 to 30%.

CONCLUSIONS AND FUTURE ASPECTS

There is widespread animal husbandry in mountainous Tajikistan, and livestock keeping is largely determined by environmental conditions. The various types of pastures are mainly distinguished by the seasons of their main use. The very reduced areas of pastures in the mountains and their remoteness from areas with good summer pastures have been responsible for the creation of an all-year-round grazing system, which has led to a strong reduction in biodiversity and a change of pasture type.

Overgrazing over centuries has led to a substantial change of the vegetation from its natural species composition. Pastures are contaminated by unpalatable plants — mainly *Cousinia* and *Acantholimon*, but also many other harmful and poisonous herbs and nonproductive grasses. Not only range degradation, but also the loss of biodiversity and accelerated soil erosion are consequences of a prolonged unsystematic pasturing. Development of methods for sustainable use and for the restoration of natural pastures, and creation of highly productive cultural pastures is the most effective and reliable way to combat the degression of pastures to maintain pastoral forages for cattle and other livestock.

For nature conservation and for maintaining a high biodiversity in vegetation and pastures, it is necessary (1) to systemize the pasture of cattle (create good management plans); (2) to use the same territory only once in 3 years; (3) to apply, once in 2 to 3 years, small doses of mineral fertilizers for the improvement of quality and biomass of the plants; (4) to apply meliorative measures for the improvement of the pasturelands; (5) to get local communities to remove (by hand, because all summer pasturelands are located on steep slopes) the poisonous and unpalatable plants brought in by cattle as manure from the winter pastures; and (6) to demonstrate (on experimental plots) to the local communities and farmers, progressive technologies for efficient conservation and improvement of high-mountain pasturelands, e.g. management of water and soil in the pasture zones; the regulation of cattle grazing; the restoration of forests, where possible; and the use of crops as an antierosion measure and to promote a species-rich grass cover.

Last but not least, it will be very important for the future development of the region to use alternative energy sources to achieve independence from organic fuels. This would be the best way to preserve the unique pasture vegetation that protects the soil from degradation. Use of wind-power generators is a

prospect in many regions of Tajikistan, especially on the high Pamirs, where pastures are used all the year round. In addition, Tajikistan, due to its geography and natural climatic conditions, is a very suitable region for the widespread use of solar radiation. The number of sunny days is from 250 d (Fedchenko Glacier) to 330 d (Murgab, East Pamirs) per year, providing 2000 to 3000 h of radiation per year. The intensity of the solar radiation reaches up to 1 $kW.m^{-2}$ (on average, 500 to 700 $w.m^{-2}$). Such high-potential power from solar energy resources is not used at all. Thus, in the future, the use of solar energy could become an important step for biodiversity conservation in the high-mountain pastures in the Pamir-Alai.

SUMMARY

Natural pastures and haymaking areas occupy more than 3.5 million ha in Tajikistan. They are the major sources of various high-grade forages for livestock. The reserves of forages on pastures comprise more than 1.6 million $t.a^{-1}$ of dry mass. Fodder productivity varies from year to year, and therefore, does not ensure a stable source for livestock. In recent years, fodder productivity of pastures has decreased due to anthropogenic reasons. There are six different types of pastures, depending on vegetation and altitude and four types depending on land use. Each type is characterized by the composition of plants, productivity of the pasture, function, use, and other features. Grasses are almost completely deprived of regeneration by intensive grazing, and valuable fodder grasses are the first to disappear, e.g. *Poa bucharica*, *P. bulbosa*, *Dactylis glomerata*, *Helictotrichon asiaticum*, *H. hissaricum*, *Festuca pratensis*, and *Allium varsobicum*. Pasturable areas have been transformed by prolonged and excessive grazing into inconvenient or marginal soils. Nowadays, unpalatable grasses make up 75 to 90% of the herbage. In total, the production of fodder mass has decreased to 20%, or possibly, even 10%. Better methods for the sustainable use and restoration of natural pastures and the creation of cultural pastures are urgently needed (Breckle et al., 2001; Breckle, 2003) to prevent further pasture degradation and to provide livestock with pasturable forages.

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