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TREE-RINGS FROM THE UPPER TIMBERLINE IN THE KARAKORUM AS CLIMATIC INDICATORS FOR THE LAST 1000 YEARS

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Parole chiave: concentrazione CO_2 atmosferica, alberi decorticati, fluttuazione a medio termine, *Juniperus sp.*, karakorum.

Abstract

Climatic sensitivity, mid-term fluctuations and tree reaction responsible to the fertilization effect of atmospheric CO_2 enrichment were analyzed by using the ring-width from 69 Juniper trees in the Karakorum (N-Pakistan). The skeleton plot method gives proof of the strong climatic sensitivity from trees at or near the upper timberline (4000 msl). The measured ring-width shows mid-term fluctuations in the raw data (1/100 mm), which reflect climatic fluctuations. A positive, CO_2-forced growth reaction in strip barked trees, as suggested in the results of GRAYBILL ET ALII (1993) in bristlecone pine stands (California), is not observed in the Karakorum.

Juniper trees as climatic indicators?

There is general agreement that tree growth highly depends on local environmental factors such as soil conditions, humidity and local climate, or on stress factors like damage through human or animal influences. Climate must also be considered as a regional impact, and therefore extreme stress conditions (e.g. cold or dry vegetation period) are supposed to be marked regionally as pointer years (SCHWEINGRUBER ET ALII 1990). Only few publications deal with the extremely slow growing *Juniper* trees (BILHAM ET ALII 1983; BRÄUNING 1994; GRAYBILL ET ALII 1992), but none of them discuss mid-term climatic fluctuations. LUCKMAN (1992) points out that non-indexed chronologies of a limited region from old, non-overlapping curves can be climatologically interpreted. In recent years the increasing atmospheric CO_2 concentration seems to create a positive trend of changing growth rates, especially on strip barked trees, as GRAYBILL ET ALII (1993) have observed in index values of *Bristlecone pine* stands. These authors guess that trees with destroyed crowns and rudimentary cambium (strip barked trees) possess reduced rootsystems and react in an extraordinarily positive way in the stems woodproduction. Rock exfoliation on steep sites is suspected to be the principal stimulus for the loss of cambium (KELLY ET ALII 1992: 117).

Our long-term research programme on environmental conditions and changes in the Karakorum checks a multitude data and information including tree ring analysis

