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DENDROCHRONOLOGICAL ANALYSIS OF ČEŘENIŠTĚ LANDSLIDE (CZECH REPUBLIC)

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ABSTRACT *DENDROCHRONOLOGICAL ANALYSIS OF ČEŘENIŠTĚ LANDSLIDE (CZECH REPUBLIC)*

The Čeřeniště landslide is located in the Natural Park of České Středohoří Mts. with 1063 km^2 extension. During Tertiary the volcanic activity occurred here in response to the Alpine orogenic processes with effusions, outbreaks and injections of basalts, trachites, phonolites, tuffs, tuffites (with diatomites and coal). The Čeřeniště landslide is 1050m long and 700m wide. The upper section of the slope is deformed by very slow creep movements of lateral type, reaching up to 100m of depth (SUCHÝ 1999). This section is separated from the central and lower section by a distinct platform inclined to a saddle form. The platform has suffered from more shallow and frequent movements of sliding character. Landsliding in the central and lower section of the slope occurs mostly in the weathered superficial zone reaching considerably higher rates of movement. The dendrogeomorphological analysis was made tHrough samples taken from 36 trees, mostly *Fagus sylvatica* L. and few *Acer pseudoplatanus* L. and *Quercus rubur* L. Trees affected by the movement of the landslide had typical stem tilting and shown specific reduction growth anomaly (suppression) that could last for few years or many decades. Through the analysis of these anomalies was possible, in the time investigated (1870-1999), to identify the western and lower part of the landslide as the active one, with different events of activation/reactivation dated in 1940, 1954, 1956-57, 1966, 1969-71, 1976, 1978-80, 1982, 1987-88, 1991, 1992, 1995. The relationship between particularly wet seasons of the nearest gauge station (Doksany) with the dating of the anomalies indicate an easy susceptibility of this part of landslide to movement.
Key words: dendrogeomorphology, mass movement activity, rainfall.

SOMMARIO *ANALISI DENDROCRONOLOGICA DELLA FRANA DI ČEŘENIŠTĚ (REPUBBLICA CECA)*

La frana di Čeřeniště è situata nel Parco Naturale dei Monti České Středohoří di 1063 km^2 di estensione. Nel Terziario quest'area fu caratterizzata da un'attività vulcanica legata all'orogenesi Alpina con l'emissione di basalti, trachiti, fonoliti, tufi e tufiti (ricchi di diatomiti e carbone). La frana di Cereniste ha una lunghezza di 1050 m ed una larghezza di 700 m; la porzione più alta del versante è contraddistinta da un movimento lento tipo creepinig con superficie di scorrimento profonda, superiore ai 100 m. Questa porzione della frana è separata da quella centrale e bassa da una piattaforma a sella; quest'ultima zona ha sofferto di frequenti movimenti superficiali di scivolamento. La zona centrale e bassa della frana interessa la porzione superficiale alterata ed è dotata di movimenti più frequenti e rapidi. L'analisi dendrogeomorfologica è stata eseguita su 36 piante, la maggior parte delle quali appartengono alla specie *Fagus sylvatica* L., con alcuni campioni di *Quercus robur* L. ed *Acer pseudoplatanus* L. Gli alberi disturbati dal movimento mostrano un tronco inclinato ed improvvise anomalie di crescita riduttive, che possono durare pochi anni o diversi decenni. Attraverso l'analisi di queste anomalie è stata individuata, nell'intervallo di tempo esaminato, 1870-1999, come attiva la porzione più bassa ed occidentale della frana. Le principali date di attivazione e/o riattivazione sono: 1940, 1954, 1956-57, 1966, 1969-71, 1976, 1978-80, 1982, 1987-88, 1991, 1992, 1995, ben correlabili con stagioni particolarmente piovose.

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INTRODUCTION

The Čeřeniště landslide belongs to the Natural Park of České Středohoří Mts., created in 1976, with 1063 km^2 extension and 41 strictly protected zones.

The aim of this study was to investigate Čeřeniště landslide with dendrogeomorphological techniques to reconstruct the mass movement activity.

Trees are able to record the stress due to landslide movement in different ways like: inclination of the stem, shear of the rootwood and stemwood, corrasion scars, burial of stemwood, exposure of rootwood.

Anyone of these events may cause responses such as production of reaction wood, suppression or release of growth, termination of growth, sprouting and succession (SHRODER 1978; STRUNK 1997).

