Bhutan-German
Sustainable RNR*-Development Project (BG-SRDP)

*RNR = Renewable Natural Resources

Jointly implemented by the Ministry of Agriculture/Royal Government of Bhutan
and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
GTZ Project No. 92.2267.0-01.100
POSTAL ADDRESS: P.O.BOX 362; THIMPHU / BHUTAN

German Technical Cooperation

Project Document No. 44

Plant formations in central Bhutan and the challenges of conserving biodiversity

II: Follow-up survey of natural Tsenden stands

October - November 1999

Tsenden at Cheri Monastry, near Thimphu

Prof. Dr. Georg & Dr. Sabine Miehe
Faculty of Geography
University of Marburg
Deutschhausstr. 10
D-35032 Marburg/Germany

In collaboration with: **D.B. Gurung**
NRTI Lobesa

With support from: RNR-RCs Yusipang and Bajo

TABLE OF CONTENT

TABLE OF FIGURES

Abstract

Natural stands of the Tsenden, Bhutan's National tree, are still widely unknown. Forestry nurseries are mainly supplied with seed from Indian cultivars, the identity of which is doubtful. The present contribution aims to strengthen the awareness of the risk that the few remaining natural Tsenden forests in Bhutan might vanish before their extent is assessed, their biology and dynamics are understood and their gene pool is conserved.

Brief ecological observations made in three relict Tsenden forests indicate that the cypress is a light-demanding pioneer initiating primary or secondary forest successions after the destruction of the broadleaved understoreys, due to landslides or episodic fires. Tsenden, however, is threatened by frequent fires, high grazing pressure and logging. For the time being, the plantation of nursery saplings appears to be the most efficient measure for the genetic conservation and propagation of Bhutan's National tree. A respective action and research program has been proposed.

Preface

This paper summarizes the results of follow-up studies on biodiversity problems in Punakha and Wangdue-Phodrang Dzongkhags. Due to the short time available and the actual demand for information, the field studies concentrated on the Tsenden forests in the project area, and the remaining time was used to discuss future in-depth studies on *Cupressus* with relevant Bhutanese institutions.

After the first short visit of the Chuselumba site in October 1998 (see BG-SRDP Project Document no. 40), more detailed observations and some example records could be made in 1999 in Chuselumba, Dangchu and the upper Pho Chu areas. Fieldwork was focussed on the following questions:

(1) What is the natural habitat range of the Tsenden?

(2) What are the main constituents of natural Tsenden forests?

(3) Which natural regeneration modes can be deduced from the structure of Tsenden forests, and which conclusions can be drawn with regard to sustainable forest management and conservation?

(4) What are the main threats to natural Tsenden forests?

(5) What are the main research needs and necessary actions following from these findings?

These points are outlined and discussed below. A comprehensive site description, a research plan related to Tsenden and the itinerary of the visit and photos are presented in the appendices.

We are thankful that the recent stay in Bhutan enabled us to intensify our scientific contacts with NRTI Lobesa and RNR-RC Yusipang. Special thanks are due to Mr. Phuntsho Namgyel, Program Director, RNR-RC Yusipang, for his interest and fruitful discussions. We were extremely lucky to be accompanied by Mr. D.B. Gurung, NRTI Lobesa, during field excursions, and very grateful for his help and valuable scientific contribution to this survey. Therefore, our thanks are also extended to Mr. Dorji Wangchuk, Director of NRTI, for his kindness to suspend D.B. Gurung from the lecturing duties. We also thank Mr. A. Baskota and his staff for facilitating the field trips.

Again, we thank all Bhutanese partners in talks and on excursions for their assistance, hospitality and interest. Special thanks are extended to Mr. Reinhard Wolf/BG-SRDP and his team for perfect logistic support and fruitful discussions.

1. State of knowledge about the present distribution of Tsenden forests in Bhutan

Whereas planted Tsenden trees are well-known and eye-catching across Bhutan, the knowledge about the natural occurrence of Tsenden is still somewhat accidental, and thus rudimentary, as no systematic inventory was made so far (Fig.1):

- In Wangdue-Phodrang, Tsenden forests on W-facing flanks on the lower Punakha Tsang Chu (Chuselumba area, visited in 1998 and 1999, map 1 in Appendix 1) became known as a timber resource for the reconstruction of Taktsang Monastery; URA & DOMPNIER (1999) mention that also for the restoration of Punakha Dzong wood is being extracted from this forest.
- In Punakha, Tsenden populations from the upper Pho Chu (visited in 1999, map 3 in Appendix 1) were known as a resource of shingles for Punakha Dzong.

  As early as in 1915, these forests were observed by COOPER (1933, p. 75), and the use of the wood for the maintenance of sacred buildings was mentioned, but this source was evaluated as late as in 1980 by LONG.
- From the W flanks of Pele La (Wangdue-Phodrang), wild Tsenden was reported by LONG (1980) and GRIERSON & LONG (1983). Near Nobding, large amounts of Tsenden logs could be seen last year (NAMGYEL 1999); they originated from the opposite side of the Dang Chu, the Phinchho Chholing Chu W of Dangchu (visited in October 1999). This valley is being examined as a possible Forestry Management Unit (FMU) at present. (NORBU & WANGCHUK 1999 mention that this valley is locally called Ngoe Chu, contrary to the map). D.B.Gurung identified further small populations of Tsenden in a lower tributary valley of the Dang Chu opposite Nobding (map 2 in Appendix 1).
- There are reports about Tsenden forests in the upper Pe Chu ("Belakha" N of Beli, map 3 in Appendix 1) and even from Eastern Bhutan (Trashigang, possibly planted groves) and in the Kargang Chu NW of Lhuntshi (Karma Dukpa and Akey Dorji, BG-SRDP, pers.comm.), but these occurrences are not confirmed yet.
- Rebecca Pradhan/RSPN, has observed wild Tsenden forests W of Tashiyangtse.

Fig. 1: Location of natural Tsenden stands visited and reported so far

These records indicate that wild populations of Tsenden are much wider distributed across Bhutan than previously assumed. Moreover, the limited amount of stands visited so far indicates that the altitudinal range is at least as wide as that of the Blue Pine *(Pinus wallichiana)*, i.e. c. 1600 - c. 3100 m asl. Accordingly, the associated plant communities and climatic conditions vary a lot as well.

At its upper limit, the Tsenden merges with the similarly looking Cupressacee, *Juniperus recurva*, on degraded sunny slopes (seen with binocular in the Ngoe Chu; LONG (1980) has observed it near the Pele La) or gives way to *Pinus wallichiana-Quercus semecarpifolia* forests (Chuselumba). The maps indicate altitudes between 3000 and 3100 m for the observed upper limits.

The optimum zone of Tsenden, however, seems to be situated within the Evergreen Oak Forests. The climate station Nobding (Fig. 2) shows the typical, humid climate conditions of this zone.

Special information about the Tsenden forests visited is compiled in Appendix 1.

Fig. 2: Compilation of climatic diagrams representing areas where Tsenden grows

2. Structure and species composition of Tsenden forests

The typical structure of a Tsenden-Oak Forest in mature stage - as seen in Chuselumba - is as follows (Fig. 3, Photos 1 and 2):

The main tree layer, here only up to 15 m tall, is constituted of evergreen oaks and *Eriobotrya hookeriana*, with a laurophyllous understorey, and overtopped by an open stratum of *Pinus wallichiana* and *Quercus semecarpifolia* which may attain 30 to 35 m in height. This type of forest is quite common in the moderately dry areas of Central Bhutan. The Tsenden storey is just superimposed, forming an open canopy that rises up to 15 m from the upper limit of the oak and pine crowns. Tallest Tsenden individuals were estimated to measure between 45 and 50 metres in height, with maximum diameters (DBH) up to 3 metres. Depending on slope angle and degree of disturbance, the Tsenden canopy may be closed or very sparse.

This is the structure of a highly diverse forest. The number of vascular plant species distinguished was lowest in the driest habitat recorded (47) and highest in the most humid one (c.120).

According to its wide hygric and altitudinal range, Tsenden may overtop broadleaved forests of quite different species composition:

A fairly dry stand was recorded on a SW-facing rocky spur in 2640 m in Chuselumba: Tsenden grows in open *Pinus wallichiana-Quercus semecarpifolia* forest here, with a sparse laurophyllous understorey and grass-dominated ground layer (Photo 14).