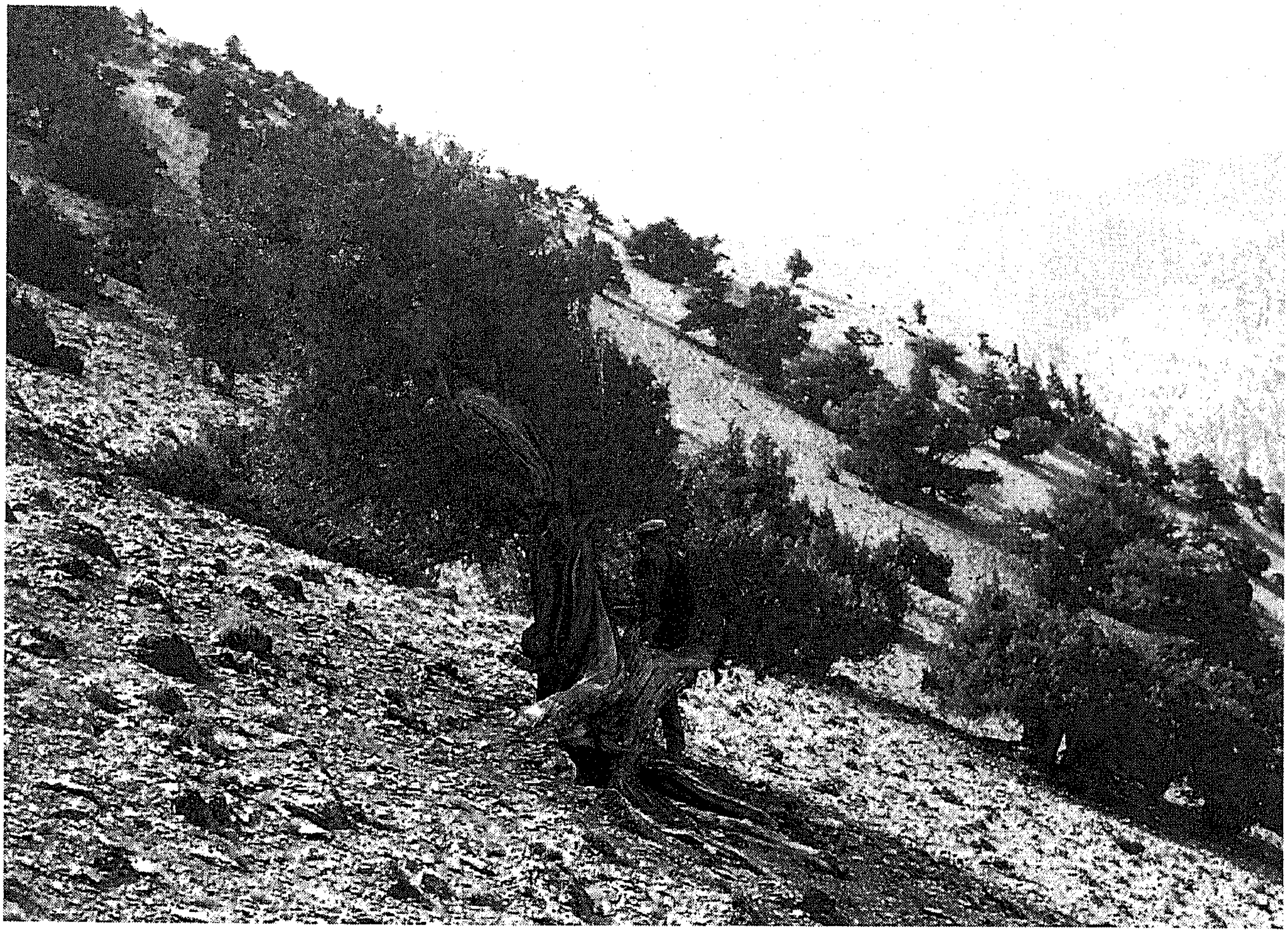

Photo 1 - *Juniper* trees in a typical open stand near the upper timberline at 3900 msl - Morkhun Valley, Hunza-Karakorum (Pakistan).

and uses them eventually in the reconstruction of climate. In this article the following questions and topics are discussed: 1. Are slow growing *Juniper* trees sensitive to environmental conditions, especially climatic signals? 2. What is the reaction range of individual trees of homogeneous stands in extreme pointer years? 3. Do mid-term growth fluctuations exist and to what extent can they be interpreted? 4. Is the increase of atmospheric CO_2 concentration detectable in the growth curves of strip barked *Juniper* trees as a superimposed trend?

Material and methods

69 core samples from four phytosociologically homogeneous, open *Juniper* stands (photo 1) in the Hunza-Karakorum have been analyzed (Esper 1994). The relatively dry sites are located in the Morkhun Valley and cover the altitudinal range between 3560-4000 msl (Fig. 1). Average annual rainfall at this altitude is estimated to reach appr. 500-700 mm (Weers 1995:70), and mean monthly air temperatures in summer 1991, measured at a station in Bagrot Valley at 3780 msl are as follows: May 1.8 °C; June 9.7 °C; July 11.3 °C; August 12.2 °C; September 8.7 °C; October 0.7 °C (Cramer 1994: 211).

Year to year chronologies were established based on the skeleton plot method, which also permitted the identification of 'absent rings' in the individual samples.