The use of dendrocronology was very useful to investigate mass movement activity, as seen in many studies (ALESTALO 1971; OROMBELLI & GNACCOLINI 1972; TERASME 1975; CLAGUE & SOUTHER 1982; HUPP 1984; BRAAM et al. 1987; BEGIN & FILION 1988; JIBSON & KEEFER 1988; VAN ASH & VAN STEIJN 1991; STRUNK 1992; DENNELER & SCHWEINGRUBER 1993; FANTUCCI & MC CORD 1995; BAUMANN & KAISER, 1999; FANTUCCI & SORRISO VALVO 1999).

Most of the trees examined in the area belong to the species *Fagus sylvatica L.*, while few of them belong to the species *Acer pseudoplatanus L.* and *Quercus ruburL.*

GEOLOGY AND GEOMORPHOLOGY OF STUDY AREA

The locality of Čeřeniště landslide is situated in the north-western part of the Czech Republic in the volcanic České Středohoří Mts. that belongs to the Bohemian Massif, as shown in the Czech Republic Geological Map (Fig.1). During Tertiary the volcanic activity occurred here in response to the Alpine orogenic processes. The volcanic activity connected with formation of the rift system (graben) under the Krušné hory Mts. has been manifested by effusions, outbreaks and injections. From the petrographic point of view there are basalts, trachites, phonolites, tuffs, tuffites, but also diatomites and coal there. Cretaceous sediments, mostly claystones and sandstones are penetrated by volcanic bodies. Rather complicated tectonic frame of the rift resumed in the block structures (CAJZ et al. 1996).

The main neovolcanic phase started in Oligocene, and denudation lasting up to the present time began as early as at the end of Tertiary. Cutting through the České Středohoří Mts. in Quaternary, the Labe River eroded its valley to the depth of about 100m (KRÁL 1996). Steps slopes of the Labe River valley are prone to landslides and rockfalls.

About 500m SW of the Čeřeniště Village on the right bank of the Labe River, several types of extensive deformation can be found which developed on the western slope of the basaltic Kupa Hill 635m a.s.l.

The Čeřeniště landslide is 1050m long and 700m wide. The upper edge of the scar area is 602m a.s.l. while the lowest face of the accumulations 340m a.s.l. General inclination of the slopes is 14°.

The upper section of the slope is deformed by very creep movements of lateral type, reaching up to 100m of depth (SUCHÝ 1999).

This section is separated from the central and lower section by a distinct platform inclined to a saddle form. The platform has suffered from more shallow and frequent movements of sliding character. The main body of the slope has been built at least by six lava flows with separations formed by intercalations of predominantly clayey character. An X-ray analysis detected dominant fraction being smectites which are volumetrically highly unstable. Such a material results in formation of weak slipping planes and zones. These support development of very slow lateral gravitational movements.

Landsliding in the central and lower section of the slope occurs mostly in the weathered superficial zone reaching considerably higher rates of movement.

MATERIAL AND METHODS

To carry on the present research were made two dendrocronological samplings, one in July 1997 and the second in September 1999, using a non destructive sampling with Swedish incremental borer.

Totally were sampled 36 trees: 2 of them uphill of the main crown, 10 close to the main crown, in the upper part of the older landslide, 4 in the central part of the main landslide and 20 on and close to the more recent active zone in the lower section.

Most of the samples belong to the species *Fagus sylvatica* L., while few of them to the other species: *Acer pseudoplatanus* L. and *Quercus robur* L. and are located in the lower and western part of the landslide as shown in the Dendrogeomorphological Map (Fig. 2).

The sampling strategy was usually to take two cores from each tree, the first one in the direction opposite to the stem tilting and the second one at 90° or 180° respect to the first one, totally were analysed 61 cores.

All the cores were located on a wood support, cut, sanded and dated through the standard dendrochronological methods, then measured with a 0.01 mm accuracy through a micrometer. The cores' measures and dating were controlled with the program Cofecha (HOLMES 1983) to find possible double, false ring and reading mistakes.

Once all the samples were correctly dated, they were subjected to the visual analysis to find abrupt growth anomalies as sudden decrease (suppression) or increase (release) that last more than three consecutive years, according to SCHWEINGRUBER et al. 1990 (Fig.3).

All the anomalies found on trees' samples stressed by landslide movement were sudden growth reduction (suppression); some of the growth curve of samples with and without growth anomalies are shown in the following Figure 4 where the red arrows sign the year of growth suppression.

More than one growth anomaly was found in some trees living along the border of the most active landslide in the lower part.