- The wet side of the hygric range known so far was met on N-facing slopes in the Ngoe Chu (2650 m): here, Tsenden overtopped mixed Hemlock-oak forests with *Magnolia campbellii, Acer sikkimense, Tetracentron sinense* in the main canopy and a fern- and tall-forb-dominated herb layer on mossy ground.
- The lowest record we made near the Si Chu/Pho Chu confluence at 2,030 m in N exposure, where Tsenden accompanies Warm Broadleaved Forests *(with Castanopsis tribuloides, Schima wallichii, Michelia* sp. and *Quercus lanata)* near their upper limit. The lowest altitude at which relict Tsenden forests occur is at c.1,600 m in the upper Pho Chu, according to farmers' information (we were unable to visit these forests due to high water in the Si Chu which blocks the passage during most of the year, see Appendix 1).

The determination of the plant collection will allow the compilation of tables showing the variation of species composition in the localities visited so far. It is not to be expected that there are any characteristic (indicator) species accompanying the Tsenden in all communities, though. In contrast, Tsenden appears to be an accidental addition to floristically quite different forest communities, as such being comparable with the Blue Pine.

Eco-physiologically, however, the Tsenden grows best at the humid end of the hygric range of *Pinus wallichiana*: in the driest habitats visited (S- to W-facing slopes influenced by the valley wind in Chuselumba), there is a strong competition between Tsenden and Blue Pine in young stages, and the Tsenden seems not to grow fast and tall enough to shade out the pine in older stages. On dry crests Blue Pine tends to form the canopy, with some Tsenden in the undergrowth, suffering from lack of light. So far, Tsenden was not observed in areas where spruce grows on higher slopes.

Fig. 3: Schematic sketch of the structure of a little disturbed Tsenden forest

3. On the dynamics of Tsenden forests

3.1 Natural regeneration modes

One of our main questions concerned the natural regeneration modes of Tsenden forests.

Typically, the cypress constitutes the top tree layer, being absent from the lower storeys. All Tsenden trees in a certain forest unit are apparently of similar age, and no regeneration can be observed on moderately steep flanks. Under little disturbed conditions, only rocky crests and slopes steeper than c. 40 degrees apparently do provide enough light for the regeneration of Tsenden in mature forest, because the stands remain naturally open here. In such habitat various juvenile stages of Tsenden can be observed in the understorey (Photos 14 and 15). Under a more shading canopy, Tsenden very rarely comes up in the open mineral soil exposed by uprooted trees (seen by D.B. Gurung only once in the Ngoe Chu). Larger forest gaps are obviously necessary for the establishment of a new Tsenden generation. Massive germination was observed in recently logged areas in Chuselumba, but the seedlings were concentrated to lanes and landings where the handling of logs had exposed plenty of bare soil.

Most of the seedlings apparently die during the dry season. This is indicated by the fact that very few older saplings can be seen. These are almost exclusively found on sunny patches along the trail where the ground vegetation had been completely destroyed.

On slightly E-inclined, recent Tsenden clearings in Chuselumba (2650 m, 27°24'10"N/89°56'22"E) we made three checks for Tsenden saplings. Solitary, fruiting *Pinus wallichiana* and *Cupressus* trees were left behind on these plots. The preparation of rectangular Tsenden logs caused large deposits of wood slash that was only slowly overgrown by pioneer plants. We differentiated our counts of "established" (i.e., more than one year old) *Pinus* and *Cupressus* saplings according to the substrate:

Table 1: Numbers of established *Pinus wallichiana* and *Cupressus corneyana* saplings, depending on the substrate (size of plot: 240 m²)

(1) bare humic mineral soil, more or less covered by mosses and herbs
(2) bare wood slash, slightly weathered
(3) herb-covered slash (more than 30% cover, *Strobilanthes* sp. dominant)

Substrate	*Cupressus*	*Pinus*
(1) mineral soil	6	48
(2) wood slash	2	11
(3) herb-covered slash	0	6
growth height (cm)	7-30	10-70

The table shows that open mineral soil, incompletely covered by mosses and herbs, is the best substrate for the establishment of both conifers. On all substrates, however, the number of Blue Pine saplings exceeded that of the Tsenden by 6 to 8 times, and also the average growth height of the Blue Pine was taller. When we checked three more clearings in the vicinity, it turned out that the first plot was exceptionally favourable for the Tsenden: no established Tsenden saplings were found on the others (despite the presence of mature Tsenden trees!), in contrast with rich amounts of pine regrowth.

Possible reasons are to be discussed and further investigated:

(1) Seed resources

Of course, the relation between Tsenden and Blue Pine saplings depends on that of the parent trees on the plot. Tsenden had been the dominant species in the tallest tree layer before the logging operation, whereas Blue Pine was more sparsely present in the next lower storey. Blue Pine was not logged, contrary to Tsenden, of which only some understorey trees with smaller trunk diameters were left behind. These trees, which suffered from lack of light under the tallest canopy, have sparse crowns and small amounts of fruit, if they are fruiting at all. Thus, it is imaginable that after an initially favoured seed dispersal - going along with the felling and handling of the mature canopy trees - there is a phase of minor or failing seed production, until the former sub-canopy trees have regenerated in the light and gained fertility. The risk is that by that time, the ground cover might have closed again!

In 1998, c. 1kg of cones were collected from fallen branches of these left-over Tsenden trees, but no germination was achieved. Possibly the sowing conditions were unfavourable, but bad quality of the seed could also be an explanation. In October 1999 D.B. Gurung examined the fruits and found that only about 10% had developed endosperm. If this low vitality is a general feature in Bhutanese Tsenden or the effect of selection in the course of logging (leaving the least vital trees behind), requires further studies.

In contrast with the Tsenden, the Blue Pines were fruiting in abundance (seeds not checked for vitality).

(2) Drought tolerance

The fact that there are plenty of Tsenden seedlings on suitable substrate but only rarely older saplings, indicates that most of the seedlings die after the first monsoon. As Tsenden occurs as high as around 3000 m a.s.l. where frosts are a regular feature during winter, **drought** is the most probable natural threat to the seedlings. If the counted Tsenden saplings on our example plot are examined in this respect, it turns out that all of them had survived the first

dry season in the **shade**: the 6 saplings on moss-covered mineral soil grew up in the midday shade of a tree stump, and the two that germinated on wood chips enjoyed the midday shade of a fallen trunk (Photo 13). In contrast, the pines did not show such clear preferences for shady micro-habitat, obviously being more drought-resistant. In this respect it is astonishing that the germination of Tsenden is not or little inhibited in late autumn (when the dry season starts): seed that appeared to be immature and were rejected by D.B. Gurung and thrown behind the house germinated at once by the end of November 1999. Systematic sowing trials will show how the germination behaviour develops in the course of the winter and the following spring.

(3) Competition for light

Tsenden seedlings are in a conflict: they have better chances for surviving the drought if they grow up in the shade, but they need much light for quick growth. During the decisive first two years, Tsenden saplings are, with 10-20 cm, smaller than those of the Blue Pine (15-40 cm), and thus in greater danger of being overgrown by faster-growing plants in the ground layer. Consequently, open mineral soil is not only the best substratum for Tsenden germination but also for the survival of the seedlings. Wood chips slow down the recolonisation of the ground by the vegetation cover, but germination on this substrate is highly risky because the soil under the chip layer might not be reached by the roots in time. The major competitor of the conifer saplings on the studied clearing in Chuselumba was a scrambling semi-woody perennial herb (*Strobilanthes* sp.) that forms a dense, up to 50 cm tall pioneer ground layer within a few years. Several Tsenden seedlings were observed to have been overgrown by this tall herb, whereas the distinctly taller pine saplings could compete better (Photos 11 and 12). A grass sword that establishes on older clearings, steep rocky flanks or landslide areas, seems to be less harmful to Tsenden saplings.

(4) Impact of browsing

Systematic counts on permanent observation plots are necessary in order to decide how strong the impact of grazing and browsing on the survival rate of Tsenden seedlings is. It is assumed that both, cattle and wild herbivores (sambar in the first place) eat Tsenden seedlings "by accident" in one go with the herb layer, and they certainly kill some others by trampling. Traces of browsing were observed on young Tsenden trees along the loggers' and cattle trails, but rarely on pines, the saplings of which are much more tough, unpalatable and likely to be deliberately avoided by the herbivores. Thus, the Blue Pine is in a better competitive position also in this respect.

3.2 Conclusions concerning the dynamics of Tsenden forests

These observations on logging sites suggest that major disturbances of the mixed oak forests are a precondition for the regeneration of the Tsenden top storey: most of the shading trees must disappear, and the ground should have plenty of bare or mossy patches that are only slowly recovered by tall-growing herbs.