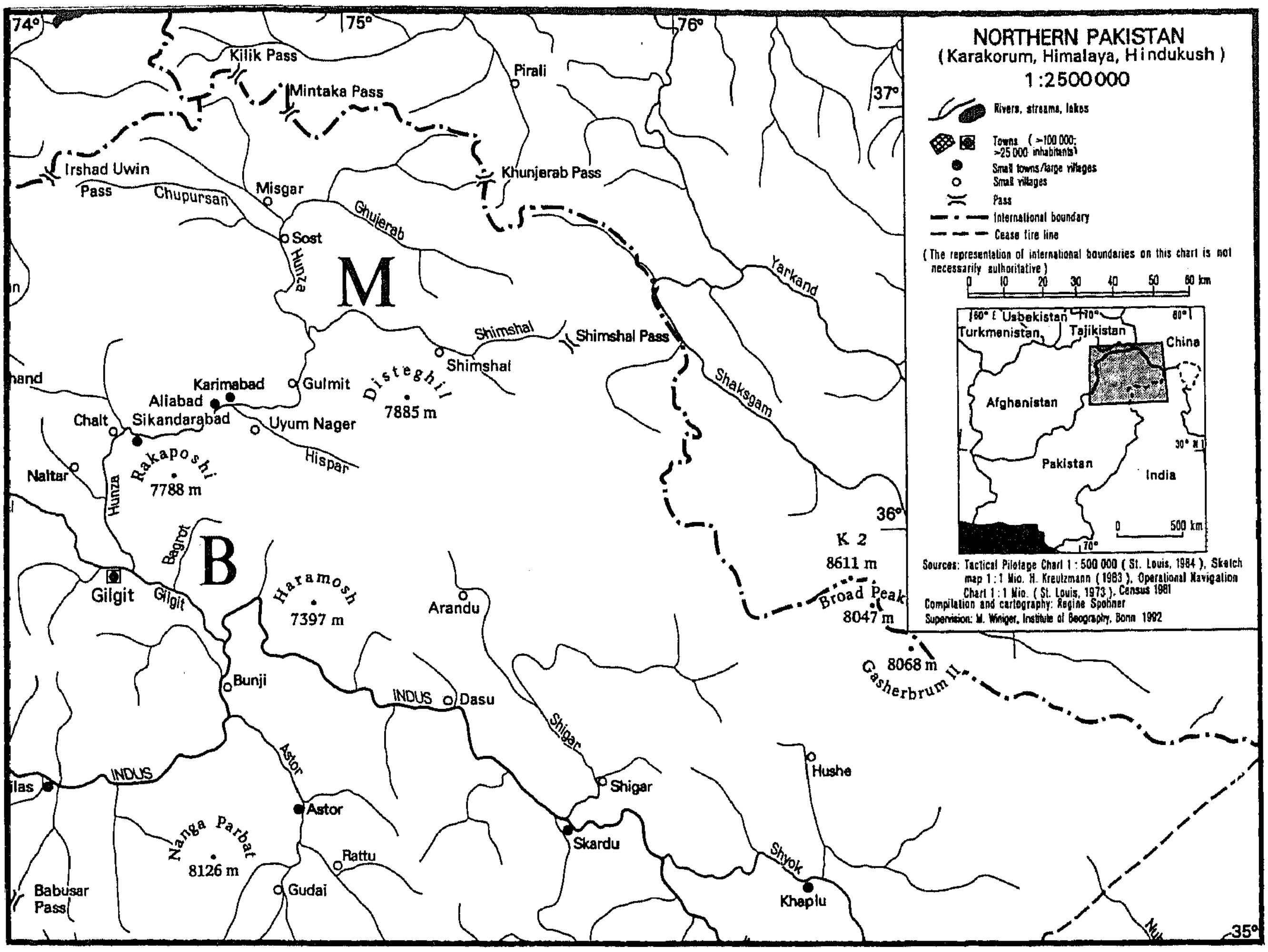

Fig. 1 - Map of Northern Pakistan and the Karakorum. The sample areas are indicated with M (Morkhun Valley) and B (Bagrot Valley).

Cores from very old living trees (up to 1,500 years) clearly proved that reliable chronologies might be developed for the past 1000 years, but due to statistical reasons, (i.e. not enough very old tree samples were collected), and in order to eliminate age dependant growing characteristics, the time series for only the last 250 years will be discussed further. Individual time series, based on the measurement of the width of tree rings, (only tree species of >160 years were considered), were statistically treated by t-test (limit = 5), sign test (limit = 70%) and level of significance (limit = 99.9) and finally summed up in order to produce averaged curves.

Results

Skeleton plot

The skeleton plot method clearly proved the homogeneity of the sample material and at the same time its climatic sensitivity. Years with negative stress (narrow rings) were assigned as 'unfavourable' when >60% of all tree rings of this year were narrow; 'favourable' environmental conditions based on >40% of the trees react in terms of wide rings. Based on these criteria an astonishingly high number of 52 'negative' and 50 'positive' pointer years could be identified within the 250 year period 1741-

