Fig. 1 A view of Blue Lake with Birch-Spruce forest. The near denuded site is closer to the settlement. Photo. A.U.Khan, July 2001.

Graziers bring their families and stay their for most of the summer, ranging from six to eight months. The extraction is mostly confined to the side closer to the settlements. The forest has wide tracks and is crisscrossed with pathways. They have good ground cover of litter, but very little regeneration was observed as compared to the intact forest. The wood extracted is generally used for thatching and fuel locally and also carried to the alpine meadows during summer. These fragments with increasing settlements are in a vulnerable state, as they are prone to further degradation. In the absence any regular monitoring the presence of Spruce in the Birch stand and on the mountain slopes could be either looked upon as the tree limit rise or it might be a relict from past vegetation.

iii Relict trees and small stands along established routes of herders.

The area includes the annual route of the herders which extends from temporary settlements to scrub forest and alpine meadows. The well-trodden tracks (38000 to 45000m), are used by the herders to carry their herds to the uplands during summers. It mostly presents a barren landscape and eroded slopes. This is because the campers who accompany their herds to alpine meadows, use Birch and the scrub beyond as fuel, as it is the only satisfactory fuel available at these heights. The tree limit was, as a rule, composed of solitary senescent trees or burnt stumps with no regeneration. Regeneration

was observed in crevices on steep slopes and probably it is the steepness of the slope that discourages the casual logger from extraction from such sites (Fig. 2).

Fig. 2 Burnt stumps of birch with no regeneration and surviving relict of birch in the middle, in the rock crevices on the steep slope on route of the graziers. Photo. A.U.Khan, July 2001.

The distance measured between these relict stands and surviving forest fragments range from one to three km down slope. The bare soil along the routes are heavily trodden and compacted and is no longer suitable for germination and establishment of the Birch forest.

II Comparative assessment with 'the tree-line rise scenario'

In order to adopt an optimistic scenario in the tree-line ecotone of Pakistan it is important to appreciate the methodology and policies practiced by the European countries. The criteria listed in the method section is used here to compare the similarities and dissimilarities between the two situations. This appreciation will help us in identifying gaps and developing a rationale for the governance of alpine and subalpine areas of Pakistan.

i. Ecological equivalance between the tree limit ecotone of two biogeographical regions..

Organisms that occupy the similar ecological niches in different geographical regions are known as ecological equivalents. The tree-line ecosystem of Pakistan and

Europe can be said to be at ecological equivalence. This is because the physical habitat is similar regardless of geographic location, therefore, the species occupy equivalent niches and are closely related taxonomically resulting in development of similar ecosystems. The ecosystem similarities in these two geographically different locations is mainly due to the fact that elevation of the tree limit decreases with increasing latitude. In Pakistan it is located at lower latitude (32- 34N) with tree-line elevation ranging from 3500 m.a.s.l to 4500 m.a.s.l,. In northern Europe with increasing latitude (55 -71 N) the elevation of the tree limit decreases and ranges from 700 m.a.s.l to 1200 m.a.s.l (Fig. 3).

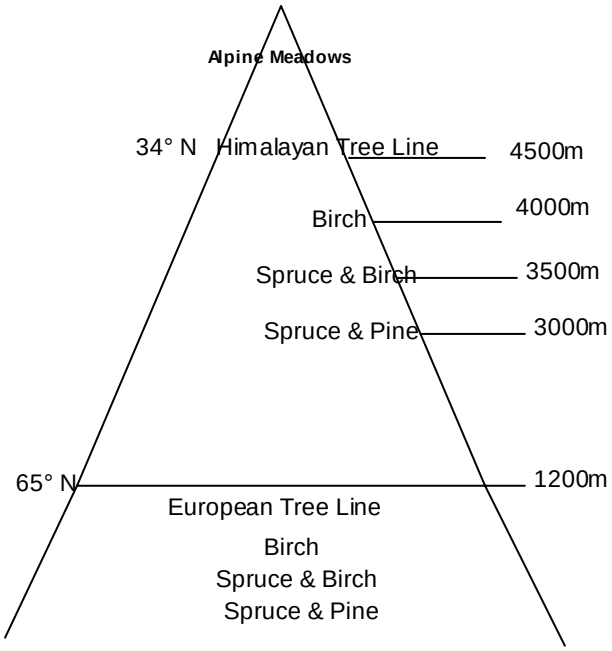

Fig.3. A hypothetical model of the approximate tree line ecotones of two biogeographical regions showing the differences in tree-line elevation (right) with the latitude (left) and similarities in species and forest types.

