*RNR = Renewable Natural Resources

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Influence of humans and their livestock on the structure and biodiversity of montane forests and alpine pastures in Bhutan

I. Preliminary results of fieldwork undertaken in 2000/2001 and recommendations

Laya herders at Rodophu, 4250m, in mid-August 2000 after their return from the higher grazing places.In the background left: a relic grove of Juniperus indica. It survived the fires that were set in order to convert the juniper forests into rangelands. The pastures are regeneration stages of different age after fire. Some are encroached by shrubs, and the herders regard part of them as overgrazed and wish to burn new areas.The recently burnt slopes show that the establishment of valuable sedges after the removal of the forest takes quite a lot of time.

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Key words: Bhutan, biodiversity, nature conservation, natural resources management, pastoralism, silvopastoral systems.

Abstract

This expedition report, given after 8 months of ecological fieldwork, focuses on the preliminary results based on observations, with the aim to promote future planning and research.

The human-generated transformation of the vegetation in the northern half of Bhutan is much more extensive than commonly assumed: Chir and Blue Pine forests replaced broad-leaved forests, with species richness decreasing with increasing human influence. Broad-leaved forests are unsuitable for intensive grazing; the maintenance of primary canopy trees is endangered. Future development has to aim at a large-scale separation of forests and rangelands.

The same applies to upper montane forests and alpine scrub, even though human interference increases the species numbers here. The best pastures have sparse or missing woody components but a robust grass/sedge cover, and they are maintained by a seasonally high grazing pressure.

A more intensive use of present pastures and a more specific utilisation of forests, will sustain a growing population and allow the preservation of relict pristine vegetation.

All ecological monitoring work required for the development of these landuse systems needs a drastic increase of botanically trained research staff in Bhutan.

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1. Introduction

Within the framework of a bilateral agreement between the RGoB and the German government, signed end of 1999, joint Bhutan-German investigations on the plant ecology of forests and alpine pastures were undertaken between May 2000 and February 2001.

The effects of grazing and fire on the species composition was in the focus of the studies. By travelling extensively in the northern part of the country, it became evident that all easily accessible forests are more or less strongly influenced by humans and their livestock. The assessment of the effect this influence has on biodiversity (expressed as plant species richness) is only possible if a comparison with more or less pristine forests is made. Thus, priority was given to the vegetation recording in least disturbed forests and alpine formations, and to the study of the natural treeline. Near the latter, extensive traditional pastures have been derived from subalpine forests on sunny slopes. The investigation of the impact of grazing and pasture management on the quality, structure, dynamic status and species richness of alpine pastures was another focal point of fieldwork.

The final aim of the evaluation is to provide scientifically grounded basic information about human influence on species composition and richness of plants in selected vegetation types of northern Bhutan: evergreen oak forests with Tshenden (to be presented in a separate account), subalpine fir, birch and juniper forests, *Rhododendron* scrub and herbaceous alpine formations.

The evaluation of fieldwork will be time-consuming because a large collection of plant voucher specimens, including mosses,lichens and ferns, has to be named.

In the present stage, preliminary results from observations are communicated. This paper is an amended documentation of the "Debriefing cum Seminar" held in the MoA at Thimphu on October 5, 2000, headed by Honourable Lyonpo Dr. Kinzang Dorji. An emphasis is given to recommendations for future research and experiments.

2. Methods and itinerary

Some 180 vegetation records were made on temporary inventory plots subjectively chosen to be homogenous and representative for a certain vegetation type. The size of the plots varied according to homogeneity and nature of the plant formation. Habitat information like location (GPS), slope aspect and inclination were also noted. The vegetation was recorded according to Braun-Blanquet's (1964) requirements of a complete floristic inventory. All plant species, even sterile, indeterminable ones, were recorded with their cover degree (in per cent). Only mosses and lichens were recorded groupwise.

Voucher specimens had to be taken from all plants that could not be identified on the spot. This resulted in a large plant collection. , The final evaluation of the vegetation records will only be possible after the determination of these voucher specimens. The collection was divided: the first set of specimens was handed over to the National Herbarium (NBC), and specimens which could not be named in Bhutan are transferred to the Herbarium of the Royal Botanic Garden, Edinburgh, where they will be named in the course of the next two years. Mosses and lichens will be sorted and sent to the respective international specialists. As there is no flora for these groups, the determination may take a longer time. All names will be communicated to the NBC. Thus the National Herbarium will have a considerable supplement to its present collection and a reliable establishment of a moss and lichen collection.

Braun-Blanquet-records were mostly made in cooperation with the accompanying Bhutanese staff in order to offer some methodological field training. For the purpose of monitoring changes in species richness, the applicability of the Braun-Blanquet method was compared with that of transect methods. Example records in the pastures around Laya indicate the advantages of either method:

a complete floristic inventory of a *Kobresia* pasture on a 10 x 10 m plot, supplemented by rare species found in the surroundings, revealed 55 species of flowering plants. 200 points along 10 m-borderlines of this plot touched 31 species in the first and 30 species in a second case. The species were not identical; thus a transect of a total length of 20 m (400 points) would yield 37 species. These are 54 to 67% of the complete inventory.

Depending on the purpose of monitoring, the application of either method is advisable. If changes in the degree of cover of the dominant grasses and herbs in the course of an experiment (e.g., burning, increase of grazing pressure etc.) are to be documented, the transect method will yield sufficient information (even with 200 points, if the record is repeated on exactly the same line: problems of demarcation!). If the focus is on total species richness and especially on changes among the rare plants, the complete inventory is demanded. As the cover percentages are estimated in the latter, however, this method is less suitable for a year-by-year comparison of cover degrees, especially if the staff changes. The herders of Laya and NP staff were already overcharged by recognising the differences between similarly looking herbs. Local names often designate more than one botanical taxon. These experiences point to the practical challenges of conducting such inventories. The country urgently needs more botanically trained staff.

In order to facilitate future monitoring of the alpine vegetation in JDNP, a small plant collection was started in collaboration with the local ranger (triplicate set of our collection). With the communication of the plant names, this local herbarium can serve as a reference by all staff undertaking vegetation studies in the park. Thus, a unique nomenclature is safeguarded.

In total, 8 months were spent in the field, with changing Bhutanese collaborators and accompaniment (see itinerary). The remaining 3 month were needed for drying and sorting of the plant collection, the organisation of field trips and the preparation of reports.

Itinerary of field trips (see also Fig. 1)

28/04/00-14/05/00	Survey of natural forests and the treeline on the SE declivity of the Black Mountains (support through BMNP)
18/05/00-27/05/00	Survey of broad-leaved and fir forests influenced by grazing along the Rutong La trek (Bumthang - Lhuntshi), in collaboration with forestry staff from RNR-RC Jakar.
28/05/00-20/06/00	Vegetation records in evergreen oak forests, fir forests and *Rhododendron* thickets under varying grazing influence: Lhuntshi - Dong La - Chorten Kora - Pang La - Trashiyangtse, in collaboration with NRTI Lobesa (D.B. Gurung) and Bomdeling Wildlife Sanctuary (BWS).
21/06/00-28/06/00	Vegetation records in grazed juniper and pristine fir forests and *Rhododendron* scrub along the Bumthang section of the "Snowman Trek" (Jakar - Tsochen Chen - Yüle La - Jakar). Return because of damaged bridge at Dhur Tsachu. Organisation by a trekking agency.
01/07/00-29/09/00	Fieldwork along the "Snowman Trek", organised by a trekking agency: Drugyel Dzong - Chomolhari - Lingshi - Laya (joint fieldwork with JDNP staff between 30/07 and 18/08) - Tarina - Woche - Lhedi - Thanza - upper Mangde Chu - Thanza - Maorothang - Nikachu. Vegetation records in upper montane fir, birch and juniper forests and secondary and natural alpine pastures.
08/11/00-02/12/00	Survey of fir and juniper forests in Bomdeling WS (upper Kulong Chu/Trashiyangtse, upper Khoma Chu/Lhuntshi) in collaboration with BWS.
04/12/00-14/12/00	Expedition into the middle reaches of the Pho Chu (Wangdue-Phodrang) in cooperation between JDNP, NRTI, DFO Wangdue-Phodrang, RNR-RC Bajo and BG-SRDP (GTZ) Lobesa. Vegetation records in ungrazed Tshenden forests. The attempt to reach the core Tshenden area fails due to difficult access.
09/01/01-04/02/01	Expedition to relict Tshenden stands in Lhuntshi, in collaboration with DFO Mongar/Lhuntshi and NRTI Lobesa (D.B. Gurung): Lhuntshi - Ne - Kampalung - Tergang - Jasibi - Chagsum - Serchong - Dungkar - Shamling - Lhuntshi.

3. Lower montane forests in Bhutan: influence of humans and their livestock on physiognomy and species richness

The submontane and lower montane belts of Bhutan certainly have the highest biodiversity (as expressed in terms of species richness). This especially applies to the subtropical and warm broad-leaved forests, the least known ecosystems of Bhutan.

As our fieldwork concentrated on the upper montane and alpine belt, we can only give some conclusions from our observations here. These focus on the relations between

(1) warm broad-leaved and Chir Pine forests

(2) cool broad-leaved and Blue Pine forests.

3.1 The warm broad-leaved / Chir Pine forest connection

The Chir Pine (*Pinus roxburghii*) has a very wide altitudinal range from the subtropical forest to the upper limit of warm broad-leaved forest (2000-2300 m, see Grierson & Long 1983). It is generally assumed that Chir Pine forests indicate drier climates in the lower, wind-swept valleys whereas the broad-leaved forests cover more humid/sheltered slopes.

Indeed, in the main N-S-draining valleys of Bhutan a small-scale alternation between Chir Pine and broad-leaved forests can be observed: S-facing parts of the flanks that are exposed to the desiccating valley winds are dominated by Chir Pine, and broad-leaved forests stick to more shady and wind-sheltered slopes (i.e., the more humid micro-habitat). The same applies to differences in soil conditions: Chir Pine dominates on rocky ground whereas broad-leaved forests are mostly found on deeper soils. This differentiation is certainly natural near the drought limit of warm broad-leaved forests. But where is this drought limit? The major valleys of Bhutan are so much fire-influenced that it is practically impossible to assess where Chir Pine grows naturally. Comparative observations in the Puna Tsang Chu, Mangde Chu, Kuru Chu and Kulong Chu catchments indicate that human impact may shift the borderline between the Chir Pine and the broad-leaved forests far into the humid extreme of the warm broad-leaved forest zone. Observations made in the middle reaches of the Pho Chu around grazing places beyond the last permanent settlements indicate the probable gradual conversion of warm broad-leaved forest into the Chir Pine ecosystem:

(1) Selective woodcutting and initial burning of warm broad-leaved forest: valuable timber trees and fire-sensitive species are destroyed; the canopy becomes more open; the thick humid topsoil and litter layers are burnt to ashes which are washed down-slope with the next rains. Tree species with lower demands for soil nutrients and humidity but higher ones for light invade: *Quercus lanata, Quercus griffithii, Rhododendron arboreum*

(2) Repeated fires combined with grazing gradually remove the last trees of the typical broad-leaved forest, going along with further deterioration of the forest soil. Favoured by

fire and plenty of light in the undergrowth, grasses become dominant which in turn increase the risk of fire.

(3) The invasion of the Chir Pine into stage (2) forests is only a matter of time, depending on the distance to the nearest populations (no wind dispersal!). If the introduction is not done by humans through planting or cone collection, the invasion may take several centuries (judged from a peculiar isolated population in the upper Kuru Chu N of Jasibi, not in the driest habitat). It is not sure if there is any humidity limit for the spread of the Chir Pine: it is missing in some tributaries of the major valleys despite former or present shifting cultivation, but the age of these settlements is not known. In extremely humid areas, however, broad-leaved pioneer trees like *Macaranga*, *Maesa* and *Schima* spp. and fast-growing tall-forbs might out-compete the pine.

Chir Pine savannahs naturally grow on wind-exposed, dry rocky slopes in association with tall grasses, but their area has been multiplied by means of man-made fires. Therefore, the main valleys of Bhutan look drier than they are. In the example of the Punakha Tsang Chu this is proven by the successful village afforestation done in Wangdi-Phodrang (Lingmutey Chu confluence) in collaboration with the Bhutan-German RNR Development Project (BG-SRDP). On barren, indurated, claiey subsoils of a stricty S-facing, extremely wind-exposed upper slope in 1650 m, *Quercus griffithii* and *Q. lanata* have survived the third dry season together with *Cupressus "cashmeriana"* (Tshenden from Indian seed sources) without irrigation, in good condition. The average annual rainfall in Wangdi is 661 mm, in Punakha 736 mm. The surrounding slopes in comparable situation carry exclusively Chir Pine Savannahs.

This shows how drought-tolerant the drier types of warm broad-leaved forest are. As the drier sites burn more easily, they are most frequently swept by uncontrolled fires and thus the first habitats invaded by the Chir Pine. Consequently, the windward/leeward differentiation of the vegetation can also be explained by the fire frequency. The latter seems to be the decisive factor in the upper Punakha Tsang Chu.

Another indication for potential broad-leaved forests within the present Chir Pine belt are the "Shokshing" groves: people preserve *Quercus griffithii* forests because they need the leaf litter. Occasionally also other constituents of warm broad-leaved forest survive here: *Castanopsis tribuloides*, *Schima wallichii* and evergreen oaks (*Quercus lanata, Q. glauca*).