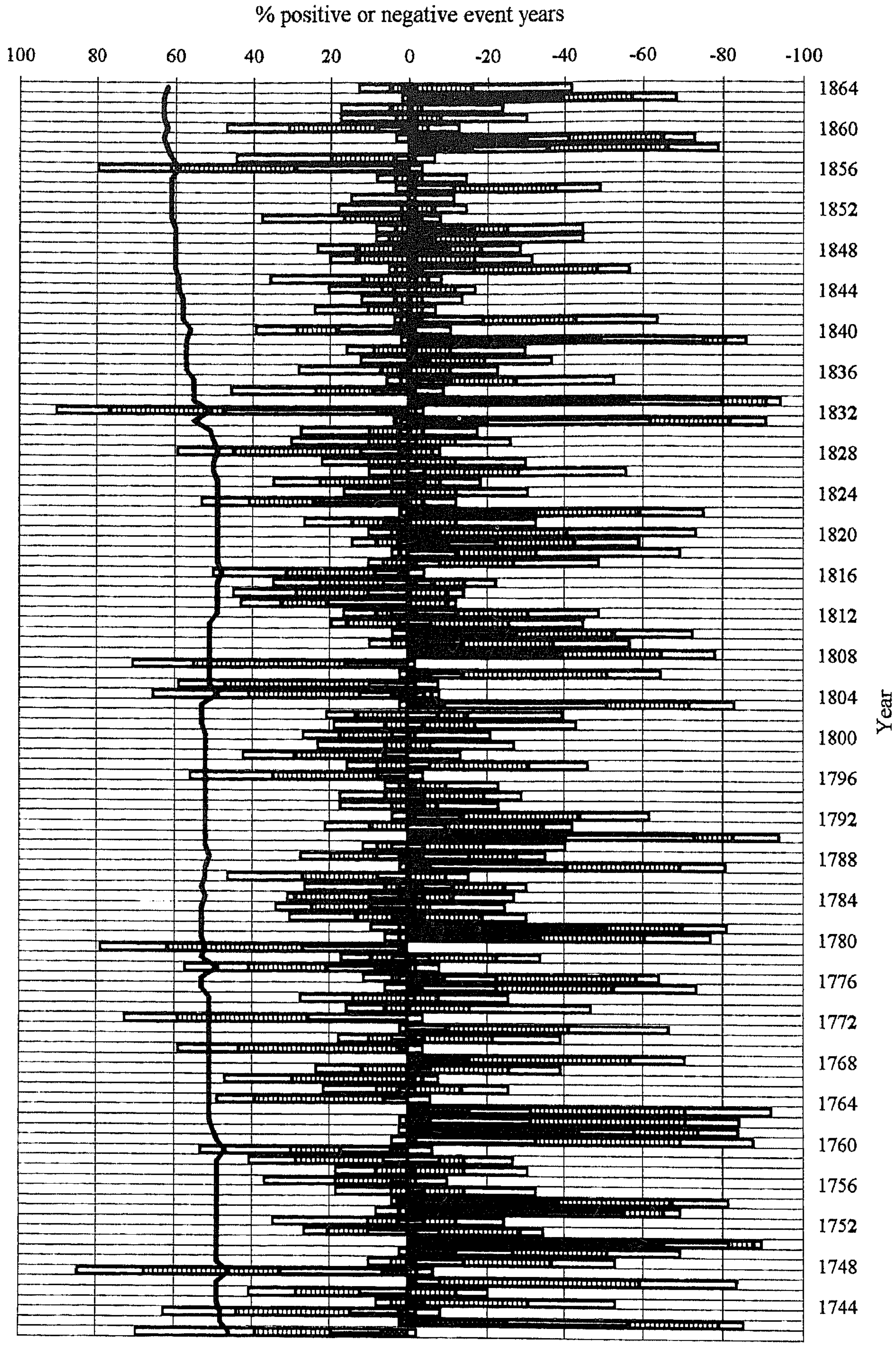

Fig. 2.a - Masterplot 1741-1864. The columns show positive and negative events in % of all trees and the intensity (black to white) in a single year. The curve above indicates the number of trees.

1990 (Fig. 2.a, Fig. 2.b). The climatic calibration, based on a 80 year record of monthly temperatures and precipitation (Station of Gilgit, 1480 msl), has still to be questioned, as the local conditions between sample Plots and the station differ considerably.

In the strong negative pointer year 1928 more than 85% of all trees build a narrow ring. Fig. 3 gives an example of the local reaction of the individual trees in the investigated test sites in Morkhun Valley (Plot 1-4, *Juniper*) and one test site in Bagrot Valley (Plot 5, *Picea smith.* and *Pin. wall.*). The ring-width ranges from extreme negative reaction to no reaction. The pointer year 1928 was dominated by the cambial activity in Plot 2, Plot 3 and the lower part of Plot 4, so that the sum of local reactions in Plot 1 and Plot 5 won't produce a pointer year. In many pointer years also opposite event years are given (e.g. negative pointer year with positive events).

Mid-term fluctuations

If a climatically sensitive and homogeneous (statistically proofed) averaged curve shows mid-term fluctuations, the variations in growth can therefore directly be interpreted as climate-fluctuations (SCHWEINGRUBER 1994). A transformation to remove age related trends into dimensionless indices would also eliminate all environmental information, which is longer than the period of the function used (LA MARCHE 1974). Working with more than 1000 year old *Juniper* trees makes it possible to analyze data in the raw dimension 1/100 mm.