Both in Pakistan and Europe these forests come under the context of sub-alpine forests and alpine scrub. The tree limit ecotone i.e. the transitional belt between the upper closed coniferous forest and tree limit of birch is composed mainly of three tree species. In Europe the Birch is *Betula pubescns* Ehrh. and *Betula utilis* D. Don, Prodr. Fl. Nep. in Pakistan, The Spruce is *Picea abies* (L.) Karst in Europe and *Picea smithiana*, Boiss Fl. Orient. in Paksitan. The Pine is *Pinus sylvestris* L. in Europe and *Pinus wallichiana* A.B. Jackson. in Pakistan. Similarly the mode of reproduction of the species is similar Spruce and Birch are mainly reproducing vegetatively and by seed regeneration, whereas Pine reproduce by seeds only.

In both ecosystems the recognized climatic climax types formations are Birch-Confier and Birch forests. Birch is the only tree capable of growing to a fair height and is the topmost tree formation. They are crooked and branchy, reflecting the severe climatic conditions. This is that limit of forest growth where conifers are unable to withstand the severity of the climate; cold and often dry winds in addition to short growing season and deep snow.

ii Anthropogenic utilization of tree-limit ecotone

The sub-alpine landscape in Europe has been extensively used by man for several centuries for summer farming, livestock grazing, logging for firewood and as a result the tree limit positions was lowered in the early 19th century. These activities gradually ceased during the late 19th century, and presently the only grazing impact is that of herds of semi-domestic reindeer which regularly graze the alpine meadows during spring, summer and autumn and interact with climate to shape current vegetation pattern in the tree limit zone. Although this aspect is little studied in quantative terms but results based on monitoring clearly suggests that for most of the 20th century tree limit rise has occurred concurrently with growing reindeer herds.

The reconnaissance survey in Pakistan clearly indicates that the surviving undisturbed fragments are only found on inaccessible rocky slopes having evidently been driven out of the more gentle slopes by excessive grazing. The present condition is the result of decades of free exploitation of Birch, which is both lopped for fodder and cut for firewood by graziers (Champion, et. al.,1965; Parker, 1951). The growth of Birch is slow and reproduction is usually wanting due to grazing and other consumptive uses; outer bark is peeled off in large strips and used for umbrellas and roofing houses, packing and in place of paper. The forest is heavily grazed in summer and is also still being steadily reduced by felling for fuel, regeneration being mostly prevented by the grazing.

These activities are acutely threatening the continued existence of Birch and solitary conifers.These trends of disturbance has further probably aggravated climate change initiated stress; driven by earlier snow melt and soil drying. In areas with strong graziers impact severe vegetation stripping and soil erosion have occurred on early snowmelt sites. The frontal expansion of bare sites has rates of several metres per year locally.

The survey of the ecotone region clearly shows that the graziers are using the fragile ecosystem beyond its carrying capacity. The traditional subsistence graziers are now exporting their products to other regions, which is obvious from the size of the herds and number and quality of construction of the houses in the temporary settlements at the sub-alpine regions. Since the Birch forest is not attractive from market point of view and because of inaccessible locations the government is not paying any attention to this fast depleting biological resource. At the moment government agencies, determine land use primarily by the livestock production capacity of the area in question, irrespective of its value to society in a more natural state. Whereas in the European case it seems that the abandonement of intensive utilization of this fragile ecosystem could be a major factor in the large scale 20th century advance of tree limits. Otherwise, the general

structure of the tree limit ecotone (tree density, growth forms , ground cover, etc.) might have followed the pessimistic scenario as being demonstrated in Pakistan .

iii Climate change scenario and growth in height of established individuals (phenotypic) and upslope migration of new individuals (genotypic).

