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RECONSTRUCTION OF LANDSLIDE DYNAMIC WITH DENDROCHRONOLOGICAL METHODS

Key-words: dendrochronology, geomorphology, mass movement, oaks, Central Italy.
Parole chiave: dendrocronologia, geomorfologia, frana, querce, Italia Centrale.

Abstract

The activity of a mass movement of slide-flow type in Central Italy (Latium) was reconstructed through the analysis of growth anomaly in 40 oak trees, 28 sampled from the landslide area and 12 from the stable surrounding areas. This analysis shows numerous date events of mass movement reactivation, most of them well connected to the rainfall data.

Introduction

Dendrogeomorphology is the analysis of geomorphologic processes through dendrochronological techniques and was first introduced by ALESTALO (1971) and used to investigate the development of many geomorphologic processes such as mass movements, fluvial, littoral, glacial, volcanic processes as well as diastrophic processes as summarised by SHRODER, BUTLER (1987), SHRODER (1980), HEIKKINEN (1994).

The effect of mass movement on living trees has been used by many authors to date the year of occurrence of landslide events (OROMBELLI, GNACCOLINI 1972; TERASME 1975; SHRODER 1978; BÉGIN, FILION 1988; STRUNK 1992; DENNELER, SCHWEINGRUBER 1993) and to correlate the mass movement activity with past strong earthquakes (JIBSON, KEEFER 1988; FILION ET ALII 1990). KASHIWAYA ET ALII (1989) have investigated the relationship between tree-ring width and heavy rainfall in a landslide prone area in Japan. Subfossil or fossil stumps were used to date old landslides (CORONA 1972; CLAGUE, SOUTHER 1982; FILION ET ALII 1990). Different kinds and intensities of mass movements (such as debris flow, rock falls, rotational slides, ...) influence the trees living on or close to the landslide prone areas in several ways.

A summary of the principal dendrogeomorphological process-event-response which can be detected on different landslides types is shown in Fig. 1.

In several studies the main effects of mass movement on the living trees were the tree inclination, damages to the root system, to the stemwood and/or the branches; these events were analysed in different ways as dating of scars and new sprouts related to the stem tilting (HUPP 1983), analysis of growth anomalies such as sudden growth changes and presence of reaction wood (TERASME 1975; CLAGUE, SOUTHER 1982; DENNELER, SCHWEINGRUBER 1993), analysis of eccentric growth (BRAAM ET ALII 1987a and b).

The landslide analysed is diffusely vege-

Process	Event	Response
	Tree inclination	- Trunk curvature - Reaction wood - Growth anomaly (suppression, release, eccentric growth)
	Abrasion of cambium	- Scar development
Mass movement	*Burial of stemwood Exposure of rootwood*	- Growth anomaly (suppression) - Sprouting
	Shear of rootwood or stemwood	- Growth anomaly (suppression) - Scar development - Sprouting
	Nudation of land surface	- Succession

Fig. 1. - Main dendrogeomorphological process-event-response due to mass movements (adapted from Shroder 1978, 1980)

tated, with many oak trees showing signs of past disturbances due to mass movements such as simple or complex stem tilting.

Evident tree inclination on the landslide, compared to the normal straight growth of trees in the geomorphological stable areas, was the indicator which gave rise to this research; its objective was to use dendrogeomorphological techniques to analyse the past mass movement activity of a recent slide-flow landslide.

Research area

The research area is located in the central part of Italy (Latium), in the province of Viterbo. This site belongs to the park named "Mt. Rufeno Natural Park". The geology of the site belongs to the Mt. Cetona - Mt. Razzano Mesozoic-Paleogenic ridge which was uplifted during the late Pliocene and border two main neogenic graben of the Tiber and Siena-Radicofani. This horst is NNW-SSE oriented and constituted by flysh allochtonous formations of the Sicilide and Liguride complexes (LOCARDI ET ALII 1975).

The horst plunges towards the centre of the Vulsini volcanic area which was created at an intersection of two (Appennine and anti-Appennine) Pliocenic-Pleistocenic distensive tectonic graben systems (Fig. 2) (LOCARDI ET ALII 1975).

The landslide examined is located on the west side of the "Fossatelo creek". The valley is east oriented and its altitude is between 250-690 m. Two formations outcrop here: on the ridge of the valley outcrops the formation "Claystone with palombini limestone" which overthrusted on the formation "Claystone with marl, sandstone and limestone layers of S. Fiora".

The first formation is made of claystone with some siliceous limestone layers (palombini) and some ophiolites. It is very chaotic and dates from the lower Cretaceous age. The second formation is made of flysh deposit, mostly clayey, with some sandstone, marl or limestone layers. Its age is related to the upper Cretaceous (BUONASORTE ET ALII 1988).