There is a drastic decline in both, species richness and structural diversity, from the pristine warm broad-leaved forests to regularly fire-managed Chir Pine savannahs. Species numbers are supposed to decline in each step of this degradation (Fig. 5), even though there is no proof in numbers yet. There is a complete change in the floristic composition. Most of the companions of the Chir Pine are widespread subtropical/tropical weeds; few rare and botanically interesting species that are naturally confined to rocky sites, owe their spread to moderate burning frequencies (e.g. *Cycas pectinata*, *Dracaena angustifolia* and some ground orchids and geophytes, most of them grow in the upper subtropical forest belt).

Even though poor in species, the Chir Pine savannas are stable and useful ecosystems. *Pinus roxburghii* is tapped for resin. Oil extraction from Lemon Grass (*Cymbopogon flexuosus*) supports many people, and the regularly burnt grass sward makes a good, erosion-stable pasture. The main constraint of the latter is its pronounced seasonality: a closed broad-leaved forest in the same locality would offer a pasture that might be less productive but palatable during a much longer period (due to the more humid microclimate). The Lingmutey Chu example shows that afforestation is feasible, even after the complete destruction of the original broad-leaved forests and their humic topsoils.

3.2 The cool broad-leaved / Blue Pine forest connection

3.2.1 Cool broad-leaved forest types and their replacement communities

Under the term cool broad-leaved forest, a large variety of broad-leaved and mixed broad-leaved/coniferous forests occur. The altitudinal range is from 1800-2300 to 2800-3200 m. The humidity range is from dry evergreen oak forests to wet *Quercus lamellosa*- or *Betula*- and *Acer*-dominated forests with laurophyllous understoreys of *Cinnamomum, Lindera, Magnoliaceae, Persea, Symplocos* spp. and a ground layer dominated by bamboos, ferns and Urticaceae. Towards the upper limit, *Tsuga dumosa* appears. After natural disturbance, *Betula alnoides, Alnus nepalensis* and (higher up) *Larix griffithiana* and *Juniperus recurva* var. *coxii* are pioneer trees in the wetter forest types. *Pinus bhutanica* (segregated by Grierson, Long & Page (1980) from *P. wallichiana*) occurs in light, edaphically dry locations (crests, rock outcrops, margins of slide areas).

At the dry end of the humidity range, the cool broad-leaved forests are dominated by oaks (including *Castanopsis* spp. at lower altitudes, solely by *Quercus semecarpifolia* at higher altitudes) and have a more drought-tolerant undergrowth (*Lyonia ovalifolia, Rhododendron arboreum, Eurya acuminata* being characteristic). Bamboos are sparsely distributed or absent. On steeper slopes, where the tree canopy is more open, the ground layer is rich in grasses. On steep rocky, sunny slopes, the Blue Pine (*Pinus wallichiana*) is naturally associated or even dominant. In this drought-determined struggle zone between broad-leaved and pine-dominated forest, we face the same situation as described for the "Chir Pine belt": the dry oak leaf litter, pine needles and grasses on sunny slopes are easily inflammable in the dry season. Burning down dry oak forests on sunny slopes is easy and yields a good, stable grassy pasture. The Blue Pine is the classical pioneer on formerly burnt extensive pastures or Tsheri fields, in association with other ungrazed woody plants (mostly Ericaceae). Human activities in the ancient settlement areas of NW- to N-central Bhutan caused a more or less complete removal of the original forest cover within the cool broad-leaved forest belt. After the ban of shifting cultivation and fire, the Blue Pine spread as a pioneer tree across vast barren landscapes in Paro, Thimphu and Bumthang (see Aris 1994 for photo documents). The Blue Pine forests we see in these areas are almost exclusively young secondary pioneer forests. As in the extended Chir Pine belt, it is almost impossible to judge which type of forest would grow here naturally. Shokshings or holy groves preserved near villages may give some hints of the potential: in Bumthang, they are mainly constituted of *Quercus semecarpifolia* or even of spruce. In Thimphu and on the way from Thimphu to Paro, *Quercus semecarpifolia* strongly regenerates in the undergrowth of the open Blue Pine forests. Where the forests are protected from grazing and woodcutting, they will soon form a closed second tree layer which will be too shady for future regeneration of the Blue Pine. These successions indicate that the seemingly dry areas would at least carry *Quercus semecarpifolia* forests.

Pinus bhutanica, the Blue Pine relative growing in the more humid range of the lower cool broad-leaved forest belt, may also form monospecific stands after destruction of the primary forest. Examples of such secondary forests are found between Pele La und Tongsa, near Mongar, in the western tributaries of the Kuru Chu S of Lhuntshi and around Chorten Kora in Trashiyangtse. From the unexpected dominance of *Pinus bhutanica* in Paro (at least on N- to E-facing slopes) we can only conclude that a considerably more humid type of oak forest would naturally grow here.

3.2.2 Biodiversity levels in cool broad-leaved forests

There is a natural gradient of decreasing biodiversity (in terms of plant species richness) from the wetter to the drier types of cool broad-leaved forest. But, within each humidity-type, species numbers again tend to decrease with growing intensity of human interference (hypothetical diagram in Fig. 5).

Many oak forests still have their "primary" canopies of tall *Quercus* trees several centuries old. In consequence of a persistent grazing pressure, however, regeneration of oaks in the forest undergrowth is rare or missing. This was also noticed by Pradhan (2000) in the strongly grazed areas of Thrumsingla National Park. The woody understoreys are strongly impoverished in species, being reduced to unpalatable *Eurya, Symplocos, Ilex* and *Daphne* spp. Norbu (2000) documented comparable processes in warm to cool broad-leaved forests in Gedu. East of Dochu La, every traveller crosses the bad scenario of the future situation in the wetter cool broad-leaved forests, after the break-down or the removal of the over-mature oak canopy.

Regularly burnt pastures derived from drier oak forests on sunny slopes have a floristic composition which differs completely from that of the oak forest, but may be fairly rich in species. Young secondary forests of Blue Pine are clearly the species-poorest ecosystems, especially if no thinning is practised. Later successional stages become richer in species and structure, especially if broad-leaved trees are allowed to reinvade.

The rehabilitation of degraded cool broad-leaved forests, and especially the restoration of oak forests in areas occupied by pines, faces three major problems:

(1) control of fire
(2) control of grazing
(3) lack of seed.

Even if grazing and fire can be controlled, it will take decades to centuries until broad-leaved trees re-invade former clear-cut areas like Bumthang or the lower Paro Chu. Where a restoration of broad-leaved forests is desired, artificial reseeding or planting of the valuable species is a necessity. Not only for an increase in biodiversity, but especially in view of future provision with firewood, forestry nurseries should start to raise indigenous oaks and other valuable timber species of the drier broad-leaved forests in large scale.

A major problem in the implementation and documentation of such trials is the fact that the Bhutanese oaks (at least 9 *Quercus*, 3 *Castanopsis* and at least 5 *Lithocarpus* spp.) are hardly known by anybody in the country. Most foresters are merely able to recognize *Quercus* as a genus. The treatment of these groups in the "Flora of Bhutan" is completely unsatisfactory, mainly because of lack of material (the precondition for a more precise key) and drawings.

3.2.3 Tshenden-(*Cupressus corneyana*-)dominated forest as a special type of cool broad-leaved forest

Tshenden forests were the only cool broad-leaved forests studied in more detail during our fieldwork campaign. Wild Tshenden forests indeed revealed to be special types of evergreen oak forests, the top storey of which is constituted by the cypress. A separate contribution will be made to the findings on the ecology of Bhutan's endemic cypress. In the context of secondary forests within the cool broad-leaved forest belt, it should be mentioned here, however, that Tshenden storeys overtopping evergreen oak forests are obviously old pioneer stages after fire. Being natural on rocky, sunny flanks (especially on limestone), the Tshenden assumably spread into broad-leaved forest habitat after the destruction of the latter by occasional fires. Being a light-demanding pioneer tree on open substrate, its ecology is fairly similar to that of the pines. Indeed, the distribution area of the Tshenden overlaps with those of the Chir pine (in the Pho Chu), the Blue Pine and *Pinus bhutanica*. The decisive differences between the cypress and the pines which explain the rareness of the Tshenden in comparison with the latter are:

- young Tshenden trees are less resistant to grazing and even more fire-sensitive than the pines
- Tshenden has been harvested since unknown times for its precious wood with first priority among all conifers in the surroundings.

It can, therefore, be assumed that the pines replaced the Tshenden in many of its potential habitats. Holy, isolated Tshenden trees (transplanted from, or remnants of, wild forests?) grow from Drugyel Dzong (Paro) in the west to Trashiyangtse and Tashigang in the east of Bhutan; wild stands occur between Wangdi-Phodrang, N-Lhuntsi and S-Tashigang according to the present state of knowledge. It must be assumed that they have been more widespread in the past.

4. Impact of humans and livestock on the dynamics and species richness of upper montane forests

4.1 Distribution and physiological limitations of fir forests in Bhutan

The distribution of the east Himalayan fir, *Abies densa*, is determined by at least three natural environmental factors:

- humidity
- drought and
- lack of warmth.

4.1.1 Humidity

Comparing the various types of fir forests we have seen in Bhutan, it becomes evident that forest structure, especially the shape and vigour of the crowns, are largely determined by the dominant epiphytes.
In the drier part of the fir area, the sparse moss cover and various lichens do not harm the crowns. Fir forests have a closed canopy with a shady forest floor. Light-demanding understorey trees like some Rhododendrons, *Betula*, *Pyrus* and *Sorbus* are, therefore, restricted to patches where old fir trees had broken down, or to steep slopes, or to the zone near the upper treeline where the fir canopy also opens.

In the wetter parts of the fir distribution area, however, liverworts form thick cushions and cloaks in the fir crowns, which are additionally colonised by ferns and even shrubs at lower altitudes (*Vaccinium, Rhododendron camelliiflorum*). Epiphyte overloading and rotting of the wood, caused by permanent humidity and fungus infections, effect the frequent break-off of fir branches and the mutilation of the crowns (lopped appearance). This mechanical destruction of the crown can reach a point at which the tree cannot grow any more. This could be observed in the Black Mountains (SE declivity above Nubji): here, the fir appears only at 3500 m; the trees at this lower limit being stunted and heavily mutilated by crown damage. (Also the whole Hemlock (*Tsuga dumosa*) belt is missing in this area!). Above 3500 m, the humidity decreases, and the epiphyte load becomes bearable for the fir. But still, the forests remain more open than in drier areas.

This indicates that at least in the most humid areas of Bhutan, the lower limit of the fir is less determined by competition than by an obvious, physiological **humidity limit** of *Abies densa*. In drier areas, the fir appears at c. 2900 m.

4.1.2 Drought

It might also be new to science that *Abies densa* has drought limits in Bhutan. The species is obviously more drought-sensitive than the central Himalayan *Abies spectabilis*. Drought-influenced limitations occur near the upper treeline, which is generally assumed to be determined by lack of warmth (summer temperatures).

We found the upper limit of *Abies densa* between 4000 and 4350 m. The highest fir treelines, however, are in Bhutan never found in strict south aspect. The more a slope is directed toward the south, the lower is the *Abies* treeline. Despite the fact that NW-to NE-facing slopes are cooler than S-facing ones, the treeline climbs highest on shady slopes. This clearly indicates that **drought** superimposes the **lack of warmth** as the generally assumed limiting factor at the treeline. Presumably the winter drought is decisive. On strictly S-facing slopes in N Bhutan, the upper limit of *Abies densa* is around 4000 m. Above, junipers take over: *Juniperus recurva* in the more humid upper valleys of north-east and central Bhutan and *Juniperus indica* in the rainshadow areas of NW to N-central Bhutan (see 4.6).

4.2 Humidity-dependent fir forest communities

Fig. 2 shows floristically defined vertical subzones of fir forest in eastern Bhutan, mainly based on conspicuous rhododendrons in the undergrowth which are identifiable throughout the year. The sequence of rhododendrons is determined by temperature and humidity. Within the upper treeline zone of the fir, the accompanying rhododendrons indicate decreasing humidity in the following sequence:

Rhododendron hodgsonii → *R. wightii* → *R. wallichii*.

The birch (*Betula utilis*) as a potential humidity-indicating, important companion of the fir, shows a confusing distribution pattern:
In the more humid areas of Bhutan, *Betula* reaches its upper limit within the fir belt, fading out around 3500 m on sunny slopes and between 3600 and 3800 m on shady slopes. In the higher valleys of the rainshadow areas in N Bhutan, however, *Betula utilis* persists on shady slopes, climbs higher than *Abies densa* and forms the treeline between 4200 and 4300 m in *Betula-Rhododendron-Sorbus-Salix* scrub forests. The reasons for this change of habitat cannot be given at present. Possible explanations are:

(1) there are different ecotypes of the birch in the different climatic areas
(2) birches in the upper Inner Valleys receive more snowfall in winter (protection from frost drought), and/or more mist in summer (protection from summer drought)

(3) the lack of *Betula* in the humid subalpine zones is not caused by physiological limitation but is an effect of competition with *Rhododendron* spp. or mosses.