With these requirements, the Tsenden turns out to be a **typical pioneer tree**, comparable with the alder (*Alnus nepalensis*, confined to wet mineral ground), the pines in the lower and middle montane belt, and the junipers in the fir belt. It fits in the category of a "habitat pioneer" sensu OHSAWA & al. (1986).

As the Evergreen Oak Forest in Bhutan does not perform any cyclic breakdown (there is plenty of regeneration in the shade of the mature canopy), the only natural events providing open areas are avalanches and **landslides**. On very steep slopes, especially on slate bedrock, periodic sliding of the forest cover together with the topsoil may keep the vegetation in permanent pioneer stages. In these habitats, Tsenden forests might form the **edaphic climax** vegetation. On moderately steep slopes, however, where landslides are rare, **fire** apparently is the main factor initiating Tsenden regrowth. This hypothesis is deduced from the observations made in the Ngoe Chu and the Si Chu:

Whereas the Tsenden canopy was oldest and highest in Chuselumba (estimate from year ring counts of stumps: 100 to 120 years), the surviving populations seen in the other two locations appeared to be much younger. In the Ngoe Chu the living Tsenden canopy was overtopped by taller dead trunks which clearly showed traces of former fire (Photo 5). Indeed, old people in Dangchu remember tales of a devastating fire that swept the entire Ngoe Chu about 60-80 years ago. Similar events are known from the Si Chu valley, where a grandmother (aged 67) told us that the Tsenden forest on the rocky flank opposite the farm was extending during her youth, after a fire her parents had seen. In the same locality we saw the remains of Tsenden forests burnt during the past spring: the fire had invaded the Si Chu valley by the ridge separating it from the upper Pho Chu, and dry Tsenden populations on rocky spurs were more strongly hit than forest patches in more humid habitat (Photos 7 and 8). Indeed, the Tsenden foliage and the flaking bark, both rich in etheric oils, are easily inflammable. The people in Kewa Nang/Si Chu believe that Tsenden trees can set themselves on fire when two stems are rubbing each other during hot and dry weather. They do not think that lightning plays a role because it is usually followed by rain.

Man-made fires, however, are probably most common. They escape from camp fires, or they are deliberately used for pasture improvement or hunting and then get out of control.

Thus, it is well imaginable that the human population has played a major role in the spread of Tsenden forests, not only due to the plantation of holy trees but especially due to fire. If this assumption is true, the only truly natural stands of Tsenden can be expected to occur on

steep rocky flanks (edaphic climax forests or cyclic pioneer stages), whereas in all other habitat types, the present canopies are remnants of pioneer forests after fire. Fig. 4 summarises this hypothesis.

Fig. 4: Hypothetic cycles of Tsenden forests, derived from field observations.

4. Threats and Conservation issues

If our hypotheses are confirmed through ecological research, the maintenance, respectively the regeneration of the present Tsenden forests requires a minimum interference of man, i.e., **periodic fires**. It is important, however, that the intervals between the fire events are long enough, because Tsenden regrowth is very fire-sensitive. If both, valuable timber and a high biodiversity, are the main management goals, at least one century of fire protection is necessary.

The fire-sensitivity of juvenile Tsenden trees probably represents the strongest ecological contrast with the pines which are pioneer trees in the same altitudinal belt. If the fire frequency is increased, pines are, therefore, likely to become more competitive and take over.

The second important factor threatening Tsenden forests is, of course, excessive **timber logging**. We have stressed earlier how high Tsenden wood is valued by the rural people. Nowadays, only sacred buildings are being restored with Tsenden wood, but how was the situation in earlier times? People who live off the roads know old farmhouses or huts on grazing places that are entirely made of Tsenden wood: we saw the uppermost settlement in the Ngoe Chu (winter grazing place) with houses partly built of Tsenden wood (Photo 3); this settlement is situated at the actual fringe of Tsenden forest. Our informant Mindu saw 16 houses completely made of Tsenden wood in the upper Pe Chu, where he also observed scattered Tsenden trees (map 3 in Appendix 1).

At least Tsenden **shingles** were used by anyone who could get them. They are still much higher valued than those made of fir or oak: as they are known to last one generation, they are even preferred to metal roofs.

Thus, it is highly probable that Tsenden was generally preferred for house constructing, as long as suitable trees were in reach or rivers could be used for transport. URA & DOMPNIER (1999) report that the old wooden bridge at Wangdue Phodrang had been constructed probably from Tsenden wood, too, in 1684. Historic sources testify its reconstruction with Tsenden wood around 1915; the timber came from Chuselumba, was taken down to the Punakha Tsang Chu by a ropeway and then dragged upstream...

It is, therefore, not astonishing that the remaining Tsenden forests all grow in remote upper valleys where there are no settlements and no roads. The lower limit of Tsenden forests (estimated at c. 1600 m in the Pho Chu) not necessarily needs to be a natural one; it might just represent the actual line of extinction. Trees planted near Wangdue Dzong show that Tsenden copes physiologically with even drier and warmer conditions.

Thus, the presence of man has certainly favoured the initial spread of Tsenden as a pioneer tree after forest fires, but, on the other hand, also limited the extension of the Tsenden-

covered areas by too frequent fires, grazing and woodcutting. The maximum historic extent of Tsenden forests can hardly be assessed, because there are few written documents, and pollen analyses cannot differentiate between the various species of the Cupressaceae family.

Modern transport facilities made the exploitation of the remaining Tsenden forests feasible at a larger scale. LONG (pers.comm.1999) observed the almost complete disappearance of Tsenden along the Pele La road within the past 15 years, including the type specimen of the recent scientific description. Cable cranes facilitate the extraction of large amounts of timber from the Ngoe Chu and Chuselumba (see also GURUNG 1999 and NAMGYEL 1999).

A third and final threat to Tsenden regeneration might be **cattle grazing**. Cattle were observed to follow the woodcutters' trails and browse on Tsenden saplings. In Chuselumba, Blue Pine regrowth that came up simultaneously with Tsenden after logging appeared to be more resistant to browsing. It is yet to be proven, however, that the overwhelming number of Blue Pine saplings, in comparison with that of Tsenden, is entirely due to the grazing factor in this locality (see previous section). Also it should be investigated to what extent the browsing is done by the wild Sambar. Whatever the reasons may be, it must be stated that Blue Pine is spreading on clearings in Chuselumba.

The ecological observations made so far allow the conclusion that the **conservation of Tsenden forests is a real challenge** right now: a number of difficult ecological questions have to be answered before appropriate conservation measures can be worked out, but immediate action is necessary to prevent the disappearance of the remaining natural stands in the meantime.

Tsenden-Oak Forests are highly diverse both structurally and in terms of species richness. Moreover, the Si Chu, Pho Chu and Ngoe Chu forests harbour a great variety of Bhutanese large wild mammals. With these properties they clearly deserve the status of nature conservation areas. The Si Chu and important sections of the Pho Chu are included in the Jigme Dorji National Park (JDNP), but the other localities are not protected yet. One of the main objectives of a nation-wide Tsenden management plan will be the designation of protection and timber production areas.

The conservation of the genetic variety of indigenous Tsenden certainly has top priority. On the other hand, the sustainable management of Tsenden stands is a challenging task for the forestry sector.

5. Silvicultural Aspects

It is astonishing that, despite the widespread knowledge about the high timber quality and the long tradition of planting Tsenden, the cypress has been relatively little included in Bhutanese afforestation projects so far. JENSEN (1990) notes 81.5 acres of pure Tsenden plantations and some 620 acres where Tsenden was planted along with other species. He examined 2 plantations after 13 years and emphasizes the rapid juvenile growth, annual increment rates that even exceed those known from the Blue Pine, and a volume growth equalling those of the fastest-growing subtropical Eucalypts.

Unfortunately, there is very little documentation about the **origin of the seed** used in the local nurseries. Most of the seed provided by the Forestry Services apparently were imported from India, named *"Cupressus cashmeriana* Carr." (JENSEN 1990), but NAMGYEL (1999) has observed that the respective seedlings raised in Bhutan are being labelled as *"Cupressus corneyana* Carr." The origin of the Indian seed is unknown; it is well possible that the parent trees were cultivars in European botanical gardens, raised from seeds of cultivated Tsenden trees in Sikkim. In fact, CARRIERE (1855, 1867) made dubious descriptions of both taxa, based on young cultivated trees. This led SILBA (1987) to the redescription of the Bhutanese Tsenden, based on a tree growing near Nobding, which is now to be called "*Cupressus himalaica* J.Silba". But the author does not further deal with the specimens imported from India.