Fig. 4 contains the superposition of averaged curves of the four test sites and the trend of all 49 individual series in order of the minimum square distance method (linear regression): transitional phases are characterized by inhomogeneities between different sites (e.g. years 1820-1830, 1978-1990), whereas strong negative signals can be identified e.g. in 1750, 1833, 1865, 1895, and 1928. For the period of 250 years two main aspects become evident: (1) a slight trend towards better growing conditions might be proposed for the last 100 years. (2) a series of 'optimum' and 'depression' phases (defined as annual differences to the average tree ring width of the whole period) is altering. Interestingly, the unfavourable 100 year period from 1825-1925 includes phases of significant advances of many glaciers in the Karakorum.

CO_2-related growth trends

The rapidly increasing differences between the growth curves of strip barked and full barked trees, which have been observed after 1870 in the cambial activity of *Bristlecone pine* stands in California and which were believed to be related to the increasing effect of atmospheric CO_2 (GRAYBILL ET ALII 1993), could not be confirmed in the old *Juniper* stands of the Karakorum.

As the hypothesis of varying efficacy of CO_2 on different growth-forms suggests, strip barked trees should build more stemwood than the full barked. The fertilization effect of increasing atmospheric CO_2 is supposed to be extraordinary in strip barked trees because of the reduced rootsystem. The ring width series of Karakorum's *Juniper* strip and full barked trees show no differences which can be related to the registrated CO_2-increase and above all there is