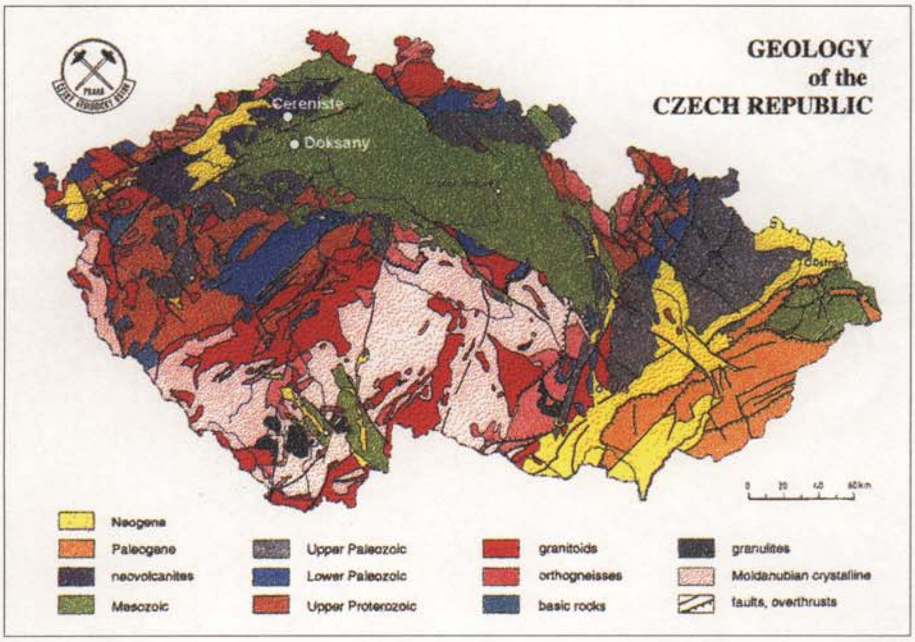

Figure 1: Geological Map of Czech Republic

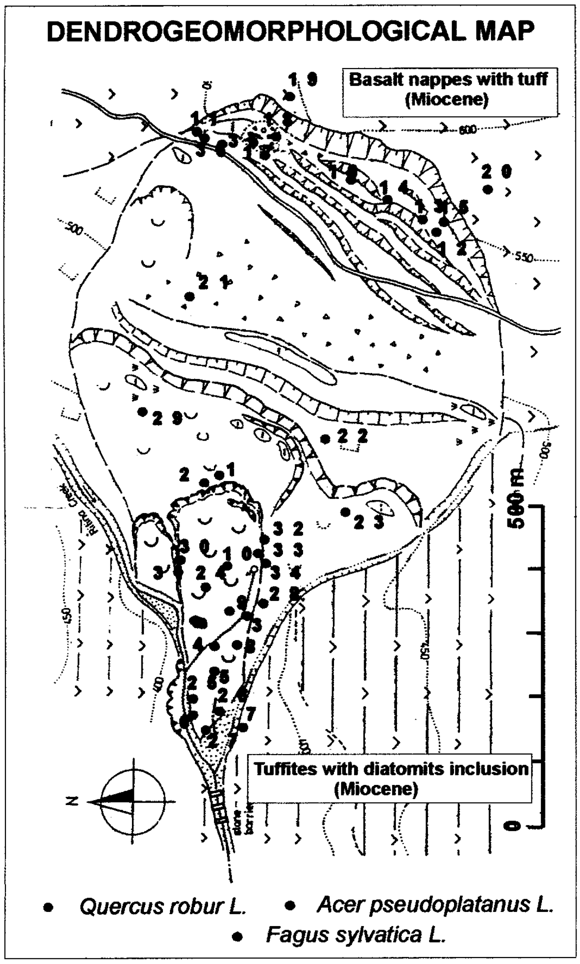

Figure 2: Dendrogeomorphological map with sampled trees

RESULTS

Temporal Analysis of Landslide Activity

The time interval investigated through tree sampled living on the landslide and the surrounding area was 1870-1999. In this period the eastern part of the landslide, close to the main crown, was stable, with the exception of tree n°11, that shown some anomalies in 1885 and 1905, and tree n°14 with an anomaly in 1956 (this one was affected by a local movement of a debris deposit where it lives).

The central part of the landslide was also mainly stable in the period examined, except one anomaly detected in tree n°23 in 1995.