4.3 Remarks on mapping of fir forests

As we have been asked to communicate any ground check information that might be of use for future new editions of the Land Use Working Maps, it might be worth mentioning that the mapping of fir forest areas above 4000-4100 m is in need of revision. In some areas of N Bhutan, fir forest is indicated up to 5000 m. These areas either refer to juniper forests and scrub (sunny slopes), or *Salix* scrub, or (*Betula*) - *Salix* - *Rhododendron* scrub and forest.

4.4 Species richness and human influence on fir forests

Natural fir forests are extremely poor in vascular plant species: we recorded less than 10, including woody constituents. The number of mosses and lichens, however (not determinable in the field), may be manyfold, even though considerably lower than in the middle montane belt where the highest floristic diversity is to be expected.

Natural fir forests are thus the species-poorest forest ecosystems in Bhutan, if we only consider the vascular plants.

Human interference on fir forests extremely differs throughout the respective areas we have seen in Bhutan: it is of course strongest on easily accessible slopes and ridges within reach of settlements and grazing places. Here, woodcutting for shingleps has a devastating effect. Above Tarphel (Trashiyangtse, in the area of Bomdeling WS), our estimation was that more than three quarters of the cut wood are wasted. Even though the area is not overpopulated, the demand of a few people to roof their houses causes a local desaster in the forest.

In the upper valleys of N Bhutan, the intensity of utilisation of fir forests, the degree of threat, respectively, likewise depends on the distance to settlements, and on the aspect. One example is Lingshi which we are convinced to be potentially situated in the fir forest belt (shady slope). The demand for construction wood during several centuries has pushed the border of the fir forest several kilometres downstream. Unfortunately, the habit of cutting young conifers for the purpose of prayer flag poles accelerates the eradication of the species, especially in areas where regrowth is sparse in consequence of climatic limitations or grazing.

On the other hand, completely virgin fir forests occur on shady slopes near the fir treeline within the same areas. The main reason is the snow cover during winter, preventing access to woodcutting and grazing. In summer, shady fir forests are hardly grazed either in the yak-rearing areas, because yaks prefer the open sedge pastures in the alpine belt.

Sunny slopes within the fir belt, however, are preferably cleared for summer pastures of cattle and horses, and for yak pastures in winter and the intermediate seasons. The most common tool for clearing is fire; in areas with a more strict fire control trees are girdled. In grazed regrowth stages of these forests the less palatable junipers are favoured. In this way, secondary *Juniperus* forests are established (see 4.5).

In cattle grazing areas fir forests are grazed in all slope aspects in summer. The forests look intact – especially from the distance –, but fir regeneration is browsed by cattle: most of the forests are overmature, some started to collapse (examples seen in BWS, upper Kulong Chu, upper Khoma Chu). What follows is a mixed deciduous broad-leaved and *Rhododendron* secondary forest. A proper regrowth of the fir can only be observed on boulder slopes (not grazed) in such areas.

One of the consequences of human interference is the **increase in species richness:** seeds of alpine plants are brought from the surrounding pastures into the forests by grazing animals. Higher species richness, however, is not necessarily beneficial: many of the additional species are widespread weeds (see chapter 6). Trampling opens the moss cover and favours the germination of species which need open soil. The expansion of tall-forbs in the undergrowth causes an unknown decrease of the moss diversity.

Most common indicator plants for human interference in fir forests are: all *Daphne, Berberis, Rosa* and *Piptanthus* spp. Out of the Rhododendrons some are favoured by disturbance as well (e.g., *R. hodgsonii, R. lanatum, R. arboreum* var. *roseum*, not grazed and more or less light-demanding).

Among the herbs, many Compositae, especially *Senecio* spp., are useful grazing indicators. The presence of *Podophyllum, Potentilla, Fragaria, Valerianaceae* and *Hemiphragma heterophyllum* clearly indicate disturbed conditions.

Summing up, it is evident that forest grazing is in the long run and overall the major threat to the fir forests. Shinglep extraction is another issue. It may be a question of time that with the general progress more and more houses will be metal-roofed and this pressure on the forests is solved through development. Yet, the forest grazing problem will persist as long as uncontrolled grazing is practised. We would like to stress that the optimistic view concerning the regeneration of fir forests, given by Gratzer, Rai & Glatzel (1997), based on experiences in Ura, might not be representative for major parts of Bhutan.

4.5 Recommendations

Within the framework of CORET, the RNR-RC Jakar undertakes a comprehensive research program on fir forests. Its extension throughout Bhutan is worthwhile and necessary.
Biodiversity aspects of disturbance in the fir forest belt need to be quantified, especially with respect to tender ferns, mosses and liverworts. In the more densely settled areas of central Bhutan, fir forests are endangered by both, woodcutting and grazing. Strong grazing pressure suppresses fir regeneration. In areas where fir regrowth is missing, an at least temporary exclusion of cattle is recommended. A wider distribution of metal roofs will reduce the demand for shingleps and thus the pressure on fir timber. Financial support of villagers who want to invest in metal roofs would be a very efficient environmental conservation measure.

4.6 Juniper forests: a little known but endangered ecosystem and wood resource

4.6.1 Distributional range of juniper forests in Bhutan

There are two main types of juniper forests in Bhutan:

(1) The first one is largely secondary: the various forms of *Juniperus recurva* replace the fir after fire clearing. Typically, the junipers form the forest fringe around grazing places in fir forest.

Juniperus recurva forests only occur in the wetter parts of Bhutan, where *Abies densa* naturally covers all exposures, including the south-facing slopes. Here, the natural stands of *Juniperus recurva* are on rock cliffs too dry for the fir.

These juniper secondary forests are richer in vascular plant species than the natural fir forests : first, cattle imports seed of weedy herbs; second, the juniper forests are more light, especially in younger successional stages. The light favours the growth of grasses and sedges that are in turn preferred by cattle.

(2) The second type of juniper forest is largely natural on sunny slopes. It covers large areas in Northern Bhutan, in the rain-shadow areas of the Inner Valleys of the Himalayan Main Range, where the sunny slopes are too dry for the fir (*Abies densa*, see fig. 3). These

juniper forests are constituted by a different species: *Juniperus indica* (included with the synonym *Juniperus pseudosabina* in the Flora of Bhutan). Where these juniper forests are preserved, they may cover an altitudinal range of 1000 metres and more (mostly between 3600 and 4600m, being most common between 4000 and 4400m). Possibly, in the rainshadow areas East of Lunana, the highest treelines of the Himalayas occur: we found a dwarf tree of 3 metres at 4750m above Lugi Tso.

At these altitudes, there is a transition to shrubby, dwarf juniper formations, which we will deal with later on.

Juniperus indica forests are the economically most important forest type in the yak-grazing areas of Northern Bhutan. Unfortunately, their extent is not shown on the Land Use Working Maps, because juniper forests are not differentiated within the category of coniferous forests.

In NE Bhutan, *Juniperus recurva* (mainly a variety with short branchlets like the shrubby *J.squamata*) replaces *Juniperus indica* on sunny slopes above the fir treeline (Bomdeling WS: upper Kulong Chu, upper Khoma Chu; upper Nikha Chu, according to R. Pradhan (pers. comm.) also upper Mangde Chu around Dhur Tsachu). As *J. recurva* does not climb as high as *J. indica*, the vertical extent of juniper forests is much smaller under natural conditions (4050 - c.4250 m).

Mixed stands of *Juniperus recurva* and *J. indica* occur in climatically transitional areas, e.g., around Laya (upper Mo Chu) and in the NW of the upper Mangde Chu catchment (NE Wangdi-Phodrang).

Juniperus recurva var. *coxii*, the glaucous variety with long, drooping branchlets and a Tshenden-like habit, only forms secondary forests, far beyond the treeline. Naturally, it is an admixture in disturbed broad-leaved forests or on rock outcrops within the upper Hemlock (*Tsuga dumosa*) zone in the more humid areas.

In the following, we largely deal with the natural juniper forests on sunny slopes of the Inner Valleys of northern Bhutan. Here, future research should focus on because protective measures are urgently needed in the yak-grazing areas.

4.6.2 Status of Preservation

Traditionally, the juniper is a holy tree comparable to the Tshenden which is confined to lower altitudes. The local needs of the people, however,effected that there are hardly any pristine *Juniperus* forests left.

The main reason is that the sunny slopes within the forest belt are needed for winter grazing because all other slopes are snow-covered during a long time.

Consequently, most of the accessible juniper forests have been cleared by fire, in order to extend the pasture area.

A second threat to the *Juniperus* forests is their high value for fuel. The present use of juniper wood in the sparsely settled areas of Northern Bhutan is by no means sustainable : as the felling of living trees is forbidden, the trees are so heavily lopped and their trunks girdled that they die sooner or later – then being free for felling. Additionally, trees are debarked in order to have dry tinder in reach, and inconciously (or deliberately ?) injured with the knife on passing by. These practices are worst in Lingshi area where *Juniperus indica* trees have drastically been reduced already. Here, also the waste of this valuable wood for fencing is widespread.

The present over-utilisation of juniper wood is made worse because regrowth is extremely slow: relatively young trees with 10 cm trunk diameter only were up to 400 years old, according to year-ring counts (it has to be proven if these structures are proper year-rings). Trunks and branches with these dimensions are commonly used as firewood, but also tree trunks of 30 - 40 cm diameter are piled up in handy pieces in the summer grazing camps (seen in Laya area).If the age of the thickest tree trunks occurring in the same habitat as the 400 year-old "young" tree is extrapolated from these figures, one arrives at around 3000 years[3]. These old junipers of Northern Bhutan might thus well be the oldest living beings of the country. They are either burnt down on the slope, or in the yak tent, or in the homesteads. Larger and larger distances have to be made to supply the summer grazing camps with such firewood from near the treeline.

Even though it appears that large firewood stock is available in forests burnt c. 15 to 30 years ago where dead trunks remain, wood from living trees is preferred in practice.

Our rough estimation is that at least 80% of the *Juniperus indica* forests in the surveyed area (JDNP and Lunana) have been burnt 10 to 30 years or even longer ago and are now found in different regeneration stages. The information about the date of burning, given by the local herders, were rather contradictory, but the main time of forest clearing seemed to have been during the early 1960’s.

Regeneration of *Juniperus indica* and *J. recurva* is fair (even on grazed slopes) but the growth especially of *J. indica* is slow, as indicated by the narrow year-rings. Young trees or resprouters on slopes burnt 30 years ago are only between 0.6 and 1.5 metres tall. Thus, the

[3] A juniper tree of this age, however, has not been recorded yet from the Himalayas

firewood consumption and **clearing rate of juniper forests is much faster than the regrowth rate** in most areas**.**

Consequently, with regard to both, nature conservation and sustainable RNR management, the ***Juniperus indica*** **forests are the most threatened ecosystems in Northern Bhutan**.

This sad perspective contrasts with the fact that the **secondary plant formations** establishing on burnt juniper slopes are the species-richest plant communities recorded in the upper montane belt (we counted up to ca. 100 species, excluding mosses and lichens!).

So, the question is:

What is desired by the National Park Policy:

- Protection of the species-poor natural forest? (it might harbour several wildlife species such as musk deer, *char*, in summer also Takin), or,
- Maintenance of species-rich secondary formations (which include a large number of beautiful grazing weeds like *Meconopsis* and orchids, which are absent from pristine forests)?

A possible solution is the **compartmentation** of the area into zones of different landuse modes and intensity. We will refer to this below.

4.6.3 Research needs and necessary actions

Juniper forests in northern Bhutan, constituted by *Juniperus indica* (syn.: *J. pseudosabina*, auct. non Fisch. & Mey.!), a traditional holy tree, are of great economic importance for the subsistence of the local people. With growing population and rising numbers of yak these forests are increasingly endangered by woodcutting and fire. The following measures are recommended:

1. Conduct a forestry inventory of the remaining juniper populations including mapping (the present Land Use Working Maps do not differentiate juniper forests)

2. Evaluate the conservation status of the juniper forests, incl. density and extent of the populations, degree of disturbance, age of the trees, importance of the habitat for wildlife, occurrence of rare plants, etc.

3. Evaluate the relict juniper populations with regard to future modes of utilisation: standing volumes, productivity of wood in view of the slow growth as opposed to estimated demands of firewood

4. Investigate the regeneration ability of juniper forests with regard to locally necessary protection from grazing (artificial regeneration measures will probably not be necessary, as natural reseeding is fair)

5. Consider the compartmentation of juniper-wooded areas into
(a) woodlots, eventually combined with winter pasture (i.e., traditionally used juniper forests and scrub; present scrub pastures, long-established "Bepa"(*Kobresia*) pastures) between solitary trees
(b) forest reserves (core zone of protection from fire, woodcutting and grazing), according to the criteria investigated under (2).

6. Improve consciousness among the local people concerning the slow growth of the junipers and the exhausting resources. Search for substitutes in firewood (birch, willow, rhododendrons) and the propagation modes of the latter, in collaboration between the rural people and extension officers. Reconsider the rules concerning lopping and use of dead wood. Support the spread of solar devices and small hydropower units ("pico hydel").

5. What is the effect of traditional rangeland management on the high-altitude ecosystems of Bhutan (high-altitude pastures and *Rhododendron* thickets) ?