Thus, up to now, nobody knows how far the Indian cultivars of Tsenden are related with the indigenous populations in Bhutan. They look very similar, except for the glaucous juvenile foliage which the Indian trees tend to keep much longer than the Bhutanese ones (but see Photos 14 and 16!). Probable differences concerning the genetic diversity, growth rates, habitat demands and wood quality are yet to be investigated. Some foresters gained the impression that the typical aromatic scent of Tsenden is much weaker in "*Cupressus cashmeriana*" wood than in the Bhutanese one, but the respective plantations are still too young for a proper comparison (the hardwood has the strongest scent and also the best timber quality).

This situation again is a challenge for the Bhutanese Forestry Services and research: The genetic pool for reforestation measures can be enormously enlarged if seed from natural Bhutanese Tsenden forests are systematically used in the nurseries. Old planted indigenous trees show that Bhutanese Tsenden still grows at altitudes as low as 1200 m, exposed to dry valley wind and annual precipitation totals around 600 mm (Fig. 2). Even though excellent growing parameters are reported from the Indian cultivars (JENSEN 1990), the indigenous Tsenden forests certainly provide ecotypes for a wider range of habitats.

The second argument for nursery trials with seed from natural Bhutanese Tsenden forests is the preservation of the endemic taxon and its still unassessed genetic variety. This is an essential part of any sustainable use of natural Tsenden stands.

As far as our brief observations indicate, Tsenden as a light-demanding pioneer tree is not likely to produce much spontaneous regrowth when single-tree felling is practised in natural mixed forests (Photo 19). More light is provided in clear-cut patches, but here, tall herbs spread so quickly that they threaten to shade out the small cypresses, and again, pines are more competitive (research on permanent observation plots should prove these assumptions scientifically!). Hence, supported natural regeneration probably needs careful management: vital parent trees have to be preserved on the clearings, cattle has probably to be excluded and weeding might be necessary during the first 3 to 4 years. If research trials confirm these assumptions, it appears to be less complicated but more reliable to replant harvested Tsenden populations with saplings raised in nurseries from seed collected in the same area. Probably it is necessary to clear at least part of the broad-leaved understorey, too, in order to provide enough light. The experiences gained in the Rimchu plantation can be useful for the establishment of nurseries at the logging site.

The nature of the Tsenden as a pioneer tree on open substrate makes it even more promising for plantations on degraded land. First experiences gained in the BG-SRDP-supported community plantation on a windward S-facing slope at 1650 m above the Lingmutey Chu/Chang (Tsang) Chu junction are quite encouraging (Photo 21). It is planned to use Tsenden saplings of local seed resources in future plantations.

The main conclusion from these preliminary findings is: we need to know much more about the ecology of the Tsenden, but we must start to save the natural stands immediately, if the conservation of their biodiversity and any future utilization of the promising timber resources are desired.

The following recommendations, therefore, have two parts:

(1) Immediate actions in administration and management

(2) Research priorities.

6. Recommendations

6.1 Immediate actions for the conservation and sustainable use of Tsenden forests

Natural forests dominated by Bhutan's National Tree are a unique feature in the whole Himalayas. Therefore, the Tsenden is worth to be included in the top priority list for the national conservation policy, in one category with rare medicinal plants (*Cordiceps*) and the precious mammals (luckily, part of these mammals' habitats are identical with the Tsenden forests, e.g., the winter-grazing areas of the Takin!).

As long as no complete inventory of relict Tsenden forests in Bhutan is available, it is necessary to prevent the irreversible destruction of the genetic and environmental resources of Tsenden forests. Immediate actions should include:

(1) The complete stop of logging activities in small relict populations such as the Chuselumba site (see map 1 in Appendix 1), where almost all vigorous top storey trees in reach are already cut and natural regeneration is not safeguarded yet. NORBU & WANGCHUK (1999) recommended the strict protection of the Ngoe Chu forests as well. The stop might be handled as a moratorium, until practicable strategies for natural or artificial regeneration have been worked out.

(2) Governmental prohibition of trade with Tsenden wood, and restriction of logging activities to the timber quantities needed for the maintenance of historic sacred buildings, until a scientifically founded management plan for the sustainable use of Tsenden forests is available.

(3) Strict control of the necessary minimum logging activities in every stage: prospection and planning in close cooperation between foresters and nature conservationists: this includes joint marking of individual trees, with care to be taken that future seed trees are left in the top storey, that any logging is avoided on steep flanks with high risk of erosion, that the main wintering places of rare animals are not disturbed, and that grazing by cattle is restricted (as long as the effect on Tsenden regeneration is not known).

(4) Any logging activities should be accompanied by reforestation measures similar to the Rimchu model. Priority is to be given to Tsenden raised from local seed (cooperation with the research institutions). The best opportunity to collect mature cones in large quantities from vital trees is during the logging procedure, because the crowns of standing trees are rarely in reach.

6.2 Tsenden research plan

Management plans for the sustainable use and conservation of Tsenden forests are needed at a time, when almost nothing is known about the ecology and present distribution of the cypress.

Therefore, the Tsenden should become one of the focuses in basic and applied forestry research. The research work has close links to practical forest conservation and management and can largely be done by Bhutanese foresters and scientists.

The first research proposal (G. & S. MIEHE 1998) was commented by NAMGYEL (1999); discussed with RNR-RC Yusipang and the BG-SRDP and supplemented after the recent field survey. The short form of the program submitted to RNR-RC Yusipang is given in Appendix 3.2. Comments will be given in this chapter.

(1) Inventory of natural Tsenden stands

The complete inventory of the relict Tsenden forests in Bhutan is the main precondition for any management plan concerning this valuable natural resource. Only if the extent of the different populations is assessed, it can be avoided to over-exploit small stands such as the Chuselumba relict, and it can be decided where limited timber extraction is ecologically justified.

Due to the nature of Tsenden as a light-demanding pioneer tree, and to the high value of its timber for the local people, a main refuge for the cypress are steep rocky flanks (Photos 7-9) where common forest inventory methods fail. The difficulties to map Tsenden forests are made worse by the fact that up to now, it was not possible to distinguish the Tsenden from other conifers on satellite imageries or air photos (D.B. Dhital, FRDS, pers. comm.); therefore, any extrapolation with GIS techniques remains unrealistic for the time being.

Thus, we rely on the local people's information in the initial phase of the inventory. Calls for information were already started among the DFOs and in an article published in KUENSEL (on February 26, 2000). When the localities are known, more or less detailed checks should be done by inventory teams. Special attention should be paid to the dynamic status of the forests: depending on the date of the last fire, the second-growth forests might be still too young for exploitation, and such areas would be more suitable for conservation than for timber extraction.

(2) Trials on the regeneration of indigenous Tsenden

(2.1) Continuation of germination experiments

During our 1999 field survey, Tsenden cones from the relict forests visited were collected. Due to lack of time and climbing equipment (rotten or immature cones dominate on the ground) it was impossible to collect seed from individual trees, as proposed. This difficulty should be overcome in future. The ongoing trials are being made with samples from Chuselumba and Ngoe Chu. On the occasion of the IUFRO[1] Seminar on Broadleaved Forests held in November 1999 in Lobesa, seed samples were distributed among the representatives of those RNR-RCs who were interested in participating in the sowing trials. In this way, the germination rates can be tested in different habitats. D.B. Gurung, lecturer at NRTI Lobesa, prepared and distributed the seeds and circulated instructions for the cultivation according to the experiences with conifers gathered at NRTI. He will undertake the trial in Lobesa and coordinate the efforts made in the RNR-RCs. Main questions to be answered are:

- What is the best sowing time?
- Does the seed require any special treatment to facilitate germination?
- What is the germination rate (in comparison with the Indian cultivar)?
- Is there any preferred altitude for the nursery?

For further cultivation trials, systematic seed collecting should be initiated by the DFOs, possibly in the course of the Tsenden inventory. The aim is to establish provenances (plantations of Tsenden from different areas serving as future seed resources), also for conservation purposes.

(2.2) Studies of the natural regeneration of Tsenden on permanent observation plots

These studies are urgently needed for the elaboration of sustainable management strategies of Tsenden forests. For example, it is not sure whether natural regeneration takes place at all in mature forests where selective logging is undertaken. Preliminary observations suggest that clear-cutting (including the broad-leaved undergrowth!) and subsequent plantation will give more reliable results. It is worthwhile, however, to prove these assumptions on permanent observation plots according to the experiences collected in other forest stands.