The lower and western part of the landslide was an active zone since 1940, that could be the dating of creation of this new landslide area. Most of the trees (66 %) living in this zone was affected by growth anomalies related to landslide movement events. The events recorded are in 1940*, 1954, 1956-57, 1966, 1969-71, 1976*, 1978-80*, 1982*, 1987-88, 1991-92, 1995; those events signed with a star "*" are the stronger ones that involved more than one tree.

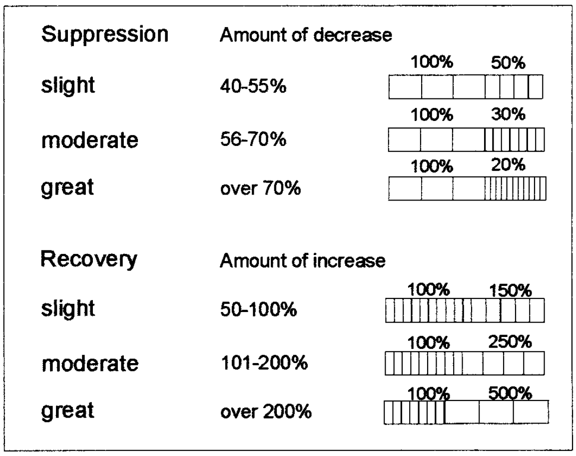

Figure 3: Growth anomalies classes (from Schweingruber et al. 1990)