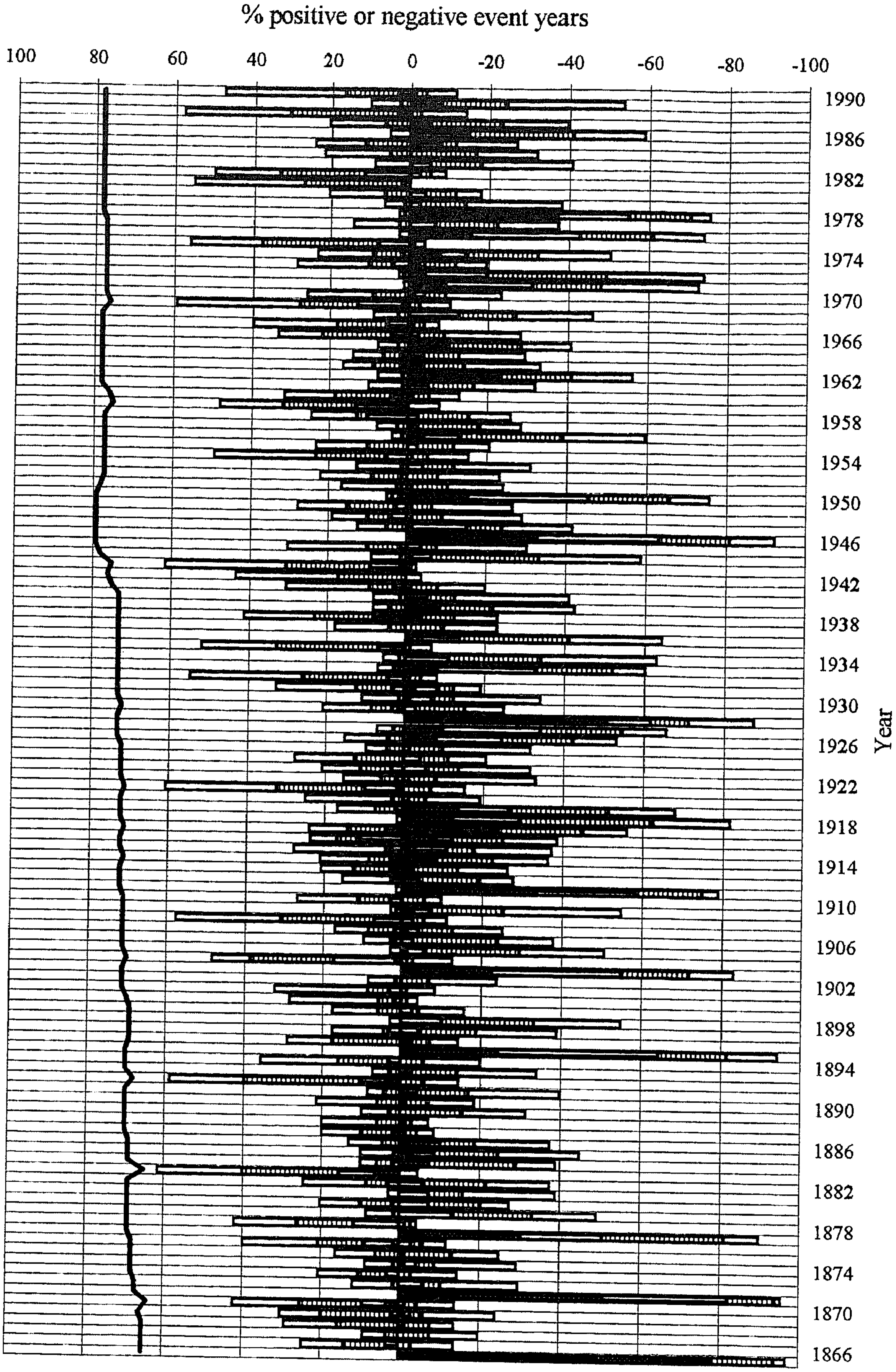

Fig. 2.b - Masterplot 1865-1990. The columns show positive and negative events in % of all trees and the intensity (black to white) in a single year. The curve above indicates the number of trees.

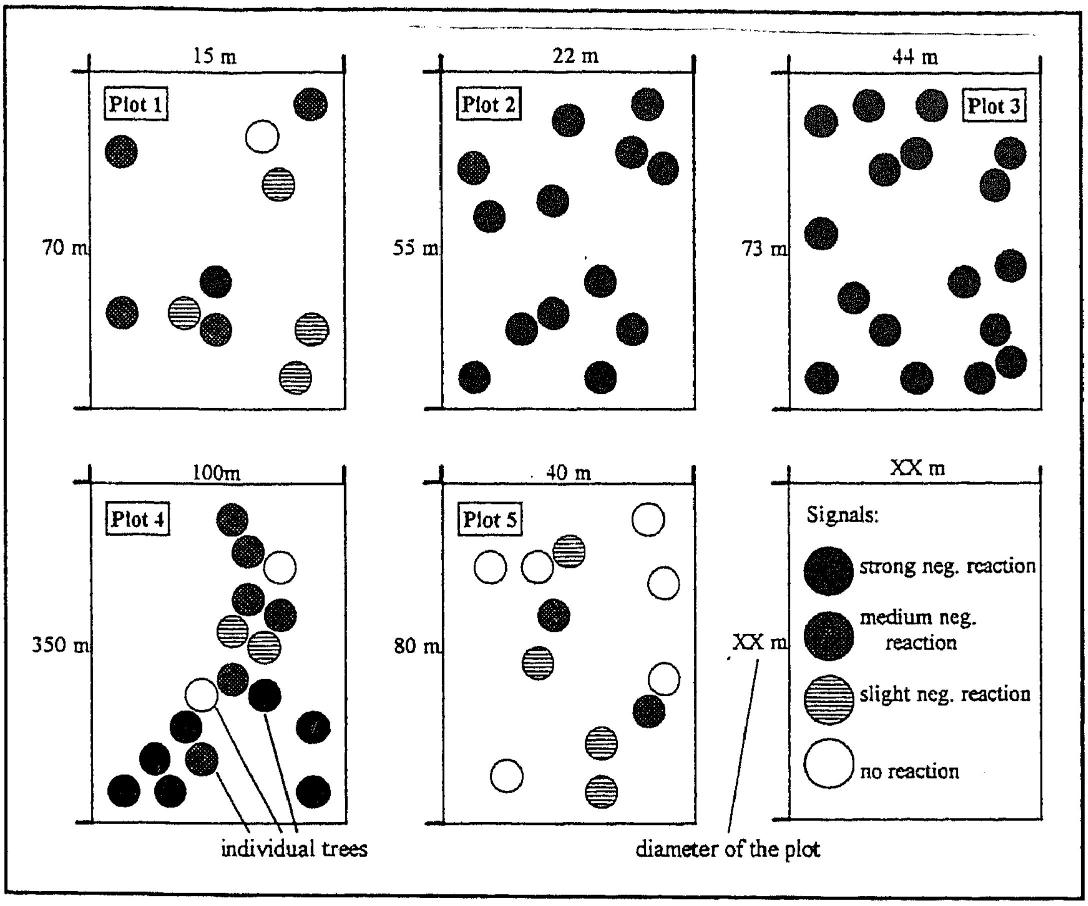

Fig. 3. - Local reaction. Ring-width of individual trees (events) in the negative pointer year 1928.