The main variants to be studied are:

[1] International Union of Forestry Research Organisations

- Undisturbed mature forest: most probably there will be no Tsenden regeneration during the observation period until the top-canopy trees break down or a fire hits the area. But, if any Tsenden trees germinate, the fate of the seedlings can be followed up.
- Tsenden forests where selective tree felling was done (e.g., Chuselumba or Ngoe Chu): permanent observation of the regeneration in the gap of the canopy.
- Tsenden forests with more or less clear-cut patches (Chuselumba or Ngoe Chu): select a plot where young Tsenden already established (e.g., our example plot in Chuselumba, 2620 m, 27°24'37''/89°56'56'') and, in comparison, where no Tsenden germinated yet. Where cattle is present, exclosure plots should be included in order to study the influence of browse on Tsenden regeneration.
- Recently burnt areas: a suitable site is the Si Chu/Pho Chu confluence, where a fire burnt down accessible parts of Tsenden forest on rocky slopes (Photos 7-9) in spring 1999. An older succession might be studied above Bjaphu Gönpa in the upper Lumbam Chu (Chhura Lum; map 1 in Appendix 1; binocular observation only!) in Chuselumba.

In view of the sparse regeneration of Tsenden, the size of the observation plots probably has to be increased, compared with the Bhutanese forest research standard. Some of the parameters usually measured might be omitted in order to make the recording work still feasible within a realistic time. The plot design should be discussed with those colleagues who collected experiences on permanent observation plots in the course of RNR-RC research.

(2.3) Enquiries of the local population

Much of the forest structure met in the different areas can be explained with the knowledge of the local people. It is worth spending a longer time during the surveys with interviews about the environmental history (last fires, grazing intensity, grazing patterns, permanent or temporary settlements, materials used for house construction at present and in older times; where are the nearest Tsenden trees/forests people remember? Did they expand or shrink in extent during their or their parents' lifetime? What did their grandparents tell about the Tsenden? What do they think about cattle's influence on Tsenden regeneration?).

Interviews should also be made in the following site:

In the Tepchekha hamlet (E-facing flank of the Chang (Tsang) Chu opposite Chuselumba, 1850 m, 27°23'N/89°53'E), there is plenty of spontaneous regrowth from planted, old Tsenden trees in the *Artemisia* scrub surrounding the farm houses. Small, dense groves formed on the leeward side of the parent trees, with young Tsenden trees in all age classes. From this it can be concluded that favourable conditions for Tsenden regeneration (very

unusual that close to the farmhouses!) persisted during a longer time. Interviews with the local inhabitants would yield valuable information about the regeneration behaviour of the cypress:

- Are there no domestic animals, or are they kept in stables? Or, were the animals absent for some years?
- Was there any fire near the homesteads, possibly set for "cleaning" the field margins from scrub?
- Which events can they correlate with the growing-up of the Tsenden?
- Why there is such a rich Tsenden regeneration here, contrary to other villages with planted holy trees?

A collection of interviews like this yields many ideas about the ecology of the Tsenden and may save much time otherwise spent in eventually useless experiments.

(3) Taxonomic and genetic studies

These studies should include specimens of the Indian Tsenden cultivar, in order to assess the degree of relationship with the Bhutanese trees.

In the Herbarium of the Royal Botanic Gardens, Kew (U.K.), there is an ongoing revision on Asiatic Cupressaceae, undertaken by A. Farjon. Samples from Bhutanese and Indian Tsenden will be morphologically checked there.

The genetic variation of Bhutanese Tsenden (planted holy trees, trees from relict forests) in comparison with the Indian cultivar can possibly be assessed through isogyme analyses, in analogy to the investigations on Blue Pine recently undertaken in Korea (LEE & al. 1997). The Institute of Forestry Genetics, Faculty of Forestry, University of Göttingen (Germany), is interested in the support of the necessary laboratory work and evaluation. A Bhutanese graduate student is welcome to be trained in Göttingen in the framework of a PhD or postgraduate study.

(4) Institutional framework

As suggested by NAMGYEL (1999), the Forest Resources Development Section (FRDS) of the Forestry Services Division (FSD) could take the responsibility for the **inventory and mapping** of the relict natural Tsenden stands. Possibilities of air or satellite photo interpretation should be followed up.

Studies on the **floristic composition**, range of **habitats** and natural **regeneration** in Tsenden forests could be undertaken in collaboration between the RNR-RCs (Forest

Research Program), the responsible Forest Divisions, the BG-SRDP and the NRTI. Lecturers from NRTI could establish the grid of permanent observation plots and incorporate their students in the annual routine recording work. D.B. Gurung/NRTI already initiated the sowing trials and is interested to undertake further field studies on the Tsenden. With his excellent knowledge of the Bhutanese flora, he would be well capable to carry out and coordinate such a project, in close cooperation with the RNR Forest Research Program.

For the **genetic studies**, a Bhutanese graduate student, interested in genetics and talented in mathematics, should be selected. Laboratory work and the respective training can only be done abroad. The Institute of Forest Genetics, Faculty of Forestry, University of Göttingen, would be interested in collaboration.

References

CARRIERE, E.-A.(1855): Traite general des Coniferes.Paris.

CARRIERE, E.-A.(1867): Traite general des Coniferes, ed. 2. Paris.

COOPER, E.-A. (1867): Botanical tours in Bhutan. With special reference to the genus *Primula*. - Notes R.B.G. Edinburgh 7: 67-118.

GRIERSON, A.J.C. & D.G. LONG (1983): Flora of Bhutan, Vol.1, Part 1. Edinburgh.

GURUNG, D.B. (1999): An experience in the midst of the Tsenden forest.- Annual Magazine, NRTI Lobesa, 7: 19 - 20.

JENSEN,R. (1990): Tsenden - precious and promising.- Tsenden (a general publication on forestry in Bhutan) 2/2: 23- 31.

LEE, S.W., CHOI, W., NORBU, L. & R. PRADHAN (1998): Genetic Diversity and Structure of Blue Pine (*Pinus wallichiana*) in Bhutan. - Forest Ecology and Management 105.

LONG, D.G. (1980): The weeping cypress, *Cupressus corneyana* Carr. Notes relating to the flora of Bhutan IV.- Notes R.B.G.Edinburgh 38/2 : 311 - 314.

MIEHE, G. & S. (1998): Plant formations in Central Bhutan and the challenges of conserving biodiversity. Reflections after a short-term visit in October 1998.- BG-SRDP Project Document No. 40.

NAMGYEL, P.(1999): Tsenden - *Cupressus corneyana* ? National Tree of Bhutan. -In: BTOR 99/2, RNR-RC Western Region: Yusipang.

NORBU, P.W. & S. WANGCHUK (1999): Report on the feasibility of FMU under Wangdue Dzongkhag. FRDC/FSD/RGB, Thimphu.

OHSAWA, M., SHAKYA, P.R., & M. NUMATA (1986): Distribution and succession of West Himalayan forest types in the Eastern part of the Nepal Himalaya.- Mountain Research and Development 6/2: 143 - 157.

SILBA, J. (1987): Nomenclature of the weeping Himalayan Cypress (*Cupressus*, Cupressaceae).- Phytologia 64/1: 78 - 80.

URA, K. & R. DOMPIER (1999): Bridges of Bhutan. - Tashi Delek (Druk Air's Inflight Magazine) 9-10: 13 - 25.

Appendix 1: Site-specific information on Tsenden stands

1. Chuselumba

The relict forest in an area called "Chuselumba" grows on the steep upper flanks of an eastern tributary valley of the Chang (Tsang) Chu (unnamed in the maps), c. 8 km S of Wangdue-Phodrang. Access is from Hisithangkha via Bjaphu (Byaphu) in 6-7 walking hours (with porters) to the grazing place and loggers' camp below the forest (1940 m, c. 27°24'30"N/89°55'40"E), or, with fast porters in one long walking day, to the centre of the Tsenden forest near the actual upper limit of the logging area (2640 m, c. 27°24'10"N/89°56'22"E). There is a good camp place but water has to be carried up in 1 hour's tour (both ways). Camps and the estimated extent of Tsenden-dominated forest are shown on map 1. The lowest relict Tsenden was found on the logging track at 2350 m, the actual lower margin of Tsenden-dominated forest (with logging gaps) was traced at 2550 m. The actual extent of Tsenden-dominated forest was estimated in the field at about 500 hectare (GURUNG 1999), but a rough mapping according to slide interpretation (Photo 10) yielded only about 80-100 ha (areas with predominant pines, where only solitary *Cupressus* trees occur on rock outcrops, were not included in the area marked on map 1). The upper limit of Tsenden could not be reached in the field because of inaccessible rock precipices, but binocular analyses from the opposite slope indicated that Tsenden is replaced by *Quercus semecarpifolia* and *Pinus wallichiana* near the crests around 3000 m.