5.1 Comments on the origin of pastures and the status of *Rhododendron* thickets

First, we would like to comment on the term "Natural Pastures" as used in the Land Use Working (LUW) Maps. These pastures are natural in so far as no artificial pasture improvement (such as irrigation, fertilisation or reseeding) is done. On the other hand, the term "Natural Pasture" should not mean that these ecosystems are naturally devoid of woody perennials: we estimate that at least 95 % of the mapped "Natural Pastures" in the survey area were derived from different natural woody plant formations by livestock holders.

As outlined above, all accessible slopes we have seen in northern Bhutan are potentially forested up to 4200 - 4600 m (Fig. 3). Above the treeline, tall to dwarf *Rhododendron* thickets extend up to c. 5000 - 5200 m in all aspects except south-facing slopes, where dwarf junipers usually dominate (*Juniperus squamata, J. recurva, J. indica*, shrubby, creeping forms). The *Juniperus* colonies form mosaics with grassy patches, the latter dominating especially in dry, rocky habitat and near the upper limit of the junipers. On south-facing slopes around 5000 m, towards the upper limit of closed alpine vegetation, the only natural grasslands of the alpine belt occur.

The *Rhododendron* thickets, ranging in height between 10 cm and 2 to 3 metres, with much varying cover degrees, are mostly classified as "scrub forest" in the LUW maps. "Scrub forest" is classed with the broad category of forests in these maps. In this way, the area covered by forests is considerably overestimated (e.g., Gasa Dzongkag: the Atlas of Bhutan(1997) sums up 144,872 ha of "forest" out of which 62,352 are "scrub forest". If this area is subtracted, the true forest cover is reduced to 82,520 ha. Especially in N Bhutan, further ground check will facilitate a specification of vegetation types.

Among these scrub formations, only those *Rhododendron* thickets formed by tall broad-leaved species are usually **not** converted into pastures (see below). All other alpine woody formations are used as summer pastures - with the herders' desire to reduce the woody components in favour of palatable herbs. For this purpose the easiest tool is **fire**.

So we can state that a large proportion of high-altitude pastures have been established by fire-clearing. They are maintained by grazing, trampling, woodcutting and locally by reburning.

The above-mentioned large-leaved *Rhododendron* thickets (*Rhododendron aeruginosum, R. whightii, R. bhutanense* being most common) are still largely untouched by humans and their domestic animals. The main reason is that they grow on shady slopes, thus being snow-covered in winter and not easily set on fire. The wood, however, is patchwise cut for fuel purposes around settlements and summer camps.

Some remarks on this formation are worthwhile, as it covers important areas:
There is no plant formation we have seen in Bhutan that is poorer in flowering species (less than 10 usually).These plant communities bear an unknown (but higher) number of mosses and lichens and harbour an unknown number of wild animals. One of these is undoubtedly of great economic importance: the musk deer. Furthermore, quite a number of birds chose this habitat.
This 0.5 to 3 m tall scrub is still a largely pristine ecosystem. It covers extended areas between 4000 and 4800 m and is virtually unknown scientifically.

5.2 Main physiognomic pasture types

The pastures derived from the dwarf *Rhododendron* and the juniper formations vary a lot in structure and floristic composition. We have listed the main physiognomic types below, without going into details. It is important to note, however, that the best pastures are derived from the juniper formations on the sunny slope, in close contact with the natural Cyperaceae mats occurring in the upper alpine belt. These are probably also the oldest pastures.

(1) Tall-forb pastures derived from forests

These formations are mainly used as winter pastures. They are derived from juniper forests (rarely from spruce and fir forests in the wetter areas, or at lower altitudes) on sunny slopes. Among all pastures, they are richest in flowering plant species (maximum at least 100 per plot; species number increasing with the age of the successional stage after fire, if scrub encroachment and tree regrowth take place). Non-graminoid herbaceous plants dominate, of which only small proportions are preferably grazed. The standing biomass of these pastures is high, and hay making is therefore widespread in these formations.

(2) Pastures dominated by rosette plants and grasses

These pastures represent later successional stages after fire-clearing of subalpine coniferous forests on sunny slopes, under the impact of a higher grazing pressure than in type 1 (often used as winter and occasional summer pasture). Rosette plants replace the tall-forbs; grasses (Gramineae) are favoured by the light; they increase the value of the pasture. Species richness is still similar to that of type 1.

(3) Cyperaceae-dominated pastures with rosette plants and creeping *Cotoneaster* on sunny slopes

This is an obviously long-established pasture type on sunny slopes between 3700 and 4800 m.

Most characteristic is a more or less closed, solid turf layer built up by sedges (*Kobresia* spp.,called "Bepa", i.e.,"Tibetan grass", in Laya area). The turf is quite resistant to trampling, thus protecting the underlying soil from denudation and erosion. Moreover, the "Bepa" grasses are more resistant to grazing and trampling than the Gramineae, even though preferred by the yaks. These properties are mainly responsible for the high value of this pasture type. Relatively high stocking rates are possible without severe risks of erosion. In many places these pastures are grazed throughout the whole year, with peaks of grazing pressure in winter (lower altitudes) or summer (above c. 4200 m).

The number of flowering plants present in these communities varied between 40 and 60 in most of our records; it is slightly higher than in the natural grasslands and much higher than in the natural woody juniper formations.

In most locations, it is evident that these *Kobresia* grasslands have replaced former juniper forests and juniper dwarf-scrub of unknown density. It is unknown whether the junipers were removed by fire or woodcutting plus high grazing pressure. Unfortunately it is not known either since when these pastures developed. Consequently, one cannot predict any time scale for the establishment of the *Kobresia* pastures from the natural forest and scrub formations. It is even uncertain whether *Kobresia* pastures will still develop from the present earlier succession stages after fire (pasture types 1 and 2) : the present, old *Kobresia* pastures might have developed under climatic conditions different from the present ones.

(4) Dwarf-shrub - dominated pastures

These pastures are mixed herbaceous and woody formations of different origin. Two types are most comon:

(a) Grazed, fire-cleared sunny slopes invaded by weedy dwarf-shrubs (*Rhododendron lepidotum* being most common). There are transitions to the pastures rich in rosettes and grasses(type 2); species numbers may be similarly high. The grazing value is low; herders tend to abandon these pastures in search for better ones. Due to the lack of a closed herbaceous cover the slopes are susceptible to erosion in many places.

(b) Grazed natural alpine *Rhododendron* dwarf-shrublands with Cyperaceae and rosette plants. These pastures have similar herbaceous components as the Cyperaceae-domiated ones (3), but they grow in all aspects except the strict south exposure and have important cover degrees of dwarf rhododendrons (*Rhododendron setosum, R. anthopogon*), creeping willows (*Salix* spp.), and tall *Kobresia* sedges (*Kobresia nepalensis*).

The cover percentage of *Rhododendron* dwarf-shrubs is reduced by trampling if stocking rates are high. This may favour the spread of Cyperaceae but also create much open soil. The latter process facilitates erosion processes and landsliding on steeper moraine slopes. The quality of this pasture, therefore, largely depends on stocking rate, dwarf-shrub density and slope degree. Accordingly, also the number of plant species varies a lot.

There are, of course, numerous further pasture types which can be specified in a proper classification following thorough field studies.

One of these should be mentioned because of its large extent: *Kobresia pygmaea* mats, a high alpine type of sedge grassland in the rainshadow areas of NW to N-central Bhutan. These usually grow above 5000 m, where the seasonal frost movement of the soil is strong enough to keep the plant cover open. The dominant sedge remains as low as 0.5 to 1 cm at these altitudes, thus beyond the reach of grazing animals. The dwarf-shrub *Rhododendron nivale* and cushion plants are the dominant associates. This vegetation type is of very low grazing value. In rare cases summer grazing places are established here, merely some favourable locations are grazed (streamsides, *Kobresia schoenoides* - dominated swamps). A strong grazing pressure in the Cyperaceae-dominated pastures of lower altitudes (type 3), however,effects the spread of *Kobresia pygmaea*. Here, it grows up to 4 cm tall and constitutes one of the tough and valuable "bepa" sedges on firm turf resistant to trampling.

5.3 Traditional rangeland management versus nature conservation policies

When traditional grazing management in northern Bhutan is evaluated, it has to be borne in mind that the present yak numbers and concentrations are a fairly recent development (see also Gyamtsho,1996,2000). In the past, there was no need for any systematic pasture improvement in order to increase the carrying capacity of the delimited grazing territory. Still today, the strategy how to feed more animals is traditional: new pastures are opened by fire, instead of maintaining and improving the existing ones.

Example: one herder from Laya wished to fire-clear *Rhododendron* dwarf-scrub on steep moraine slopes in order to expand his pasture, but he did not use a former juniper forest area burnt some 15 years ago, which is now being encroached by *Rhododendron lepidotum*.

This shows that the mentality of these herders is still that of a shifting existence with seemingly unlimited resources.

These remarks should not be misunderstood as a moral disqualification of the yak herders: it is only attempted to categorise this stage of landuse development in common terms of comparative environmental history.

If a pasture deteriorates in this most extensive stage of landuse development, one just opens a new one by burning. After more or less all south-facing slopes are cleared by fire, it can be foreseen that the up to now untouched large-leaved *Rhododendron* thickets will be fire-cleared for grazing.

The impression was gained during the survey that the yak-herding societies within JDNP are in a phase of accelerated establishment of new pastures since the early 1960's, and this phase goes on.

According to the herders' information the main bottleneck is the availability of winter forage. Growing demands of winter pasture will increase the pressure on the remaining juniper forests on south-facing slopes. This also applies to *Juniperus recurva* forests of NE Bhutan (Bomdeling WS).

5.3.1 In which habitat is burning an appropriate measure to improve pastures ?

We have to admit that we found **no** evidence that fire-clearing is **the only** appropriate tool for the initial opening or maintenance of pastures.

Fire-clearing is certainly **unfortunate** in the following habitats:

(1) *Rhododendron* thickets on steep shady slopes, especially on morainic slopes steeper than 30°:

Due to the fact that natural *Rhododendron* thickets lack any herbaceous undergrowth, the slopes will be subjected to land slipping and erosion before a pioneer vegetation can establish itself, especially if they are grazed immediately after fire. We have seen landsliding on morainic slopes burnt 13 years ago; those slides are still expanding due to trampling effects. It is alarming that the substrate movement is faster than the recolonization by plants in this habitat.

(2) Boulder slopes with only small or missing soil pockets:

There is definitely no use in burning thickets on rock-dominated slopes. With the woody plants, the moss cover of the boulders is removed, and what follows is a very slow recolonisation by lichens and mosses, by ferns and other unpalatable tall forbs. The sparse sedge vegetation that will establish in the few soil pockets after several decades is not worth the destruction of virgin biotopes. Furthermore, there is an increased danger of intensified rockfall in case the slopes are steeper than 35°.

On the other hand, fire-clearing might improve the grazing value in the following vegetation types:

(1) Dwarf *Rhododendron* scrub in all aspects except south exposure (*Rhododendron anthopogon,R. setosum*):

If these shrublands are already open (naturally or due to grazing) and interspersed with sedges, and if the slope degree is less than 30°, burning might be a quick and easy measure to favour the growth of Cyperaceae. A similar effect, however, might also be achieved by an increase of the stocking rates, because the above-mentioned rhododendrons are sensitive to trampling.

From many areas it is known that the ashes provided by burns have a fertilising effect especially on grasses, and the Laya herders questioned supported this view, but no respective analyses are available from the yak pastures of Bhutan.

(2) Dwarf juniper thicket-grassland mosaics on south-facing slopes:

Junipers have the value of grazing weeds because they are not browsed. If they are burnt, pioneer herbs and grasses rapidly invade from the surrounding alpine mats, soon followed by sedges. The same effect, however, is also achieved by cutting the shrubs manually; the juniper wood, moreover, is valued as fuel in summer grazing places. In view of the firewood shortage in the summer grazing areas, it is irresponsible to burn down these resources. Recolonisation of the junipers after fire is very slow, whereas careful lopping will safe the individuals and allow them to regenerate faster from coppices.

(3) Reburning as a tool against scrub encroachment on sunny slopes:

Cyperaceae-dominated pastures with rosette plants (type 3) tend to be encroached by weedy *Rhododendron lepidotum* dwarf-shrubs and creeping shrubby *Cotoneaster microphyllus* (pasture type 4), at the expense of the highly valued Cyperaceae. In these cases **re**-burning of the **once-established** pasture areas might be a useful tool in order to favour the sedges and the palatable grasses.

We did not come across any example of this reburning measure in Laya, but in Lunana it seems to form part of the traditional pasture management. **Mechanical clearing** of *Rhododendron lepidotum (R. nivale* at higher altitudes) is an additional, effective practice here; the dwarf-shrubs are not destroyed on the spot but used for incense and for lighting fire.

Within the forest belt, the main **legal constraint of reburning** bush-encroached winter pastures is the fact that trees have grown up since shifting cultivation and burning were banned: these lands are now under forestry laws, and the pasture is lost.

Former pastures that are now re-occupied by trees but still of higher value as a pasture than for forestry purposes might be worth to remain pure pasture areas, with permission to remove woody perennials for pasture improvement. If the carrying capacity of these pastures is increased in this way, one can afford to protect other parts of these forest areas as forest reserves.