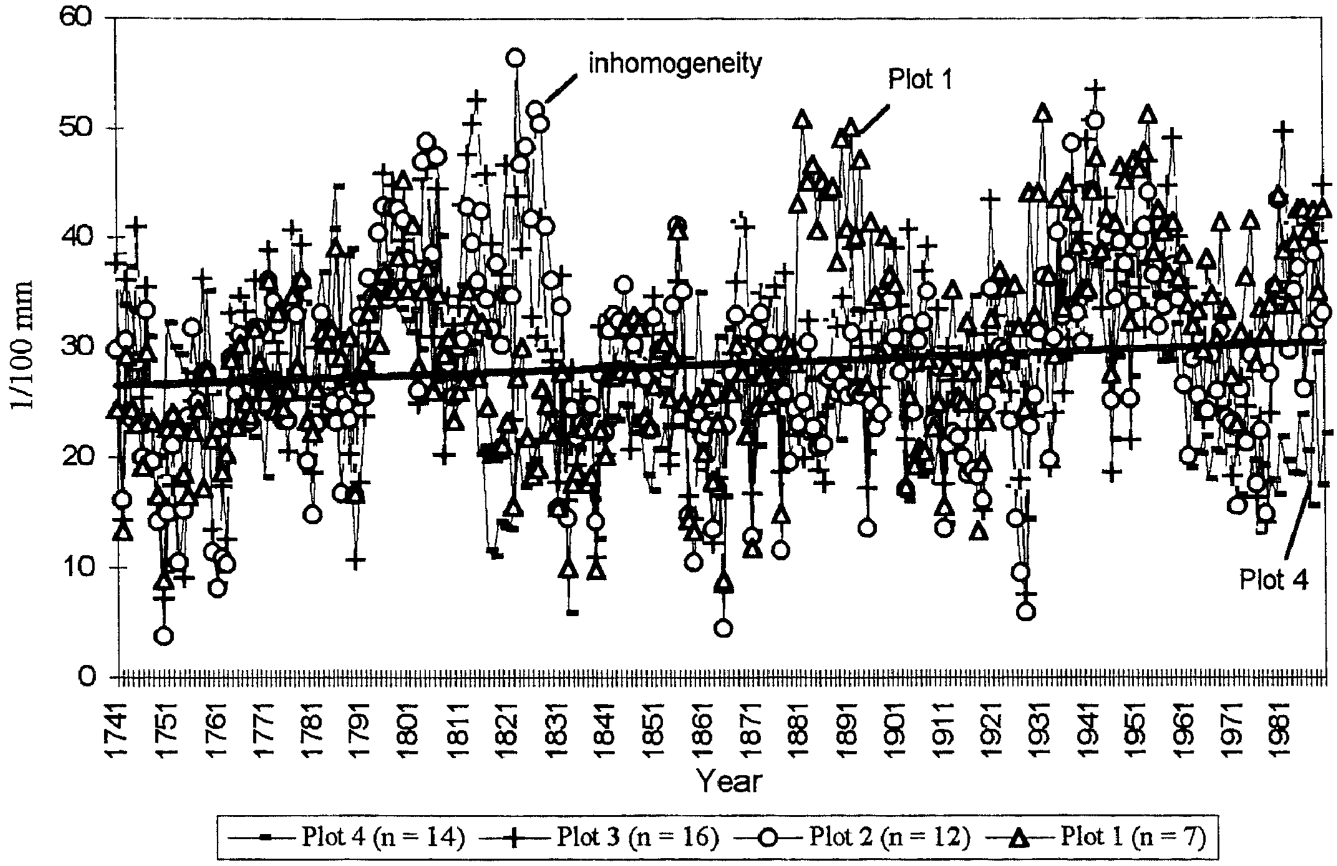

Fig. 4 - Averaged trees ring curves (*Juniper*) for the test sites in Morkhun Valley and linear regression for the period 1741-1990. The Plots 1-4 include different exposures (SW, E); n indicates the number of individual samples for each test site.

no scissormovement in ring-width between the growth forms after 1870.

Conclusions

The following conclusions can be tabulated: 1. Analysis of the climatic conditions of pointer years indicate that temperature as well as rainfall are both controlling factors of tree growth (ESPER 1994:103). 2. In the 250 year period 1741-1990, pointer years can be registered very frequently. 3. The analysis of local reaction permits the study of growth in individual trees in extreme pointer years. Among others, it proves that opposite events are not unusual (e.g. negative events in positive pointer years). 4. There is a very high probability that the observed mid-term fluctuations in the growth of *Juniper* trees reflect climatic variations, e.g. the 'depression' period surrounding 1850, a time of glacier advance in the Karakorum. 5. The presence of increasing CO_2 content in the atmosphere is not detectable in the ring width of *Juniper* strip barked trees. These results coincide with SCHWEINGRUBER (1994), who points out that no dendrochronological field studies in the north- and southhemisphere prove the fertilization effect on trees in natural stands.