According to the field checks, nearly all exploitable sites have already been reached by the logging activities; harvesting and transport of the remaining trees will be much more difficult and risky. Thus, there is a temptation to cut also those easily accessible trees which were initially left as seed resources for natural regeneration. Tsenden trees adapted to lower altitudes/drier climatic conditions have already disappeared from this area. The remains are largely adapted to rocky sites at higher altitudes. This means that the genetic variety of the Chuselumba Tsenden forest has already been impoverished. Strict protection of the relicts is strongly recommended.

Cattle followed the woodcutters to all logging sites. Where logging was absent also cattle tracks were not to be seen. The effect of grazing on Tsenden regeneration might be studied near our campsite.

In October 1999 there were no logging activities ongoing, but several felled trees and prepared logs were still sighted in the forest.

On forest gaps and clearings created by logging, regeneration of Blue Pine was plentiful, in contrast with that of Tsenden which was rare. A suitable permanent observation plot is just a little W of our camp c. 20 m upslope on the flattend part of an upper slope. The clearing is quite young. For comparison and further studies on Tsenden regeneration, the oldest clearing should be selected in addition (we did not find it, but local villagers from Bjaphu know it).

Another Tsenden population most probably grows one valley further to the north, at the head of the Lumbam Chu above Bjaphu Gömpa (map 1). According to binocular search from the opposite slope S

of Khatekha, this is a young regeneration stage, probably after fire. Contrary to the observations in the logged mature forest, young Tsenden seemingly dominated the regrowth (Blue Pine was well differentiated from Tsenden by its yellowish needles end of October). The crest at the head of the valley (3200 m) was dominated by *Quercus semecarpifolia*, c. 100 m above the uppermost Tsenden (here with plenty of Blue Pine). This site would be worth a ground check, combined with interviews of the people at Bjaphu, in order to supplement the knowledge about the Tsenden dynamics and ecology. Also grazing is expected to be practised here.

A small mature stand of Tsenden was observed on the rocky upper ridge separating the Lumbam Chu and the next southern valley with the logged forest. It is obviously inaccessible and safe from fire, surrounded by Blue Pine forest.

2. Nobding-Dangchu area

The upper Dang (Tang) Chu catchment probably had extensive Tsenden forests in the past, but relicts only survived distant from settlements.

The SE side of the Dang Chu valley W of Nobding was uninhabited and more or less untouched by man before the construction of the Pele La road, because the old trail followed the river. Long (pers. comm. 1999) observed many mature trees along the roadside in 1982 and 1984, both above and below the road some km W of Nobding. By 1999 they were all cut down, except two or three mature trees on landslide areas below the road and - luckily - some juvenile trees. The occurence of Tsenden around 3000 m W of Pele La (LONG 1980) still has to be proven.

Opposite Nobding, some small populations of Tsenden can be observed in rocky steep flanks of a small tributary valley W of Sil, draining the southern flanks of the Sebjigang range (c. 27°35'N/90°09'E). These were obviously observed by earlier travellers, too (LONG, 1980). The most extensive survived Tsenden population in this area grows in the NW tributary of the upper Dang Chu, called "Phinchho Chholing Chu" in the 1:50 000 map of 1966, but "Ngoe Chu" by the local people (according to Pasang Wangchen Norbu /FRDS). The influence of people's settlement on the occurrence of Tsenden becomes very clear in this area: whereas in the densely populated upper Dang Chu, the only Tsenden found are holy trees near gompas, extensive Tsenden forests were preserved in the parallel Ngoe Chu: on its eastern flanks N of the uppermost temporary settlement („Nyesa“,winter grazing place), and on the western flanks, c. 1 km upstream of the junction with the Dang Chu, the forests appear N of a small tributary, where the ungrazed gorge section starts (c. 2320 m, see map 2). On the southernmost rocky SE-facing flank on this side, Tsenden is mixed with Blue Pine, which is absent from the Tsenden forests further up the valley. In contrast, *Tsuga dumosa* is a common associate at higher altitudes. Also the presence of *Acer*, *Betula*, *Magnolia*, *Persea* and *Tetracentron* shows higher humidity conditions than in Chuselumba.

Our access was from the Pele La road, from the upper Sambaso Chu, via Chhibasi and Tazidinkha to Dangchu school, and on the following day we crossed the lower part of the ridge between Dang Chu

and Ngoe Chu to the winter settlement (2660 m, 27°37'24''N/90°10'20''E) and camped below, on a riverbank at 2390 m, 27°37'06''N/90°10'01''E) in an abandoned Loggers' camp. We went upstream up to 27°38'25'', were a further gorge section starts and the tractor road ends. From a ridge opposite the winter settlement (c. 27°37'28''N) we could check the upper Ngoe Chu valley by binocular and take photographs (see Photos 4-5). This survey revealed the following:

Tsenden forest covers both flanks up to at least 27°40'; the upper limit is reached at 2800 to 3000 m according to NORBU & WANGCHUK (1999). The head of the valley is covered by *Abies densa* forests, *Juniperus recurva* secondary forests (within the *Abies* belt) and *Tsuga-Quercus* forests in the transition zone between Tsenden and fir forests. No spruce was sighted. *Pinus wallichiana* was rare at the upper limit of the Tsenden belt, mainly on crests and in young secondary forests together with *Juniperus recurva* and Tsenden (merging at c. 3000 m).

The survey point revealed that the whole valley had been burnt down some 60-80 years ago. The Tsenden showed fastest regrowth after fire, being the dominant tree of these young secondary forests. Shade-tolerant *Tsuga* and oaks regenerate in the undergrowth (Photos 5-6). *Quercus semecarpifolia* dominates in patches, especially on the eastern flanks around the winter settlement, here indicating stronger human influence.

A large proportion of the Ngoe Chu Tsenden forests is thus much younger than those of Chuselumba. Tsenden is "only" up to 40 m tall, with BHDs between 40 and 60 cm. The remains of the burnt stems still overtop the crowns of the young Tsenden by several metres (Photos 4 and 5).

Map 2 shows the approximate extent covered by Tsenden forest, estimated to amount between 2 and 3 km² (400 ha were estimated by NORBU & WANGCHUK (1999)).

There has been quite excessive logging during the last years. The old trade route along the Dang Chu was widened, repaired and extended into the Ngoe Chu up to 27°38'25''N to be used as a tractor road for timber transport to a cableway at the Dang Chu below Nobding. At least two link roads allowed log transport from major western tributary valleys. Logging concentrated on the lower, steep slopes, where the distance to the tractor road was shortest, and more mature Tsenden trees of large diameters had survived the fire in the humid microclimate of the riverbanks. On several clearings, no seed trees were spared, and much damage was caused to the understorey trees. The shallow humic soil overlying limestone was removed in places, but serious water erosion was not visible yet. The raw substratum is being overgrown quickly by fast-growing pioneer plants (*Strobilanthes*, *Rubus* spp.). A number of Tsenden seedlings were sighted on fresh clearings, but they all appeared to have germinated in 1999 only. The lower slopes opposite our camp will make good observation areas to follow up the future regeneration of Tsenden here.

The only larger juvenile Tsenden trees were found at the end of the link roads in the near of abandoned workers' camps (Photo 16). Here, much open ground and light was available. The only "natural" regrowth in a forest gap created by a fallen tree was found by D.B. Gurung on the W-facing

slope below the winter settlement: a colony of Tsenden had come up on the open soil beneath an uprooted tree.

GURUNG (1999), NAMGYEL (1999) and NORBU & WANGCHUK (1999) reported about the logging activities in this area. D.B. Gurung, Doley Tshering and R. Wolf made a rough estimate how many logs were still lying around in the forest, prepared for transport: c. 1300 m³ only along that section of the valley we had seen. Logging activities had stopped before our visit, but on our way back (shorter way along the Dang Chu directly to Nobding), we met workers preparing the road for the continuation of wood transport.

The Dang Chu villagers told us that the Ngoe Chu has plenty of wild mammals. They noticed that Takin herds who used to come down to the river in winter have disappeared since the logging operations started. Grazing of cattle seems to be concentrated on the winter season and is more or less restricted to the flank below and above the winter settlement. It might have been a temporary practice around the loggers' camps, but we did not see any clear traces of grazing on the western flanks of the Ngoe Chu. There are no summer grazing places at the head of the valley because of its steepness.