Summing up, we are aware that both measures of pasture maintenance and improvement suggested here, **fire and rhododendron cutting**, are "hot issues" in Bhutan, as burning has been banned since 30 years, and all rhododendrons are protected species. Yet, it is worth reconsidering these practices with regard to a more intensive use of the existing pastures, in favour of other areas to be left completely undisturbed. This has been suggested by Gyamtsho (1996, 2000) earlier. These suggestions are being picked up at present by the administration boards of JDNP and BWS. The set-up of experimental burning plots is in process. It should be stressed that the populations of the questionable weedy *Rhododendron* species are far from being threatened by over-utilisation or burning, even in the main areas of incense collection (Laya).

5.3.2 How to feed growing numbers of livestock without any expansion of the present pastures ?

5.3.2.1 Overgrazing versus undergrazing: the problem of unknown carrying capacity of high-altitude pastures of northern Bhutan

The problem of growing yak herds is illustrated by the following example from Laya: One herder's father bought 6 yaks some 30 years ago. They roamed freely about in unburnt *Rhododendron* dwarf-scrub. The herder's son today owns 67 yaks and feels the need to open new pastures by burning *Rhododendron* thickets untouched so far. This trend runs into conflict with the National Park policies, aiming at the conservation of the *status quo* and the protection of natural biotopes.

We are convinced that this problem can be solved, as similar conflicts have been solved in other countries.

Our impression is that the present numbers of yak can be fed on the existing pastures without any expansion. It can be assumed that the pasture deterioration complained by the herders, and the recorded high proportion of grazing weeds, are mostly the effect of **under**grazing rather than **over**grazing.

Indeed, the Laya herders designated most of those pastures as "high quality pasture" that have high stocking rates (enquiries undertaken by JDNP). The question is: are these pastures naturally favourable, sustaining high numbers of livestock, or did they improve under high grazing pressure? In fact, experiences gained in practice and long-term research in other countries gave clear evidence that high percentages of grazing weeds and scrub encroachment are favoured by **under**grazing rather than **over**grazing: Relatively few animals roaming freely about the pastures have the so-called **selective grazing habit**. This is known by every herder, and the effects are well-investigated: in an unlimited pasture, the animals can select those plants which they like best in each season. This leads to the result that the growth of the least palatable plants is indirectly favoured; these are the "**grazing weeds**" (most common in the surveyed area : *Rhododendron lepidotum, Cotoneaster microphyllus*, tall Compositae, *Potentilla* spp., see Table 1). Among these, however, there are only a few truly poisonous plants: herders confirmed that in great need (in winter or early spring, when the grasses are dry or eaten up) nearly all species are grazed.

Thus it is imaginable - and documented in other areas through experimental research - that also the "grazing weeds" are eaten if the stocking rates are high enough. In consequence, those pasture plants that are resistant to trampling and able to regenerate quickly , may spread. Luckily, this applies to the most valued "Bepa" Cyperaceae (*Kobresia* spp.), which create the protective turf layer on the topsoil. Observations support this assumption: animals' trails crossing ”undergrazed”, extensive pastures (dominated by forbs and rosette plants and encroached by shrubs) are frequently covered by dense mats of Cyperaceae of high grazing value. Trampling is probably the decisive factor here, but the local high grazing pressure and fertilisation may also play a role.

From this viewpoint it is well probable - even though not proven - that the "high quality pastures" in Laya and Omtsa, for example, have been created through a high grazing pressure. Scrub encroachment is negligible here, but fire has not been used for pasture maintenance as long as people remember.
The **maximum carrying capacity**, however, is still unknown and varies a lot in dependency of the site conditions. It is certainly highest in the valley grounds (favourable habitat of limited extent) and in the "Bepa" pastures on *Kobresia* turf on sunny slopes. It is interesting to observe that the freely roaming yaks clearly concentrate on those parts of a Tsamdrok which are generally qualified as overgrazed: the short Cyperaceae sward with dominating rosette plants. This seems to be the best proof for the assumption that the carrying capacity of these pastures is not reached yet.

Of course, there are **limitations in the increase of the stocking rate** even in these favourable habitats: true long-lasting overgrazing will result in

- the retreat of "Bepa" sedges (locally observed and noticed by the herders in the communal pastures above Laya and Lunana)

- the subsequent destruction of the protective turf layer and erosion of the exposed subsoil (on steeper slopes)

- the increase of cover percentages of those herbs that are too small to be reached by the grazing animals (e.g.,*Cotoneaster microphyllus, Rhodiola cretinii, Polygonatum hookeri*, *Leontopodium* spp., at higher altitudes also *Kobresia pygmaea*, see Table 1).

The general carrying capacity is certainly exceeded if trampling damage removes eventual turf layers and major proportions of the vegetation cover; if either annual weedy plants (Chenopodiaceae, Boraginaceae, *Cyananthus hookeri*) or thallophytic pioneers (liverworts, lichens) dominate on open soil, or open soil even remains barren and is eroded downslope. In this case an **irreversible degradation** of the pastures takes place.

These symptoms of overgrazing are still of very local extent within the JDNP and BWS. A large-scale degradation process can actually be observed in the drier "Bepa" pastures of south Tibet, under the drastic increase in yak numbers following the "get rich" policy in Xizang (Miehe & Miehe, 2000).

In the yak pasture areas of northern Bhutan, however, we gained the impression that the experience concerning the limits of the carrying capacity is not widespread : on one hand, herders complain not to have enough grazing grounds. On the other hand, we were rarely told any ecological reason for the time the summer camps are changed: the most common argument given was the muddiness of the ground around the tent. (Gyamtsho (2000), however, who worked for a longer time in the area, in closer contact with the local people, gathered other criteria: a pasture is changed when only "grazing weeds" (the less palatable plants) are left and milk yields drop significantly. The latter criterion is indeed a valuable ecological indicator for temporary pasture exhaustion, but not necessarily for its degradation.

In general, more attention should be given to the differentiation between these two phenomena (especially when discussing with local herders): temporary pasture **exhaustion** should not be mixed up with long-term **degradation** processes outlined above. If herders shift to the next grazing place, because ”all plants are eaten up”, this is not necessarily an indication of overgrazing. On the contrary, in certain habitats it might be beneficial for the pasture to force the animals to graze everything, including the ”weeds” (principle of a well-maintained rotational pasture). Decisive for the sustainability of a pasture is the length of the regeneration period (ungrazed). Hence, pasture degradation in N Bhutan was mostly observed within the forest belt, where winter pastures are also grazed in summer to some extent, and where there is no time for the grasses to regenerate.

5.3.2.2 Recommendations: Chances and constraints of intensifying yak husbandry in northern Bhutan

5.3.2.2.1 Increase of stocking rates on suitable pastures undergrazed so far

In order to search for solutions in the conflict between National Park policy and the local herders' demand, the intensification of pasture management is a neccessity. We suggest an experimental, controlled increase of stocking rates in suitable summer pastures undergrazed so far, especially in **"Bepa" pastures on sunny slopes** (e.g., scrub-encroached parts of the summer pasture on the higher slope above Laya (demonstration effect, easy access for monitoring), or in Rodophu. Also parts of the valley grounds can be more intensively grazed (e.g. in Limithang).

> A critical case are the 15 - 30 year-old successional stages after fire, replacing juniper forests on sunny slopes. These plant communities are mainly used as winter pasture. Here, encroachment with *Rhododendron lepidotum* is faster than the spread of the valuable "Bepa" sedges under present stocking rates and climatic conditions (*R. lepidotum* is fairly resistant to trampling, except in seedling stage). As mentioned above, we cannot conclude from the excellent "Bepa" pastures that formed during several centuries in ancient forest clearing areas like Omtsa and Laya that the same type of pasture will still develop on the young clearings, and we do not know either how long it takes and which stocking rates favour this transformation best.

The following experiments can help to answer these questions:

Trial 1: Graze the existing pasture with higher stocking rates

Trial 2: Reburn the pasture to reduce the rhododendrons, leave ungrazed for 3 years and graze with successively increasing stocking rates; in a variant of this trial sowing experiments with "Bepa" seeds collected in the wild can be made, in order to accelerate the pasture development (see below).

Concerning the quasi-natural, very extensively grazed ***Rhododendron setosum* summer pastures** which herders burn in silence or desire to burn, we can also give the recommendation to increase the stocking rates. There are environmental limitations, however, that are serious constraints for pasture intensification in this habitat: on stable ground, the maximum slope degree should be around 30°, on moraines 20 - 25° in order to prevent erosion and landslides. **Burning** is probably unnecessary because *Rhodododdendron setosum* is sensitive to trampling. Around the campsites of summer grazing places one can observe how trampling, high grazing pressure and manuring convert the *Rhododendron setosum* scrub into a dense, short sward of graminoids of high nutritive value (these are level or weakly inclined, strongly manured sites, however, that cannot be compared with open, steep slopes). Along the animals' trails, a similar development of Cyperaceae mats at the expense of the rhododendrons can be seen. These examples show that trampling can be a measure against encroachment by the more sensitive rhododendrons (*R. setosum, R. anthopogon*). The cover degrees of these dwarf-shrubs can be further weakened by **lopping** : the leaves are one of the sources of incense, but normally only the terminal leaf rosettes are cut. In consequence, the shrubs develop new shoots the following year, growing even more densely. If the shrubs are cut at the base, this would be a more effective **mechanical means of pasture improvement** where it is desired. The wood can be used to light fire, and the leaves for incense. This is an effective practice in Lunana.

Precondition for all experiments concerning the intensification of rangeland management is a proper **documentation**: eventual burning, counts of yak units and the monitoring of the vegetation changes have to be conducted or at least controlled by external instances (not by the herders themselves; this would resemble the situation created by a bank accountant doing his own auditing !). Proper monitoring of vegetation changes requires the demarcation of permanent observation plots and a monitoring team familiar with the flora (floristic knowledge of the herders is limited; especially for graminoids there is often one name for different species).

There are major **difficulties** to be overcome in order to undertake pasture intensification measures:

Yak are not herded in NW Bhutan; they are semi-wild animals which go where they want. Thus, grazing experiments with definite stocking rates on delimited plots can only be conducted by means of **fencing**. Choice of yak-safe fences and installation of these fences on sloping, uneven ground is a technical problem. Wooden fences should be avoided in due course.

The **lack of herding** is a real constraint also to the desired site-specific measures of pasture improvement: yak cannot be forced to stay in a certain scrub-encroached pasture area for the purpose of trampling down the shrubs and eat unpalatale herbs; they just go away because they do not find enough palatable plants. Without fencing or the nomination of reliable responsible herders it will also be impossible to exclude a pasture periodically from grazing for regeneration purposes.

It will be worthwhile to find out whether lack of labourforce is the main reason for missing herding practices. Skillful rotation systems supported by herding could certainly improve the existing pastures. It is true that the change of summer camps can be understood as a kind of rotational grazing system. Yet, within a certain summer grazing area, the animals are sent to changing slopes every morning but are then left uncontrolled. Communal grazing grounds in the village areas are never given any rest period.

5.3.2.2.2 Further measures of pasture improvement

There is hardly anything to add to the recommendations given in Gyamtsho's (1996) dissertation. A few comments will be made to the ecological recommendations given on p.218, op.cit.:

<u>"…improve soil fertility":</u>
It is doubtful whether the application of artificial fertilizers will become a common feature on open pastures, as they are hardly afforded for the cultivation of staple cereals

- None of the fertiliser legumes experimentally introduced by Dr.Pema Gyamtsho in Laya became naturalized, except the White Clover in favourable places. More should be known about the indigenous legumes (e.g., *Vicia tibetica*), the propagation of which would be less risky from the biodiversity conservation point of view.

- An easily applicable method of pasture fertilization is the following: don't collect yak droppings from the pasture ! In case they are heaped around the summer pasture camps in order to reduce muddiness, they should be dried properly and spread in small pieces on the pasture, instead of being left to rot near the campsite. This was also stressed more recently by Gyamtsho (2000).

<u>"…improve grazing management by:…"</u>

- <u>Establishing hay meadows</u>: Experiments launched by Gyamtsho (1996) go on in the area, but protected, irrigated and manured artificial hay meadows compete with the cropped fields in the village area, not necessarily regarding space (there are many abandoned fields) but possibly labour input. The Layaps did not extend their improved hay meadows on their own initiative; the experimental plots above the village are abandoned. Vast winter grazing areas or rocky slopes are traditionally used as natural hay meadows. Yet, the forage is cut in late autumn only, when it is dry and most of the nutritive value is lost. As the main constraint for cutting the meadows in summer was given the high humidity: the hay would rot in the tree crowns where it is traditionally stored. A major improvement of the winter forage would be achieved by **hay making in summer**, combined with drying and storage on simple stands as they are used in comparably wet monsoon areas of SE Tibet and in the European Alps (Fig.4). The summer date of hay making would simultaneously improve both, the winter pastures and the forage, as weedy tall-forbs would be reduced in favour of grasses. The question is if the labourforce necessary for hay making is available during the cropping period. The use of scythes instead of sickles would safe some time in meadows of sufficient extent and accessibility.