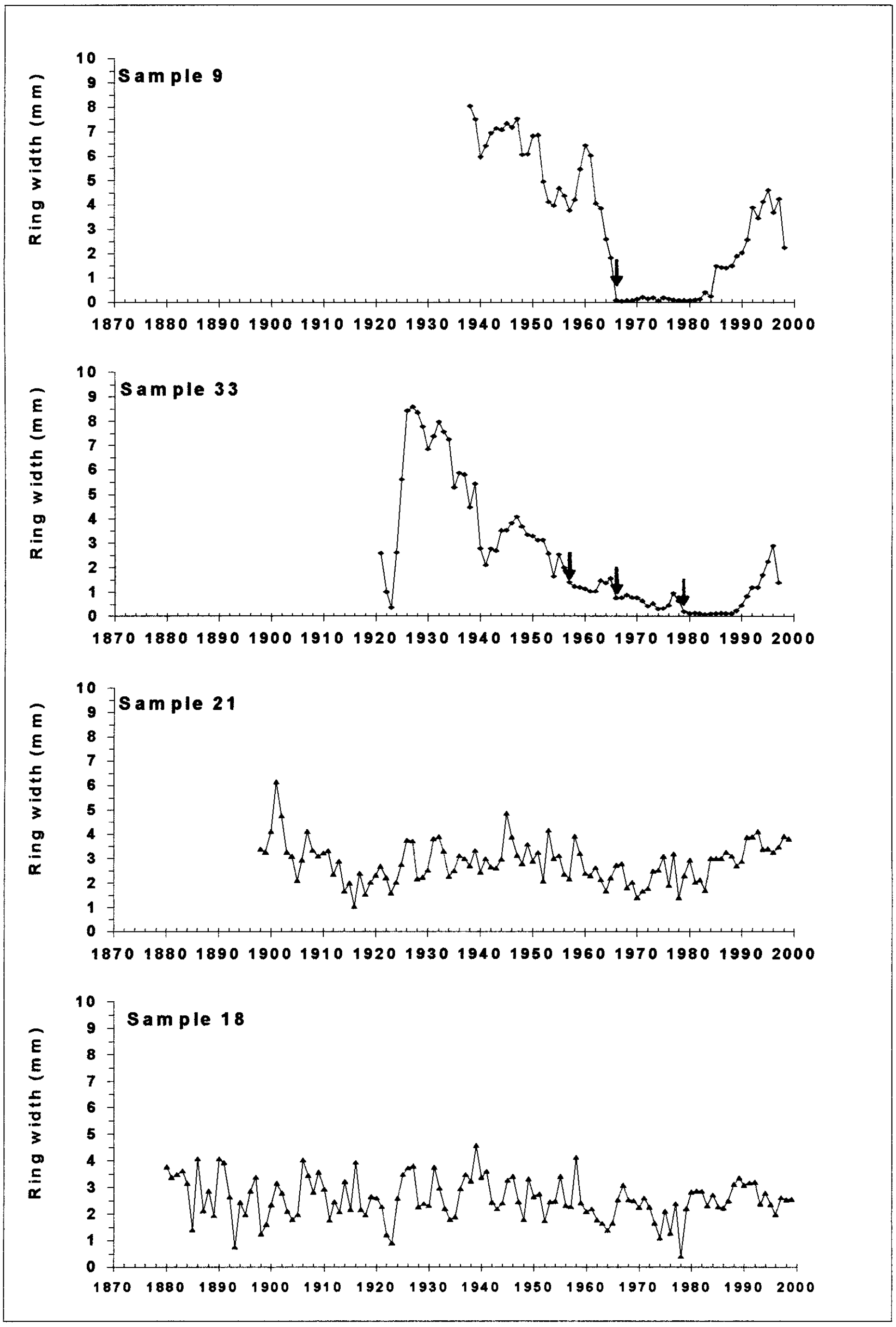

Figure 4: Ring – growth curves of trees with and without anomalies

Spatial Analysis of Landslide Activity

Using the map of the trees sampled it is possible to reconstruct the areas of the landslide activity for each one single event or for different time periods.

In this way were constructed the maps of two interesting events, occurred in 1978-80 and in 1982 where are pointed in red trees affected by anomalies, related to the mass movement reactivation.

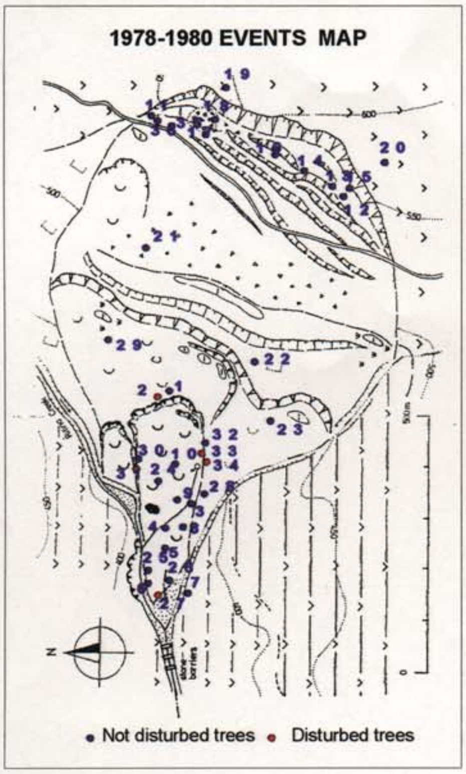

Figure 5: 1978-80 landslide reactivation events

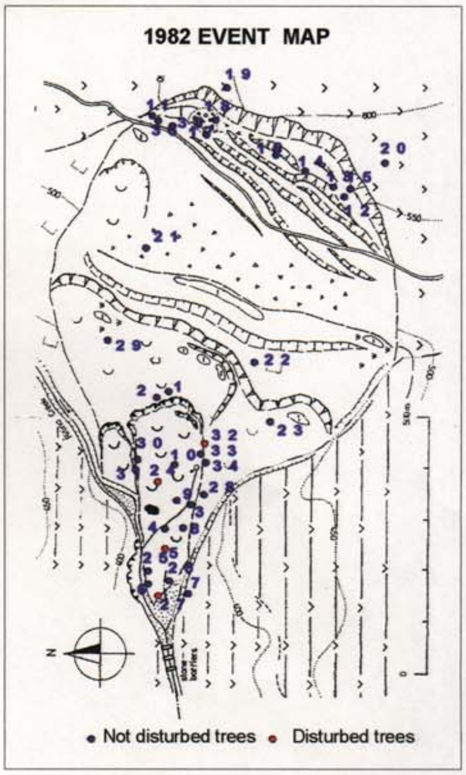

Figure 6: 1982 landslide reactivation event

The 1978-80 Events Map shows the stability of the upper and middle part of the old landslide while the most recent and lower landslide was active; trees affected by anomalies were located along the crown, sides and toe of the lower and active landslide area.

The 1982 Event Map, related to the previous year rainfall, as shown in the following chapter, testify that most of trees disturbed were placed along the landslide body.

This could be explained by a first reactivation of movement (1978-80) along the border of the more active landslide, followed by another one (1982) on the central part.

This kind of maps are very useful to understand the movement developing on a landslide in the year of reactivation, and to distinguish the active from the stable areas.