NORBU & WANGCHUK (1999) concluded from the limited extent of exploitable Tsenden stands and the steepness of the slopes that the area is not a feasible FMU and recommended absolute protection.

3. Upper Pho Chu

The upper reaches of the Pho Chu possibly harbour the largest of the three Tsenden populations, but unfortunately the centre of the forest could not be reached: access was from Jibjokha (Sambadinka) along the N banks of the Pho Chu to Kewa Nang (6 hours), one of the last permanent settlements (1720 m, 27°41'N/89°56'45''), at the mouth of the Si Chu (map 3). This wild, broad tributory river is a natural barrier preventing the access to the upper reaches of the Pho Chu during most of the year. There is no suspension bridge, and the water can only be crossed during winter (second half of November until February/March). From a viewpoint above Ganji Nang we could overlook the lower Si Chu (Photos 7-9): this valley alone has a longer extent within the Tsenden zone than the Ngoe Chu, but as far as it could be observed Tsenden has a more scattered distribution here, with stronger competition of *Quercus semecarpifolia* and rhododendrons in rocky sites. The lower Si Chu appeared to be less humid than the Ngoe Chu, but Blue Pine was not sighted in the upper valley; it seemed to be restricted to the frequently burnt vicinity of Ganji Nang. Also the upper reaches of the Si Chu showed traces of fire (see Photos 7-9), which caused a patchy distribution of different regeneration stages. The vegetation pattern in the visible section of the Si Chu suggests a still strong human impact:

The flattened triangle NE of the Si Chu/Pho Chu confluence below 1600 m was devoid of Tsenden (Photo 7): this easily accessible and seasonally grazed area is either beyond the natural altitude zone of Tsenden or it was cleared. The rocky slopes to the north of this flat area are not accessible from the Si Chu river but in the upper parts from the ridge. Also fires spread from across the ridge, as it had happened in spring 1999. It was well visible (Photo 8) that in those forest patches that can be reached by fire Tsenden tends to dominate, whereas more isolated tree groups on rock ledges are mostly constituted by oaks.

The fire ecology of Tsenden could be very well studied on this ridge between Si Chu and Pho Chu, especially the regeneration of Tsenden on that spots burnt in 1999. A necessary precondition for these studies would be a bridge across the Si Chu (a simple ropeway with a wooden box would do it), allowing the access during the vegetation period.

There are also some groups of Tsenden on the settled side of the Si Chu (Photo 9). We tried to reach them and found out that they are strictly confined to such sites which cannot be reached by man and livestock. The southern slopes of the Pho Chu around Kewa Nang are probably cleared of Tsenden since long; the c. 100 year old farmhouses contained no Tsenden wood except some shingles inherited from the ancestors. Our informant and host in Kewa Nang was Mindu, a former monk, a good and intelligent observer. His mother, aged 67, does not remember any Tsenden growing on the Kewa Nang flank, but during her and her parents' lifetime, the Tsenden population on the opposite slope (Photo 7) had expanded. Both she and her son are sure that this expansion was due to fire.

We also owe Mindu all information about the Tsenden forests beyond the Si Chu confluence.

According to his information, extended Tsenden forests grow in the Loma (? Luma) Chu, a western tributary of the Pho Chu c. 3 hours upstream of Kewa Nang. After one hour the mouth of the Yak Chu is passed on the opposite side, and after two further hours the Loma Chu is reached. According to the walking time given, and the fact that the Loma Chu is visible from the 3260 m peak (or the 3793 m peak ?) on the ridge between Si Chu and Pho Chu (visited by Mindu), it is assumed that the mouth of this tributary is at 27°44'N (map 3). From here, the very centre of Tsenden forests is reached after one further walking day Pho Chu upstream.

From this description the dimensions of these Tsenden stands are imaginable. According to Mindu's estimation from the viewpoint, the Tsenden forests overlooked have an extent comparable to the distance between Kewa Nang and Sambadinka (i.e., about 10 km as the crow flies). Map 3 merely shows the potential area for Tsenden forests in the upper Pho Chu, as indicated by the 3000 m contour line. This area amounts to c. 25 square kilometres. According to Mindu's observations, however, Tsenden seems to be of scattered distribution, being mainly confined to rock flanks where it is commonly associated with palms. Good timber trees in reach are very rare.

This obviously is the reason for the fact that recent **logging** was undertaken as far upstream as the Loma Chu confluence:

We were told that the governmental road construction company cut down about 15 huge Tsenden trees in the Loma Chu area, c. 10 years ago, which is said to have caused big damage in the forest. Planks were prepared which are still lying around in the Loma Chu valley because they were never transported downstream.

Mindu remembers other logging activities 10-12 years ago; he saw logs being floated Pho Chu downstream. It was said that the logs should provide shingles for Punakha Dzong.

Despite the remoteness of the area, Tsenden seems to be harvested since long in the upper Pho Chu: as early as in 1915; COOPER (1933, p. 75) was told that the Tsenden forests in the upper Pho Chu were "at the sole disposal of the Maharaja of Bhutan and the timber used mostly in replacing the main beams of the Gompas or temples". Cooper got stuck at a place called Dongaysam and could only observe the forests with binocular. (Unfortunately, no place with a similar name is shown on the 1:50 000 map, thus we cannot trace where the margin of the Tsenden forest was in the beginning of the century).

The N flanks of the Pho Chu are included in the **core zone of the Jigme Dorji National Park**; N of 27°41'15" both sides of the Pho Chu are under legislative protection. Traditional grazing rights, however, allow a cattle owner from Paro to use a 5,000 acre area in the Loma Chu as winter pasture. According to Mindu's information, 60 to 70 head of cattle are driven valley-up to this place the second or third week of November each year, crossing the Si Chu. These herders also set the fire for pasture improvement in spring 1999. The fact that the fire reached the Si Chu indicates the extent of the burnt area; the fire obviously got out of control. The herders who set the fire were cought by the Kewa Nang farmers but no further penalty followed.

Based on this information following recommendations for FRDS, NCS, and the JDNP management, are made:

- As the Pho Chu above the Si Chu confluence is extremely rich in rare mammals (Takin herds descend down to the river) and the Tsenden resources are still unassessed (exploitable timber seems to be rare, though), more intensive control and site inspection is necessary in order to secure the park function in this remote area. Patrols all the year round would require a ropeway across the Si Chu; otherwise access is restricted to the winter season. On the other hand, a suspension bridge or ropeway would invite the villagers to use also the E flanks of the Si Chu throughout the year, grazing included. Second, according to Mindu's information, the trail upstream of the Si Chu confluence is almost impassable before the cattle "clears" it by trampling in November (plenty of bamboo thicket).
- Mindu from Kewa Nang would be a suitable local guard for the forestry or JDNP administration, due to the strategic position of his farm (everybody has to pass). In the course of the establishment of the southern JDNP boundary, people from Kewa Nang and Ganji Nang should also get support in

the maintenance of the path (Mindu complained that he has to manage all the way from Tshachu Phu to Kewa Nang himself, while many people use the path).

- Dr. S. Miehe plans a longer reconnaissance trip to the upper Pho Chu in the second half of November 2000. Concerned forestry and JDNP personnel are welcome to join the expedition, and main goals of the survey will be discussed with the respective organisations.

4. Observations on the occurrence of bamboo in the visited Tsenden forests

Our reconnaissance trips to Tsenden forests imply the approach of least disturbed vegetation types quite distant from human habitations. Despite all climatic variations between the different Tsenden sites, the abundance of bamboo in the undergrowth seemed to be largely related with the degree of human impact. Only on S-facing slopes in **Chuselumba**, it seemed to be too dry for the growth of bamboo in 2600 m. In all other aspects, bamboo (*Yushania* spp.), was very common but especially abounding where cattle had followed the loggers (or did cattle go where there was abundant bamboo before?).

Most interesting was the bamboo distribution in the **Ngoe Chu**: here, bamboo was clearly restricted to the cattle pastures; i.e. the forest and scrub areas S and below the uppermost winter grazing place on the eastern side of the river. There was a sudden lack of bamboo beyond a precipice limiting the grazing area to the north. On the western flanks of the Ngoe Chu N of 27°37' we did not see any bamboo. This coincided with the lack of cattle's droppings.