- Improve rangeland vegetation through reseeding: For reasons of biodiversity conservation and site adaptation, we plead for pasture improvement trials with **indigenous species** that have high grazing and soil conservation values and low demands in fertilisers:

    - "Bepa" sedges (*Kobresia* spp.) reseeded on young (10 to 30 years) successional stages of the pasture after fire-clearing of juniper forests on sunny slopes, in order to accelerate their colonisation
    - creeping *Cotoneaster (C.microphyllus*) planted on landslide areas of sunny slopes up to 4800 m for substrate stabilisation purposes (this is a noxious weed in pastures, however, but it has excellent slope-stabilising properties where *Kobresia* turf is missing)
    - *Carex* spp. (*C. haematostoma, C. nivalis* and others) reseeded on landslide areas of shady slopes as palatable pioneers (creeping *Salix* spp. would be more effective in soil fixing, but they are not grazed).

There are, however, no experiences regarding the cultivation of these species yet. This concerns the timing of seed collection in the wild (in one go with hay making ?), germination rates (possibly the main mode of expansion is vegetatively in rhizomatous sedges ?), and necessary periods of protection from grazing. The latter is an essential precondition for all reseeding measures; this leads us back to the fencing/herding problem.

6. Remarks on Wildlife

We have been asked to note all sightings of wildlife, and we did so continuously during our surveys, especially during monsoon (June-September) in the JDNP.
The most thrilling encounter we experienced in the BMNP in 2500m when we heard the grunting of a nearby tiger who obviously was annoyed that we used "its" pond for fetching water.
Interviews with local herders about the presence/interference of wild animals were frustrating throughout and thus worth to communicate: Predators were mentioned freely but one animal was constantly not mentioned, even though droppings in the forest gave clear evidence of its presence: the musk deer. This clearly points to the economic value of the animal. The local herders were obviously scared to give proper information on the base of which their interests in the use of this animal might be disturbed.
In the context of **wildlife-human interaction issues** the following observations may be worth to communicate here:

Vegetation records in grazed and in untouched forests clearly revealed that **leeches** follow man and his cattle: the density of leeches is significantly higher in grazed forests. Missing leeches in sufficiently humid areas, however, may also indicate very poor or absent populations of wild mammals.

The question of **wild animal - livestock competition** in fodder resources is a challenging issue in National Parks.

Our observation on the grazing competition between **Blue Sheep** and **yak** are limited, but it was obvious, that both animals have very different grazing habits: Yaks graze nearly down to the ground, whereas Blue Sheep tend to nibble like goats. Both prefer *Kobresia* spp. Surprisingly, most of our Blue Sheep sightings were made in intensively grazed pastures and not in remote ungrazed *Kobresia* patches at the upper limit of alpine vegetation, as we had expected.

Again, the preference of Blue Sheep for intensively grazed pastures may underline the conclusion that these pastures are not overgrazed. We had the impression that Blue Sheep profit from the fact that man has transformed forests into grazing grounds: larger parts of the Blue Sheep habitats are part of a cultural landscape.

The question arises if they really prefer these pastures or rather search the near of man where the occurrence of predators and poachers is reduced. This explanation is supported by the rare or missing sightings of Blue Sheep in the remote areas of JDNP.

Marmots are widespread in parts of Northern Bhutan, especially in Lingshi and Laya gewog. We did not find any marmots in Lunana gewog or on the high grounds north of Nikachu, nor in NE Bhutan (they are reported to occur E of Me La, though).
Marmots are clearly concentrated near summer grazing places, but not in winter grazing areas. They obviously search the vicinity of man and his cattle and they prefer the sunny slopes. The burrows are dug where yak have their chafing sites or where the trails have opened steep banks in the soil. The thrown-out soil and stones cause a severe damage to the pastures. Despite the fact that marmots damage the intensively grazed pastures close to the tent or house, people tolerate their presence, even though they regard them as a pest because the yaks break their legs in the burrows.

This coincidence of strongest grazing pressure and highest population densities of small mammals is a well-known problem in many pastoral landuse systems. The causes are not understood yet.

7. The biodiversity and endangered/rare plants issue

7.1 General comments on ”biodiversity”

Since the early 1990s the usage of the term ”biodiversity” had an explosive development in the popular press, governmental reports, scientific papers and meetings. In many projects related to environmental conservation, ”biodiversity” has become a value of its own, and it is little asked what one is dealing with. Therefore, it seems to be appropriate to outline the meaning of this term in general, and for the purposes of environmental conservation in special. These remarks are partly condensed from Miehe and Miehe 1998.

7.2 What is biodiversity?

Bio-diversity in the strict sense means ”variety of life”. This is by far more than the number of plant and animal species: within a certain population, it comprises the genetic/phylogenetic variety; within a community, it includes aspects such as the diversity of species, life forms, trophic groups, food webs and dynamics in time and space. On even larger scale (i.e. one country, district or project area with different habitat types), the variety of habitats can be an expression of biodiversity ("β-diversity", in contrast with "α-diversity" referring to the biological variety within one habitat type).

This means that species richness, which is commonly equalised with biodiversity, is only one aspect of the variety of life. For instance, a herbaceous pasture can be rich in flowering plant species but structurally poor, whereas forests may be composed of a smaller number of plant species but are structurally more diverse, providing a larger number of micro-habitats.
Given this comprehensive definition of biodiversity, it is clear that the measurement of this complex is extremely difficult and labour-intensive. Numerous scientific working groups were established in order to develop feasible approaches.

For the time being, only some facets of biodiversity can be quantified, not the biodiversity per se. The choice and derivation of a measure will depend fundamentally on the use to which it will be put (GASTON in GASTON 1996).

7.3 Is a high biodiversity the ultimate goal for environmental conservation?

The term "biodiversity" is most often used in connection with concerns over the loss of the natural environment. In the context of environmental conservation issues, biodiversity is not a neutral scientific concept but perceived as a value, or as having a value: in many communities there is general acceptance that "biodiversity is per se a good thing, that its loss is bad, and hence that something should be done to maintain it" (GASTON in GASTON 1996, p. 5). But which aspects of biodiversity one has in view in each case? Mostly diversity issues are connected with the aim to maintain or increase the number of species. Often the decisive argument for conservation measures is the preservation of one or several endangered/endemic and attractive plant or animal species, no matter if these are indicators of habitats influenced by man or more or less natural environments, for ecologically stable or instable ecosystems.

When the aim of project activities is the conservation or increase of species richness, it should be borne in mind that **species richness is only one facet of biodiversity** and that the pure number of species is less instructive than the information **which** species are present: for instance, distinction has to be made between levels of species richness which can be regarded as native (= naturally evolved) and as artificial (= human generated). Thus, areas rich in species do not necessarily have high conservation priorities.

Conservation priorities should embrace other considerations such as the maintenance of the integrity and function of ecosystems, the diversity of habitats/landscapes and the level of threat of the ecosystems in question.

Yet it is not generally proved that the level of biodiversity can be used as a measure of environmental stability. The relationship between biodiversity and the functioning of ecosystems is still little understood. For instance, if conservation measures focus on watershed regulation: does it matter if this task is done by a plantation forest or a more diverse natural one? (LOVEJOY in HAWKSWORTH 1995). The same applies to the relation between biodiversity and the stability of an ecosystem. There are some indications that more diverse ecosystems have a stronger resistance in case of environmental disturbance, but there are also examples which point to the contrary (see also Gyamtsho1996, p.166). The response of a certain ecosystem largely depends on the nature of the disturbance (natural catastrophes of cyclic or periodic occurrence of ”modern”, human-generated influences, Ellenberg 1996).

Summing up, the question if high biodiversity levels are the ultimate goal for environmental conservation measures, cannot be answered straight away. The answer depends on the extent of the area under concern and the main purposes of the conservation measure.

7.4 Human impact on biodiversity

If species richness of the vegetation is taken as a simple indicator of biodiversity, as it is convenient to do as long as the ecosystems of Bhutan are not better known, we can draw the following conclusions from the examples given earlier:

Whether the floristic richness of an ecosystem increases or decreases under the impact of humans and their livestock, depends on

- the degree of interference
- the natural vegetation type.

We have seen that in naturally species-rich ecosystems, such as the warm and cool broad-leaved forests, disturbance (in the form of burning or mechanical clearing or grazing) tends to **reduce** species richness. The most drastic examples are:

- the conversion of warm broad-leaved forest into Chir Pine/grassland savannahs

the replacement of cool broad-leaved and Hemlock forests into Blue Pine ”Monocultures”.

The hypothetical decrease of species richness with increasing human interference is schematically shown in Fig. 5a.

Species that invade these secondary formations in the course of the grazing activities are common, widespread grasses and grazing weeds.

The inverse phenomenon is observed in the upper montane and lower alpine woody plant formations which are naturally poor in flowering plant species: here, disturbance **increases** the floristic richness, due to better provision with light and the destruction of the moss cover. There is not only an increase of common weedy species, but also of those plants that are quite rare in natural habitat, for example (lady - slipper) orchids or light-demanding rhododendrons.

Of course the curve of species numbers in relation to the degree of interference is not rising without any limitation here (Fig. 5b): species numbers are highest in later successional stages after fire and in scrub-encroached pastures where mosaics between herbaceous and woody components occur (= shady and sunny micro-habitats).

In most intensively grazed areas, species richness tends to decline again, but extremely impoverished communities are restricted to the immediate vicinity of grazing places (livestock resting places) or landslide and chafing sites.

This shows that it is impossible to generalise the human impact on floristic diversity in Bhutan.

Concluding, we would like to stress again that

- species richness is only one facet of biodiversity
- the absolute number of species is ecologically, and also from the conservation point of view, less important than the information **which** species are present.

Thus, the increase in species numbers is not in any case desirable. (Example: the invasion of grazing weeds into a pasture might push away rare species sensitive to trampling). The difficulty is that the frequency of plant species in Bhutan is still insufficiently known (we will refer to this below). This is a major problem for any nature conservation policy.

What to do before the distribution of plants is better known?

A reasonable compromise for the practices is the **fragmentation of distinct watershed areas into compartments of different focuses and intensities of natural resources utilization:**

- intensive pasture
- extensive pasture with other uses of the woody components

- forests used for provision with wood and non-timber forest products
- so far little disturbed vegetation units under complete protection.

This so-called "Schindele model" was introduced in Wangduephodrang by the Bhutan-German RNR Development Project (BG-SRDP) and got a wider application in Bhutan in the meantime.

A meaningful compartmentation increases the β-biodiversity (= variety of landscapes). Possible (not yet known) species endangered by over-utilisation can be preserved, and a variety of more or less human-influenced landscapes can be created or maintained.

7.5 Comments on the "endangered/rare plants" issue

It is a common habit to compile lists of endangered and rare plants in appendices of management plans and related papers.

According to our rough impressions gained during our 4-months fieldwork in subalpine to alpine areas of Northern Bhutan we can say that probably very few of the mentioned species are really endangered.

Most plants are either not specified (genera given only) or weedy widespread herbs like *Podophyllum hexandrum, Cypripedium himalaicum* or *Pterocephalus hookeri.*

Certainly there are truly rare plants to be expected. Two of them are well-known: *Fritillaria delavayi* and *Cordiceps sinensis*. Both are naturally rare and heavily collected for their medical use. As the ecology and distribution area of *Cordiceps* is still largely unknown it is impossible to assess the degree of threat to Gyazagombu. The same applies to other medical plants, to wild animals of economic value, respectively.

The Gyazagombu issue is a clear example for the fact that ecological research is a necessary precondition for nature conservation management.

For other rare plants the frequency is not yet known because they have an unknown, local economic value, or none at all. Among the latter, there might be some high alpine endemic plants of Bhutan.

One of the most prominent endemic plants of Bhutan is on the best way of becoming endangered. This is the National Tree, the Tshenden.

What is to be done to improve the situation?

It is trivial to state that an assessment which plant is rare and/ or endangered can only be made after a **complete region-wide floristic inventory,** square km by square km. This will take years or decades, depending on how many botanists are involved and how many species are being mapped. Interviews of local people cannot replace such inventories, even though some information about plants of ethnobotanical value given by local herders and collectors might be of substantial value, but there is again the risk however, that wrong or

insufficient answers are given because people are scared of possible negative consequences.
A major constraint for this important inventory is the lack of sufficient botanically trained research staff in Bhutan. This affects not only field records but also the connected evaluation (scientific identification of plants collected in the field). There is still no single list of medicinal plants of Bhutan which offers proper, definite scientific names besides the local ones. This is an unbearable situation in view of the great importance Bhutan´s flora has in traditional medicine. Already now, the present volume of plant material collected in the course of various RNR- and biodiversity-related field studies exceeds by far the working capacity of the few botanists in the country. **There is an urgent need for the increase of botanically trained staff in the National Biodiversity Centre and related research institutions (RNR-RCs).**

8. Conclusions and recommendations

We think to have enough experience in Himalayan ecology to state with certainty that reliable data, necessary for a responsible management of natural resources, need time and thoroughness to be gathered. It is misleading and irresponsible to urge the investigator or the concerned institutions for quick results.

The preliminary results of 8 months of joint Bhutanese-German fieldwork, as presented in the previous sections, mainly concern two main practical issues:

(1) the conflict between human needs to utilise natural resources and the nature conservationists' desire to preserve Bhutan's unique biodiversity levels

(2) the need of a growing population to develop sustainable means of RNR utilisation.