Correlation of Anomalies to Rainfall

Some authors related the tree-ring growth anomaly to rainfall (KASHIWAYA et al. 1989; FANTUCCI & MC CORD 1995; FANTUCCI & SORRISO VALVO, 1999) in landslide prone areas; for this study were used rainfall data of the nearest gauge station, Doksany (see Figure 1) compared to the rainfall data of others close stations (Cirkvice and Louny). The precipitation data available for the period 1951 – 1999 are monthly data; these were grouped into four seasons: Winter (January – March), Spring (April – June), Summer (July – September) and Autumn (October – December). For each season was calculated the "mean" and the "standard deviation" used to normalise the seasonal values of each year to find out the most humid seasons in the period analysed; as wetter periods were chosen those seasonal data whose value were one standard deviation or more above the mean. It is important to underline that growth anomalies recorded in a tree can be related to a stress event occurred during the growing period of that year (spring – summer) as well as to one occurred in the rest vegetation period of previous year (autumn – winter). Therefore data of a growth anomaly can be delayed one year respect to the stress event if it occurred in the previous year rest vegetative time. In the graph of Figure 7 are plotted all the wettest seasons between 1951 – 1999, compared to ring growth data anomalies (suppression) recorded by trees analysed. Also 1940 was particularly wet as indicated by the gauge station of Louny, so 83% of anomalies found can be related to one or more seasonal rainfall above the mean.

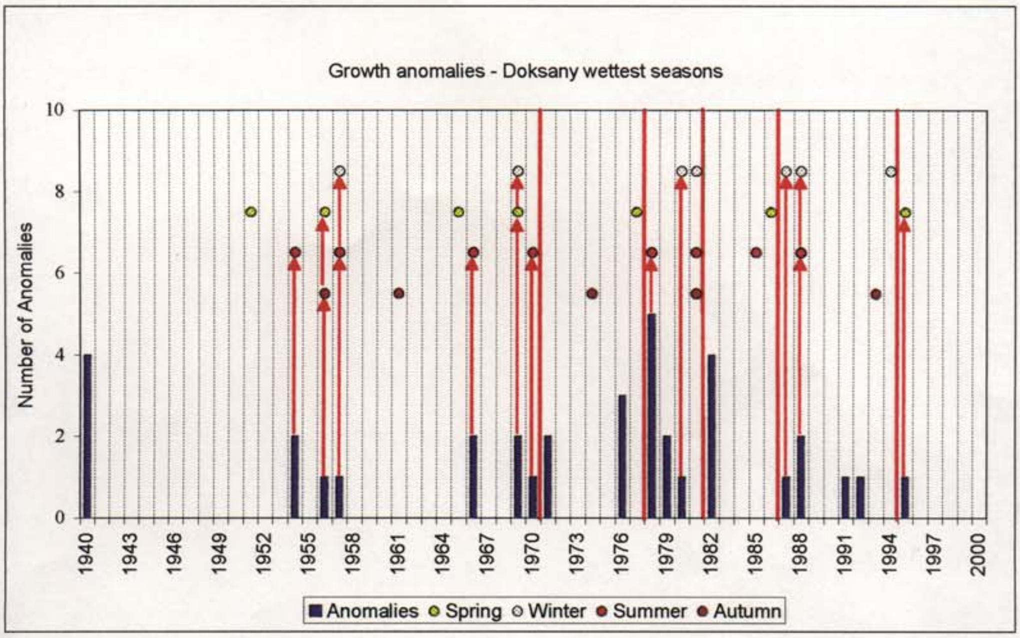

Figure 7: Relationship between wettest season of Doksany to the growth anomalies

CONCLUDING REMARKS

The dendrogeomorphological research on Čeřeniště landslide area was developed through the analysis of 36 trees which belong mostly to the species *Fagus sylvatica L.* The main results of the study was the knowledge of the landslide activity in its different parts in the period investigated (1870-1999). The only really active zone is the lower and western landslide zone where most of the trees (66%) have shown one or more sudden growth decrease (suppression) related to the mass movement. Most of trees sampled in this area shown stem tilting while the others sampled in the oldest part of the main landslide, close to the main crown and in the central platform, had vertical stem. The first movement event detected in the recent western landslide occurred in 1940, that could be the year of the activation of this landslide. Many other events were discovered by trees anomalies in this area: 1954, 1956-57, 1966, 1969-71, 1976, 1978-80, 1982, 1987-88, 1991-92, 1995. The relationship between growth anomalies and seasonal precipitation data is very good (83%) and it seems that the movement of this shallow part of landslide is susceptible to wetter seasonal rainfall, occurred in winter, spring and summer, as well as sometimes to wetter seasons of the previous year (1965, 1971, 1978, 1981, 1987, 1995). At the end it can be said that this dendrogeomorphological technique was useful to analyse the mass movement activity of the site in the period investigated.

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