This pattern of bamboo distribution clearly supports the idea that livestock play an important role in the spread of bamboo, by which factors ever. From landuse point of view, this would be positive (cattle creates the pasture it likes best and provides humans with a valuable forest resource, too), but once bamboo dominates, it suppresses the regeneration of other forest constituents and may cause reductions in biodiversity. All these phenomenons are, however, not known in detail yet. It is not known either which role occasional fires play in the dynamics of bamboo (and there are certainly differences between the various species!).

Similar observations might be made in the Si Chu/Pho Chu area. These valleys have much steeper flanks with plenty of gorges and precipices, where the natural (light) habitats of bamboo are supposed to occur. D.B. Gurung detected some scattered bamboo tufts on the inaccessible rock flank opposite Ganji Nang (Photo 7). Bamboo was common in the grazed forests surrounding Kewa Nang and Ganji Nang, and it seems to be abundant along the trail Pho Chu upwards according to Mindu's report, but these are all grazed areas.

Continued studies in Tsenden forests, including long-term observation, will throw more light on the bamboo ecology in this altitudinal zone.

Appendix 2: Call for the collection of information about TSENDEN

To all Bhutanese forestry personnel

Call for the collection of information about the TSENDEN

Within the framework of a nation-wide inventory of natural Tsenden populations, we want to collect as much information as possible from local villagers living in remote areas.

All DFOs and attached forestry personnel are kindly asked to forward this call, and to report any information to :

The Program Director,
Mr. Phuntsho Namgyel
RNR-RC Yusipang
P.O.Box 212, Thimphu
Tel: 321600 / Fax:321601
e-mail: pnamgyel@druknet.net.bt

Thank you very much for your cooperation!

Main information required:

- location (name of nearest village or other locality names like rivers, grazing places..)
- distance from nearest settlement (walking hours/days…),
- approximate size of the Tsenden population (a few trees, only on one slope, or big forest to be crossed in….hours/days)

Forests known so far are in:

- Chuselumba, Phinchho Chholing Chu (Wangdue Phodrang Dzongkhag).
- Pho Chu (Punakha Dzongkhag)

Appendix 3: Proposals for research on the Tsenden issue

1. INVENTORY OF NATURAL TSENDEN STANDS

1.1 Localisation, mapping
(in cooperation with the DFOs and the local people through enquiries and public call for information)

1.2 Classification of the degree of disturbance
(undisturbed/grazed but no logging/selective logging/clear-cutting)

1.3 Recording of woody species and their age structure in the different classes of disturbance (if possible not only Tsenden but all woody species present): tree/shrub heights, diameter of trunks, according to age/height classes defined in Bhutan.
Plot size according to Bhutanese practices of forest inventory.

1.4 Recording of the number of Tsenden and Bluepine seedlings/saplings on defined plots (e.g. 10x10 m):
- in the shade of parent trees
- in naturally open patches (fallen trees, open glades on steep slopes etc.)
- in clear-cut areas.

Further differentiation according to substrate (tree litter/slash, open soil, herb-covered soil, moss-covered soil) yields, and additional valuable information.

Note: Natural Tsenden stands grow on steep rocky slopes in most areas seen so far; these sites are inaccessible or at least unsuitable for common inventory methods. Possible GIS approaches should therefore be tested.

2. TRIALS ON THE REGENERATION OF INDIGENOUS TSENDEN

2.1 Continuation of germination experiments

2.11 Collection of Tsenden fruits at appropriate time (autumn):
- collect fruits of each individual tree in separate paper bags (if possible from the trees, not from the ground)
- store fruits in a dry place (cotton sack, paper bag) until the cones open and release the seeds
- check seeds for fertility
- count the number of fertile seeds obtained per tree individual

2.12 Sow seeds in seedbeds (at 2 to 3 different times between October and December), with separations between the labelled areas allocated to each individual, cover with a thin layer of soil.
Keep seedbed permanently moist (if there is no rain, daily watering necessary).
It is advisable to carry out the germination trials at different sites (altitudes).

2.2 Studies of the natural regeneration of Tsenden on permanent observation plots
- in relic natural forests
- in logging areas (a) cattle present, (b) cattle absent (suitable sites: Chuselumba, Dangchu area)
- in recently burnt areas (suitable site: Lower Si Chu, Pho Chu catchment)

2.3 Carry out enquiries among the local population concerning the recent environmental history (fires, grazing patterns in space and time).

3. TAXONOMIC STUDIES

3.1 Collection of herbarium specimens for anatomic studies, in the framework of the taxonomic revision of the Cupressaceae in the Himalayan region

3.2 Collection of seeds for DNA analysis abroad (probably Fac. of Forestry, University of Goettingen, Germany, collaboration with graduate students from Bhutan desired)

4. LOGISTIC PRECONDITIONS FOR RESEARCH PERFORMANCE

4.1 Funding of the Bhutanese inventory team

4.2 Export licenses for fruit and herbarium specimens for scientific/non-commercial studies

4.3 Foreign ecological counterparts (Drs.G.&S.Miehe) as well as forestry-genetic counterparts are funded from Germany.

Appendix 4: Schedule 1999

October 4: Arrival by Druk Air from Kathmandu (KB 108), transfer to Thimphu. Meetings with R. Wolf/BG-SRDP, Dr. I. Krug/RNR-RC Yusipang, and R. Pradhan/RSPN.

October 5: Meeting with P. Namgyel, Program Director, PNR-RC Yusipang, transfer to Lobesa.

October 6-10: Second survey excursion to Chuselumba Tsenden forest, in company of D.B. Gurung/NRTI, Doley tshering/RNR-RC Bajo (part-time) and local porters. Vegetation records and sapling counts, search for permanent observation plots, collection of seed.

October 12-17: Survey excursion to Dangchu area (Ngoe Chu), in company of D.B. Gurung, R. Wolf (part-time), Doley Tshering (part-time) and Kumar Tamang/Forest Guard from Nobding, (part-time) and local porters. Vegetation records and observation on regeneration in Tsenden forests, seed collection.

October 18: Transfer to Thimphu. Meetings with P. Namgyel and Mr. Tshitila/RNR-RC Yusipang, with Dasho Sangay Thinley/Joint Secretary FSD, D.B. Dhital and Pasang Wangchen Norbu/FRDS.

October 19: Meetings with Dr. Sangay Wangchuk/NCS/FSD, Karma Tsering/National Biodiversity Centre/REID, Dr. Pema Choephyel/Chief Research Officer/REID and Roy Cameron/UNV/UNDP/JDNP.

October 20: Meeting with Mr. Tshitila/RNR-RC Yusipang.

October 21: Prof. Dr. G. Miehe: Departure by Druk Air, KB 107 to Kathmandu,
Dr. S. Miehe: return to Thimphu for visa extension.

October 22: Transfer to Lobesa.

October 24-26: Survey excursion in company of D.B. Gurung and local foresters to the Tsenden area of the upper Pho Chu catchment. Return from Kewa Nang due to high water level in the Si Chu (no bridge!). Binocular check of the Tsenden stands on the opposite flank of the Si Chu (uninhabited),excursion to the only accessible Tsenden tree and interviews with the local farmers.

October 28: Transfer to Thimphu with R. Wolf. Meetings with P. Namgyel/Yusipang, D.B. Dhital/FRDS/FSD.

October 29: Thimphu - Lobesa.

October 31: Excursion to Tepchekha (opposite Chuselumba), photo documentation and observations on spontaneous Tsenden regeneration.

November 3: Participation in a presentation held by Prof. Ohsawa and his research group about recent field research on lifezone ecology in Bhutan, FSD, Thimphu.

November 9-11: Organisation and meetings in Thimphu.

November 15-19: Participation in the International IUFRO Seminar "Silviculture and Sustainable Management of Mixed Broadleaved Forests in the Himalayas" held in Lobesa. The short form of this report was presented as a joint paper under the title "The Tsenden (*Cupressus corneyana* Carr.) as a natural constituent of Bhutanese Broadleaved Forests? - Preliminary observations, ecological research needs and conservation issues" (D.B. Gurung, G. & S. Miehe, P. Namgyel & R. Wolf).

The time between the meetings in Thimphu was spent in Lobesa with herbarium work, planning and the preparation of the paper.

November 22: Transfer to Thimphu. Meeting with R. Cameron and H. Blom v. Assendelft/UNVs' in JDNP, Namgay Dendup, ICDP Warden of JDNP (Apologies: Tshewang R. Wangchuk, Park Manager, JDNP) on future research in the JDNP. Transfer to Paro. Departure by Druk Air KB 107 to Kathmandu.

Appendix 5: Photos

Appendix 6: Maps