Climate warming by 0.8^0C between the late 19^{th} and late 20^{th} century, has forced multispecies elevational tree-limit advance by more than 100m for the principal tree species in the European mountain ranges. Two principal types of elevaional tree limit change can be distinguished during this period. Phenotypic change, is in situ shifts in height of old established individuals. It is the prevalent mode of change recorded during the past century in the tree-line ecotone. Genotypic change, is the establishment and growth to tree size of newly established genetic individuals at ever higher elevations (Fig. 4).

Fig.4 The tree-limit of birch has advanced by 140 m between 1915 and 1975. This is the highest known tree-limit in Sweden. After Kullman, (2001).

Birch and Spruce have predominantly responded with phenotypic tree limit changes and have experienced the same magnitudes of elevation tree limit rise. Additionally, the Birches near the tree limit displayed annual shoots with a length that is three times

greater than the normal value for these sites. The net effect being continual densification of the tree-line ecotones (Fig. 5).

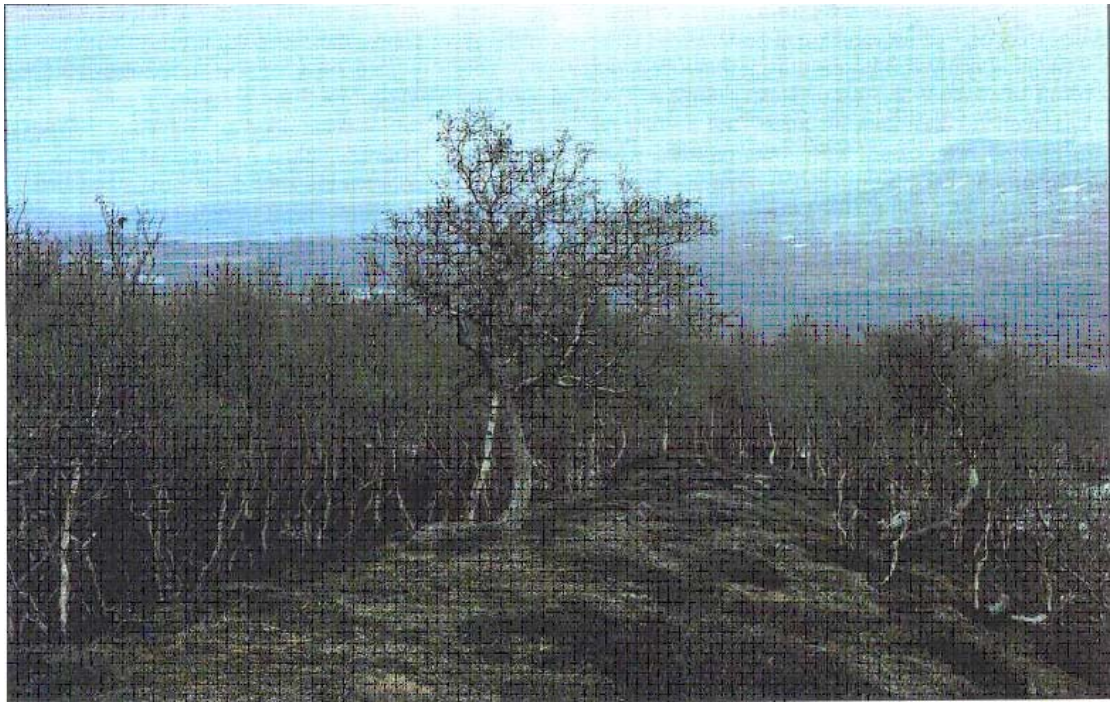

Fig. 5 In the early 20th century, the local tree-limit was marked by this solitary birch (805 m.a.s.l.), growing in an open low alpine landscape. Subsequently, in response to climate warming and earlier snow-melt, resulting in dense birch stands. After Kullman (2001).