An extension of the time series up to 1000 years is strongly recommended and will hopefully be achieved.

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ZUSAMMENFASSUNG

Jahrringe von der oberen Waldgrenze im Karakorum als Klimazeugen für die letzten 1000 Jahre

Die Auswertung der Jahrringbreiten von 69 Wacholderbäumen im Karakorumgebirge N-Pakistans ermöglicht Aussagen (1) zur klimatischen Sensitivität, (2) zu 'mid-term fluctuations' und (3) zur wuchsformspezifischen kambialen Aktivität als Reaktion auf den modernen CO_2-Anstieg in der Atmosphäre. Die Skeleton-Plot-Methode beweist den starken Einfluß des Klimas auf die Bäume an bzw. nahe der oberen Waldgrenze (4000 m NN). In der 250-jährigen Periode von 1741 bis 1990 sind hochfrequente Masterplotweiserjahre (zusammengefaßte Weiserjahre von Bäumen verschiedener Untersuchungsflächen) ausgebildet. Gemessene und zu Mittelwerten zusammengefaßte Rohwertkurven (1/100 mm) enthalten langwellige Wachstumsschwankungen, die möglicherweise Klimaschwankungen seit 1741 entsprechen. Ein positiver, auf die Düngewirkung des anthropogen angereicherten CO_2-Gehalts der Atmosphäre zurückzuführender Wachstumstrend, wie ihn Graybill et alii (1993) an indexierten 'strip barked' *Bristlecone pine*-Serien feststellen, liegt bei den 'strip barked' *Juniper* des Karakorums nicht vor.

RESUMEN

Anillos anuales del borde superior del terreno forestal en el Karakorum como testigos climáticos de los últimos 1000 años

La evaluación del ancho de los anillos anuales de 69 enebros (*Juniperus spez.*) de la parte del Karakorum que pertenece al norte de Pakistán permite realizar afirmaciones acerca de (1) la sensibilidad climática, (2) las fiuctuaciones a medio plazo y la actividad "cambial", específica a las diferentes formas de crecimiento como reacción al reciente enriquecimiento del CO_2 en la atmósfera. El método del "Skeleton Plot" demuestra la fuerte influencia que ha tenido el clima sobre los árboles que se encuentran directamente en el borde superior del terreno forestal (4000 m NN) o cerca de él. En un período de 250 años, desde 1741 hasta 1990, se han formado con una muy alta frecuencia, años guías "Master Plot" (que son años guías de árboles, seleccionados de las distintas superficies de investigación). Las curvas de los valores en crudo, los cuales han sido medidos y resumidos en valores medios, contienen fluctuaciones a largo plazo del crecimiento que posiblemente corresponden en las fluctuaciones climáticas desde 1741. Una tendencia positiva en el crecimiento que se le atribuye el efecto fertilizante al enriqueamiento del CO_2 en la atmósfera, ocasionado por el hombre, según lo demuestra Graybill et alii (1993) mediante series registradas de "strip barked *Bristlecone pine*", son inexistentes en los "strip barked *Juniperi*" del Karakorum.

RIASSUNTO

Cronologie anulari di soprassuoli ai limiti della vegetazione arborea nel Karakorum come indicatori climatici per l'ultimo millennio

Un'indagine condotta su 69 esemplari di ginepro nella regione del Karakorum – Pakistan settentrionale – permette di trarre indicazioni sulla sensitività, sulle fluttazioni di medio termine e su tipologie specifiche di attività cambiale come

reazione all'aumento attuale di CO_2 nell'atmosfera. L'applicazione degli skeleton plots mette in evidenza una forte influenza del clima sulle piante al limite della vegetazione arborea (m 4000). Nei 250 anni, che vanno dal 1741 al 1990, sono molto frequenti i Masterplots di anni caratteristici (insieme di anni caratteristici di piante di diverse stazioni). Le curve medie, costruite su valori anulari al centesimo di millimetro, contengono fluttuazioni di lungo termine che dovrebbero corrispondere alle fluttuazioni climatiche verificatesi dal 1741 in qua. Un andamento auxometrico positivo, da ricondursi all'aumento di CO_2 atmosferica indotto dalle attività antropiche, come proposto da Graybill et alii (1993) per il pino aristato, non sembra si possa riconoscere nel ginepro del Karakorum.

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