Even though scientific proof, specification and quantification is still lacking, some general phenomena are clear and will be summed up in 8.1. Main knowledge gaps that make practical implementations difficult are summarised under "research needs" (8.2).

8.1 Rural RNR utilisation versus demands of sustainability and conservation

Only in the centres of ancient settlement in Bhutan, the natural vegetation has been completely removed or transformed. The Blue Pine ecosystems in the middle montane belt and the Chir Pine belt at lower altitudes are the most famous examples. In these areas, agriculture has so much expanded and natural forests became so rare that more **intensive** modes of RNR management had to be developed: hay production and stall feeding of livestock, plantation or preservation of woodlots, and even the ban of free grazing (as in Radi/Shemgang). This shift from extensive to more intensive RNR management, going along with a clear compartmentation of the landscape into different management zones, takes place in all countries when people are forced to do it, i.e., after the more or less complete destruction of forests, the onset of severe erosion and other processes threatening the subsistence. At the moment intensification is introduced, however, the natural vegetation types have disappeared more or less irreversibly.

In the more remote areas of Bhutan, where the population density is low but growing fast, rural economy is still **extensive**. Nobody will abandon the extensive exploitation of nature if not forced to do so! This especially applies to **forest grazing**. Silvopastoral systems that are more productive and more sustainable than intensively managed pastures including hay making are yet to be identified in Bhutan. There might be some special types of open forests the tree layer of which is beneficial for the pasture and sustained despite the grazing pressure. The majority of natural forests in Bhutan, however, certainly has a lower productivity and carrying capacity in the undergrowth than the respective grasslands which would develop after the removal of the woody components. Gibson (1991, cited in Norbu, 2000) gives annual production levels as low as 200 kg/ha for the ground layer of warm broad-leaved forests. The herbaceous biomass in upper montane, mossy fir forests is still much lower, especially where there is no bamboo (the best pasture in the lower fir belt).

Shady forest floors are not suitable for intensive grazing by heavy livestock because the shade-tolerant herbs are not resistant to trampling. As soon as the low carrying capacity is exceeded, strong degradation processes are visible, going along with the exposure of open soil and a further reduction of the productivity of the ground layer. This is in strong contrast with the subalpine and alpine pastures, the quality of which seems to increase with the intensity of grazing, because the sedges which are resistant to trampling are also the most valuable forage plants. Forests with a light crown cover, which are naturally richer in grasses, are more suitable pastures than the hygrophilous shady ones.

Light oak or juniper forests on sunny slopes are, therefore, the traditionally preferred pasture areas. The more open the tree canopy, the better the growth of grasses and sedges. The best pastures have very open tree layers. These are rather legally than ecologically classified as forests. Where stable, sustainable pastures developed under shrinking tree canopies, it would be beneficial to release them from forestry laws in order to facilitate intensification measures such as mechanical clearing or periodic burning.

Shortage of winter fodder is one of the main arguments for the need of forest grazing and the traditional seasonal migrations of livestock and herders. Grassy pastures outside the shelter of the tree canopy completely dry out in winter and stop production. But, also the forest undergrowth is partly dry and less productive in winter. Therefore, a large proportion of the fodder demands have to be met by lopping trees, and by the consumption of tree seedlings and saplings. With identical stocking rates, winter pasture is thus much more detrimental to a forest than summer pasture.

Moreover, the nutritive value of natural pastures and tree leaves in winter is much lower than that of improved pastures or hay from the latter, at least in temperate areas (Roder 2000). In addition, the loss of energy cattle suffers during migration and the daily search for fodder in the forests has to be taken into account. It is to be hoped that the extension of improved pastures/hay meadows will increasingly offer more attractive alternatives to the traditional winter migration and forest grazing.

The demands of **conserving the biodiversity** in the environmentally least disturbed country of the Himalayas conflict with the subsistence needs of a growing population in Bhutan. Also the sustainable use of a natural ecosystem changes the species composition. Even the most extensive use of broad-leaved forest will cause the disappearance of plant and animal species that are most appreciated by humans. The decline in species richness in a grazed broad-leaved forest in comparison with a pristine one is yet to be quantified.

On the contrary, disturbance increases the number of plant species in shady upper montane forests and subalpine/lower alpine scrub. A general increase in species numbers, however, might go along with the disappearance of some rare, inconspicuous species, e.g. in the moss layer. The species-poor pristine forest or scrub might harbour rare wild animals. All these specifications of biodiversity conservation aspects are still to be done before it is exactly known what to conserve where.

A **compartmentation of the landscape** into zones of different utilisation modes is a pragmatic solution of the dilemma. Concentration of livestock on intensified pastures will spare certain forest areas for complete protection (forest reserves/gene pools), not only in the National Parks.

Bhutan still has the chance to prevent the overall forest destruction through strong support of pasture intensification and legal promotion of large-scale separation of pasture and forest.

8.2 Main research needs concerning biodiversity and conservation aspects of Bhutanese forests and alpine pastures

Human influence on the biodiversity of forest and alpine ecosystems in Bhutan still awaits specification. The hypothetical relation between species richness and the intensity of exploitation, as sketched in Fig. 5, has to be proven and quantified in order to provide well-grounded information for conservation strategies. Species richness is only one facet of biodiversity. Dealing with floristic inventories, it will be more important to know **which** species are present in pristine plant communities and which species vanish or invade under which mode of utilisation, than **how many** species we are dealing with. These assessments should include epiphytes, mosses and lichens if possible.

Which parts to protect in the course of the compartmentation of an area into zones of different landuse? Which animals and especially plants are really rare is still little known. A **complete mapping of the flora and fauna** on large-scale grids would be the precondition for respective conservation measures. Especially in the National Parks, the need for such a comprehensive inventory is repeatedly urged by various institutions in the country.

Only in the area of Jigme Dorji National Park, floristic inventories would take several summers and require botanically skilled team members. This aspect touches necessary developments of the institutional framework in Bhutan: the country can only answer its manifold ecological questions if more botanists are trained and employed. There is an **urgent need for the National Biodiversity Centre to increase its botanically trained staff.**

If we compare the value of information given in scientific monographs like the Ph.D. dissertations of Dr. Pema Gyamtsho and Dr. Lungten Norbu, with the quality of some short-term consultants' reports prepared in the course of the establishment of Bhutan's' National Parks, the manifold profit obtained by the scholars' monographs is obvious. We recommend the Ministry to take advantage to a larger scale of the dedication, enthusiasm and time availability of young researchers, whenever reliable data based on extended fieldwork are required.

It is a challenge for many Bhutanese plant enthusiasts and future trained botanists to deal with indigenous plants. What can be done just now to enable interested Bhutanese to contribute to the knowledge of the country's flora?

- Distribution of helpful literature to all concerned institutions and enthusiasts (e.g., "Flora of Bhutan", "Wild Rhododendrons of Bhutan" (Pradhan 1999)).

- Distribution of plant presses and instructions how to collect and press plants and how to handle a plant collection. This is a low-budget input with a long-term profit for the country's flora and ecology.

- Offer of training and refreshment courses in plant morphology and taxonomy (how to use the Flora) for all interested persons in the country, especially for foresters.

In particular, research needs related to conservation and sustainable use in subalpine and alpine environments of Bhutan can be summarised as follows:

(1) Fir forests:
- Continuation of ecological studies on the regeneration of *Abies densa* as influenced by grazing.
- Specification of grazing influence on species composition (here especially mosses and ferns might be endangered).
- Investigation of the competition between fir and juniper on grazed and/or burnt sunny slopes near the treeline of the fir.

(2) Juniper forests:
- Forestry inventory, especially of relict *Juniperus indica* populations in NW Bhutan, including mapping (the present Land Use Working Maps to not specify juniper forests).
- Study of the degree of threat and regeneration potential.
- Evaluation of juniper stands with regard to the allocation to forest reserves, woodlots or pastures.

(3) Tall-growing lower alpine *Rhododendron* scrub:
- Investigation of the function of this widespread ecosystem now endangered by expanding pastoralism in N Bhutan: Relation between structure, floristic composition of the scrub and habitat preferences for birds, large mammals and other wild animals.

(4) Intensification of high montane and alpine pastures:

- Monitoring of vegetation changes after reburning or increase of stocking rates on permanent observation plots.
- Complete inventory of pastures, in order to assess the connection between stocking rate, pasture quality and biodiversity.

(5) Medicinal/rare plants and animals issues:

- Complete mapping of the flora and fauna on large-scale grids. Economically important species might be mapped with priority if a complete inventory is not feasible.