Thickening of birch tree populations within the tree limit eotone has imposed a positive feedback loop, by changing surface albedo and wind microclimate, the stands have stabilized this ecotone, making it more resilient to subsequent climatic adversities. There is possibility that the existence of these new stands may facilitate further expansion by ameliorating edge effects within the local topography. And there is further possibilities that within the lower reaches of this newly evolved Birch woodland Spruce and Pinus may become more prominent, by increased growth of old specimens and establishment of new individuals. Expansion of Pine in the tree-limit ecotone , might be another good omen under the predicted drier climatic regime as not only it develops faster, but it establishes and endures better on dry and shallow soils than does birch.

iv. Regional base line network

In Europe the recent tree limit progression was quantified and analyzed in retrospect by the establishment of a regional baseline network comprising more than 200

tree limit sites. This network, also intended for future long term monitoring, based on investigation sites established around 1915. The large number of study sites distributed over a hetrogenous region enabled these analyses to be made along various geo-ecological gradients, e.g. climate, topography, aspect, slope and human impact which added important details to the interpretation of emerging patterns.

III Considerations for converting pessimistic scenario into an optimistic one

In Pakistan the degeneration of the tree limit ecotone is more related to anthropogenic land use changes than to climate. Therefore, intensive summer grazing in alpine region needs immediate attention as it could potentially prohibit any upward spread of birch.

The natural conservation strategy (GOP, 1992) rightly pointed out the dearth of legislation for environmental protection and resource conservation. The nature conservation policy in such regions should not only be to protect endangered species or economically important species of plants and animals but also entire habitats of tree-line ecotone under the emerging scenario of climate change. It should be based on biological aspects of the plants such as population sizes, numbers, and reproductive success and most importantly there is an urgent need for integrating agricultural and environmental policies, which appears to be the main reason for the environmental degradation in the fragile tree-line ecotone. European scenario clearly indicates that some of the measures adopted in the early 20th century are bearing the fruits in the form of tree line advance in the subalpine region in response to climate change. The Pakistan's scenario clearly shows the deteriorating plight of the tree-line ecosystem even in the protected areas. There is an urgency to set aside demonstration sites like Naltar and introduce a comprehensive restoration and rehabilitation program. Setting up of permanent plots for detailed monitoring program of tree limit performance will substantially improve the functional understanding of the tree limit ecotone. Subsequently, emphasize should be laid on establishing a network of study sites distributed over the entire region in collaboration with various other agencies monitoring glacial depletion and geo-ecological gradients in the region (SUPARCO, PARC, Pakistan meteorologist department etc.), for indepth analysis and interpretation of emerging patterns. Implementation of such practices will impose a break or retardation in the progressive tree limit decline reported but not documented for many decades.

For the sake of good governance of sub-alpine ecosystems the Government should declare the tree-line ecotones, under the looming threat of climate change, as public goods and aims of conservation should include the valuation, protection and rehabilitation of natural vegetation of sub-alpine areas . As a matter of fact public value of these tree-limit ecotones should be derived from their protection function; protection against floods, erosion, landslides and avalanches. It is an important physical welfare function at these altitudes, a function which can be safe guarded only by natural vegetation. The timely realization of the protective function of this ecosystem in Europe is already being expressed in the form of an emerging band of newly appearing tree growth above the tree-limit (optimistic scenario). Ironically, factually speaking,

protective function of this ecosystem is more significant to Pakistan as compared to Europe. The reason being that these zones are located at higher altitude and the distance to the valleys is greater and the gradient is steeper, and therefore, erosion, landslides and avalanches, resulting from destabilization of tree-line ecotone, will bring far greater scale of disaster in this region as compared to Europe. Present extensive utilsation of this fragile ecosystem leading to the disappearance of tree-line species and their seed bank, with no sign of upward migration, indeed, presents a pessimistic scenario, especially, in the context of climate change. Frequent rainstorms will further aggravate soil loss and not only erode the protective capability of this ecosystem but also the productive ecosystem downhill. Retaining a plant cover on such fragile sites, would allow the vegetation to interact with changing environment and could act as a shield against gradual climate change as demonstrated in the European scenario. At the moment there is total lack of interest at local and national level regarding the new value, 'the buffer against climate change' of these tree-line ecotones. If these values are valuated they would definitely out-weight any other consumptive value of these biological resources.

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