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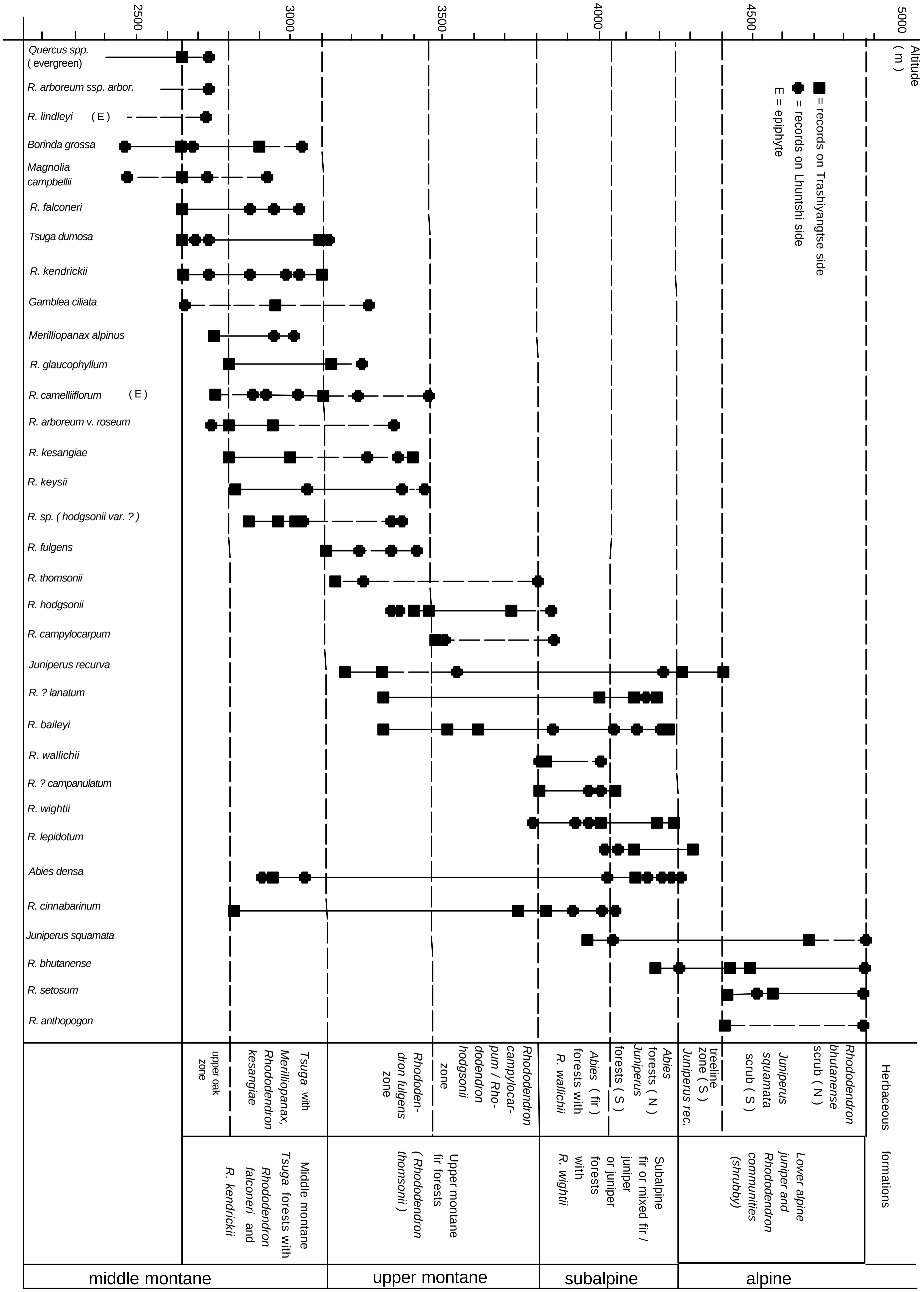
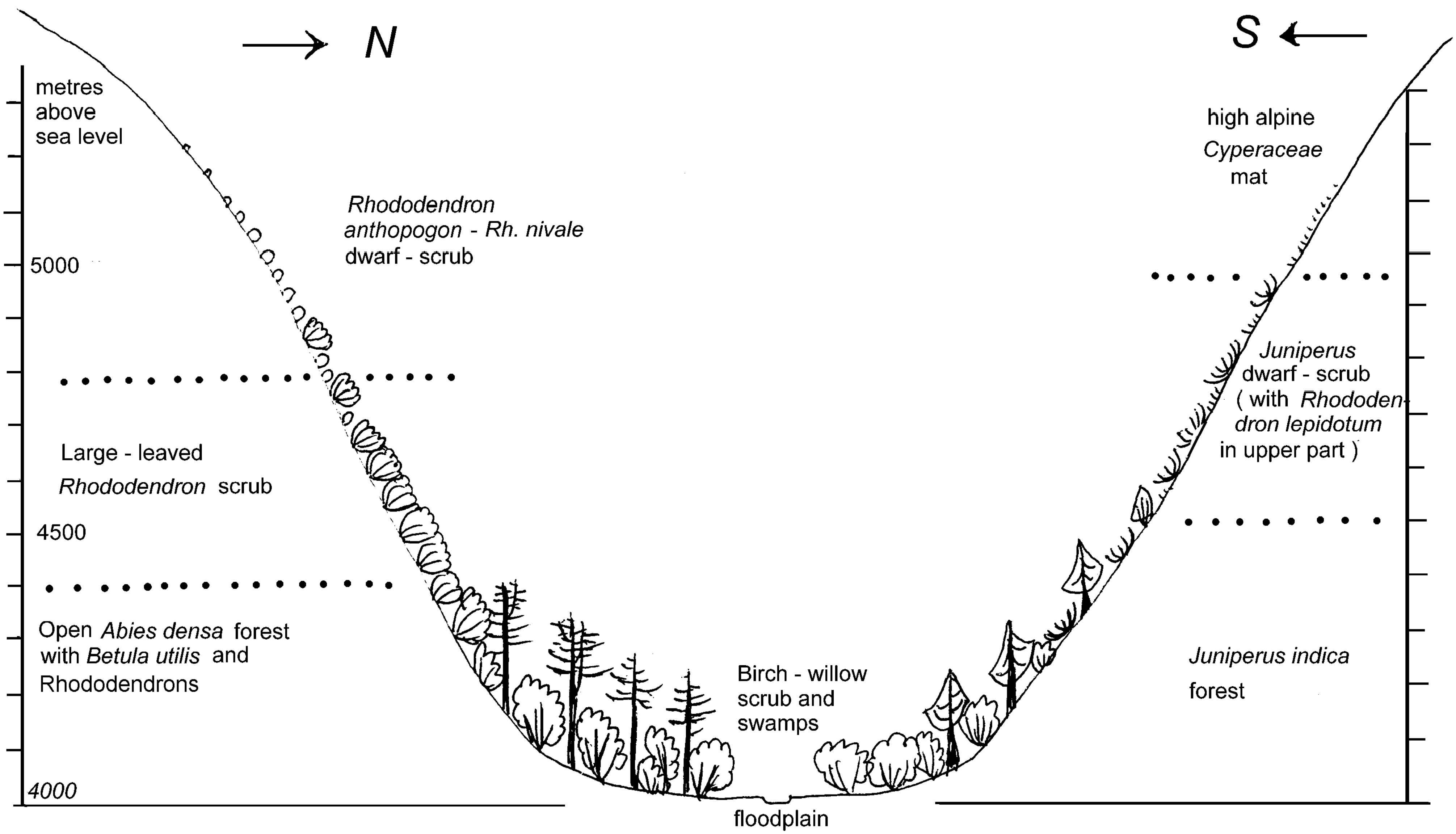
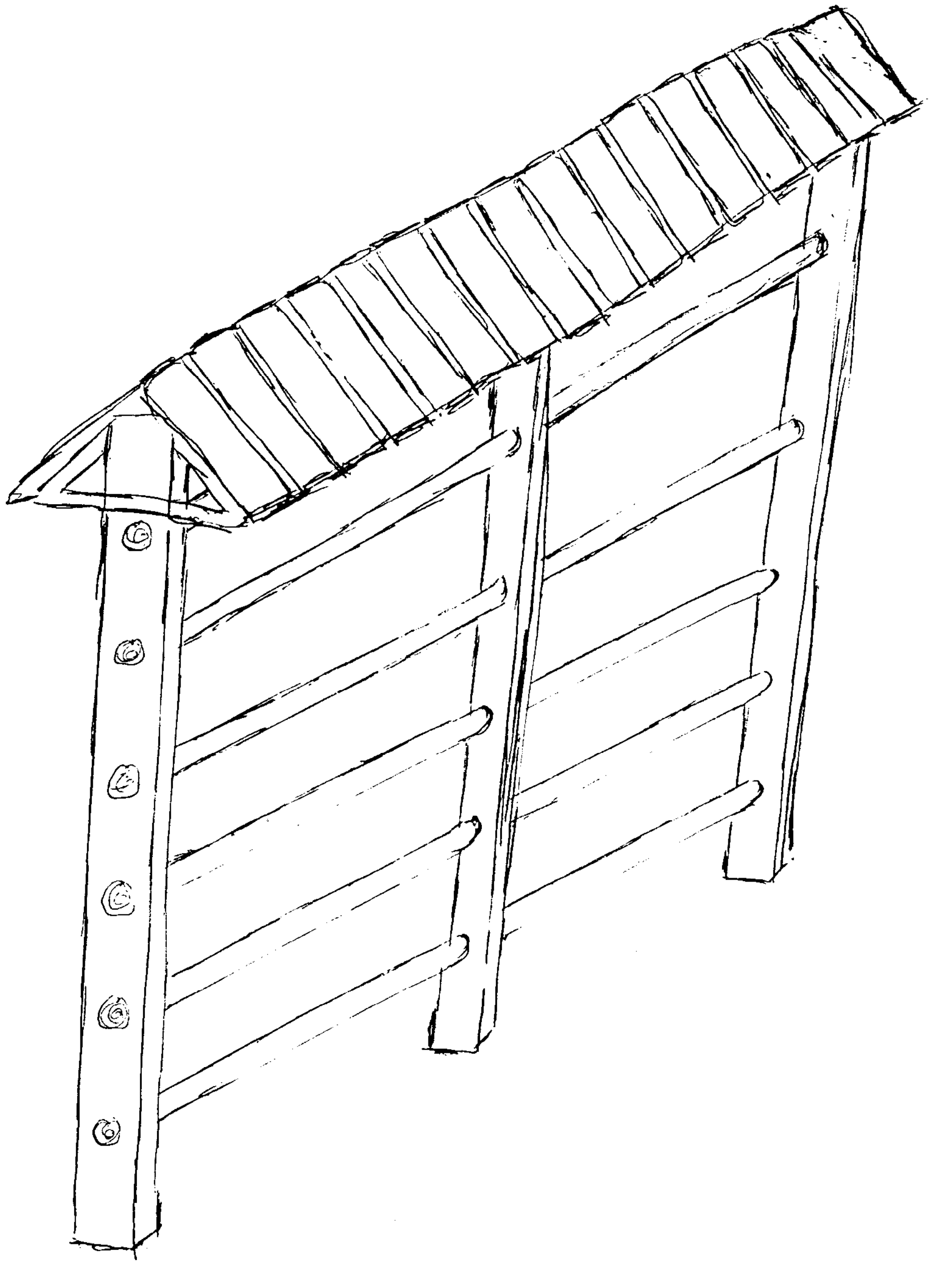
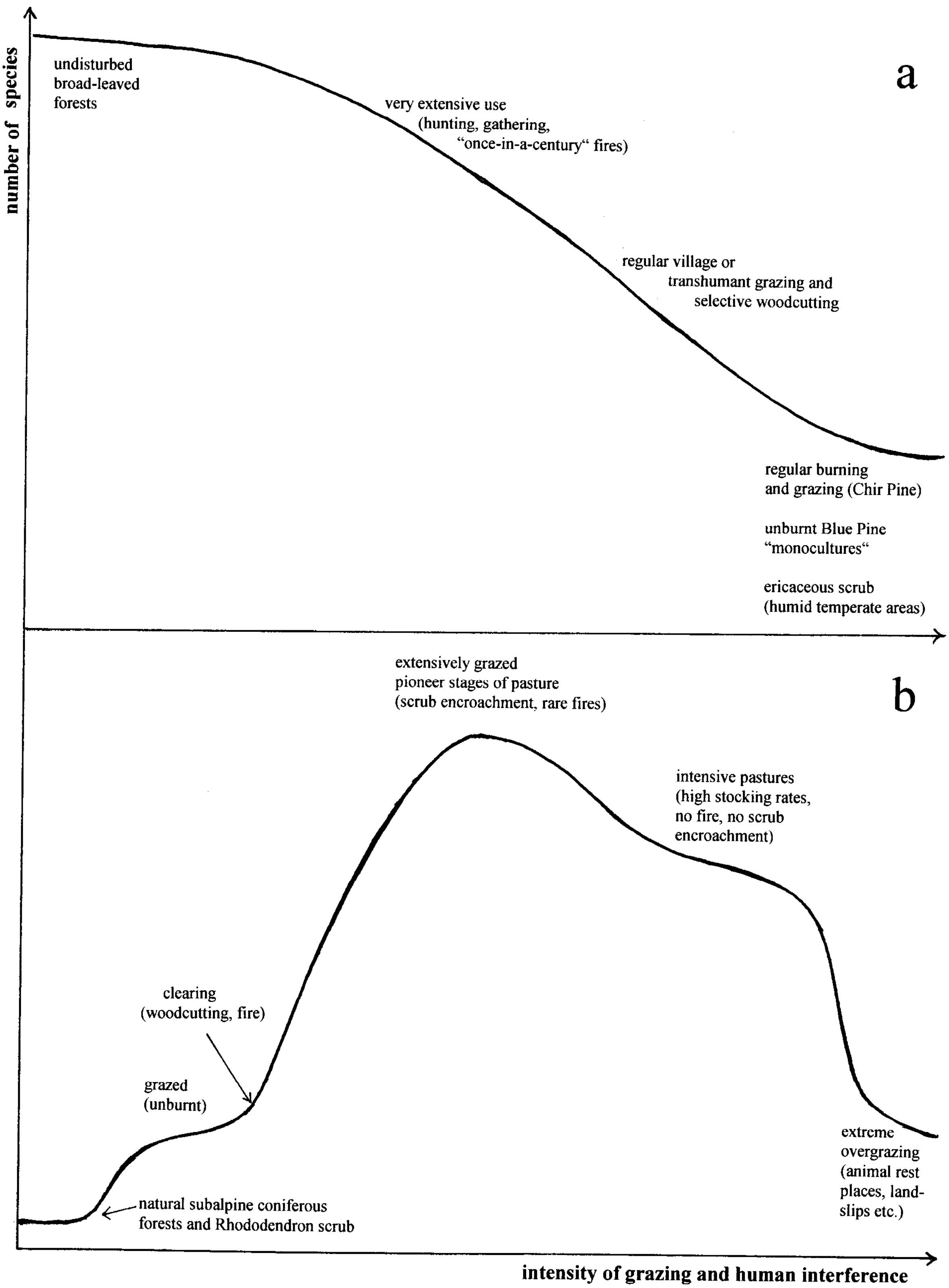

Altitude (m)
2500
3000
3500
4000
4500
5000
■ = records on Trashiyangtse side
● = records on Lhuntshi side
E = epiphyte
Quercus spp. (evergreen)
R. arboreum ssp. arbor.
R. lindleyi (E)
Borinda grossa
Magnolia campbellii
R. falconeri
Tsuga dumosa
R. kendrickii
Gamblea ciliata
Merilliopanax alpinus
R. glaucophyllum
R. camelliiflorum (E)
R. arboreum v. roseum
R. kesangiae
R. keysii
R. sp. (hodgsonii var. ?)
R. fulgens
R. thomsonii
R. hodgsonii
R. campylocarpum
Juniperus recurva
R. ? lanatum
R. baileyi
R. wallichii
R. ? campanulatum
R. wightii
R. lepidotum
Abies densa
R. cinnabarinum
Juniperus squamata
R. bhutanense
R. setosum
R. anthopogon
upper oak zone
Tsuga with Merilliopanax, Rhododendron kesangiae
Rhododendron fulgens zone
Rhododendron campylocarpum / Rhododendron hodgsonii zone
Rhododendron wallichii
Abies (fir) forests with R. wallichii
Juniperus forests (S)
Abies forests (N)
Juniperus rec. treeline zone (S)
Juniperus squamata scrub (S)
Rhododendron bhutanense scrub (N)
Herbaceous formations
Middle montane Tsuga forests with Rhododendron falconeri and R. kendrickii
Upper montane fir forests (Rhododendron thomsonii)
Subalpine fir or mixed fir / juniper or juniper forests with R. wightii
Lower alpine juniper and Rhododendron communities (shrubby)
middle montane
upper montane
subalpine
alpine



N
S
metres
above
sea level
5000
4500
4000
Rhododendron
anthopogon - Rh. nivale
dwarf - scrub
Large - leaved
Rhododendron scrub
Open Abies densa forest
with Betula utilis and
Rhododendrons
Birch - willow
scrub and
swamps
floodplain
high alpine
Cyperaceae
mat
Juniperus
dwarf - scrub
(with Rhododen-
dron lepidotum
in upper part)
Juniperus indica
forest




number of species
undisturbed
broad-leaved
forests
a
very extensive use
(hunting, gathering,
"once-in-a-century" fires)
regular village or
transhumant grazing and
selective woodcutting
regular burning
and grazing (Chir Pine)
unburnt Blue Pine
"monocultures"
ericaceous scrub
(humid temperate areas)
extensively grazed
pioneer stages of pasture
(scrub encroachment, rare fires)
b
intensive pastures
(high stocking rates,
no fire, no scrub
encroachment)
clearing
(woodcutting, fire)
grazed
(unburnt)
natural subalpine coniferous
forests and Rhododendron scrub
extreme
overgrazing
(animal rest
places, land-
slips etc.)
intensity of grazing and human interference