The first landslide movement concerned a 2.8 km^2 area on the west side of the creek from the ridge to the bottom of the valley; its age is unknown. Some following mass movements occurred on the first unstable

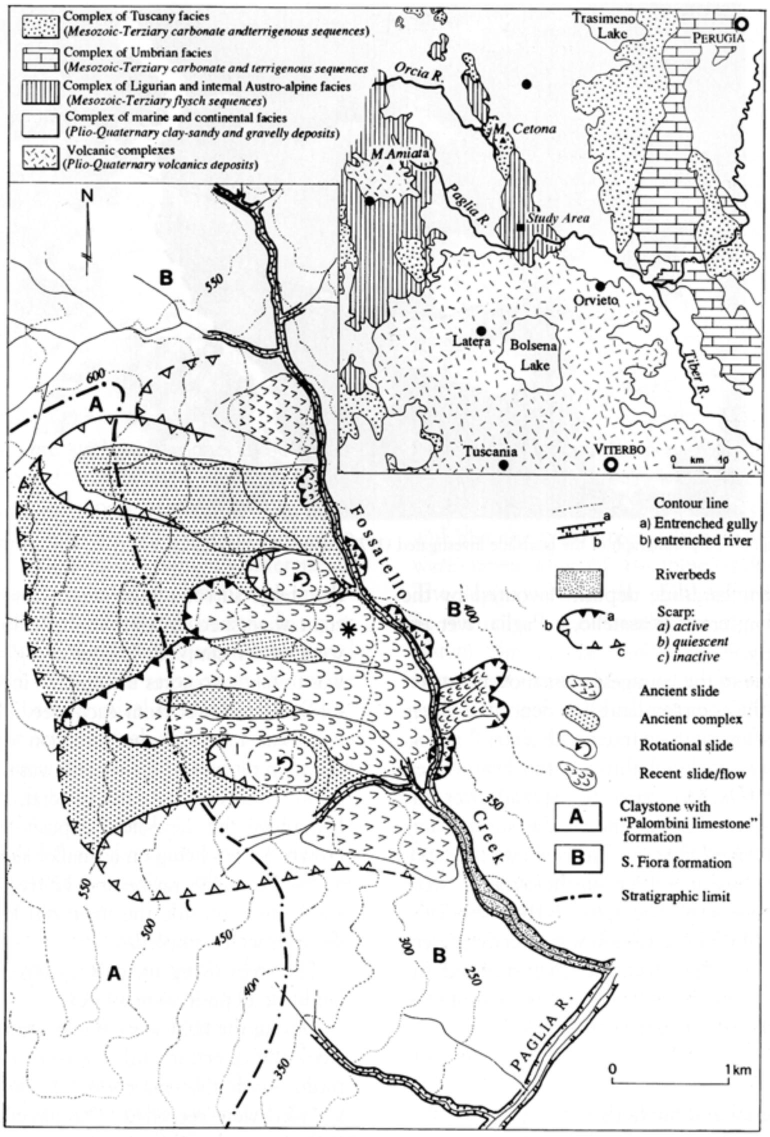


Fig. 2 - Geologic regional map and geomorphologic site map with the landslide examined marked (*).

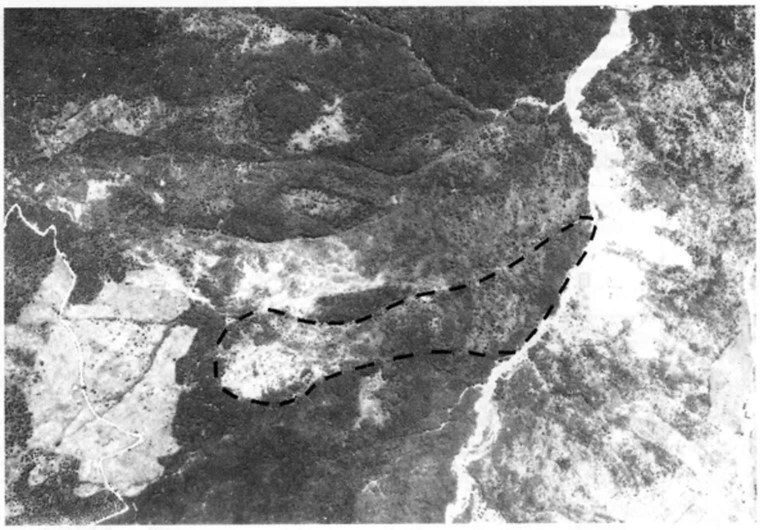


Fig. 3 - Airphotograph of the landslide investigated (1978), dotted. (Authorization S.M.A. n° 310 - 10.08.95).

ancient landslide deposit, favoured by the eroding creek Fossatello, a Paglia river tributary.

One of the youngest mass movements inside the complex landslide deposit, a clayey slide-flow type (marked with a star * in Fig. 2), was analysed through the living trees, oaks (*Quercus cerris* L.) spread over the landslide deposits and in the surrounding stable areas (Fig. 3). Fig. 3 shows the landslide area in a 1978 airphotograph. Some previous airphotographs of 1943 and 1956 show that the landslide was already present and that the vegetation that survived the mass movement was concentrated in the middle-upper part of the track.

Material and methods

During spring 1995 and summer 1994, 40 trees from the landslide deposit and from the stable surroundings areas, close to the right watershed divide of Fossatello creek, were totally sampled. The sampling strategy was to take two cores through an incremental Swedish borer from each tree. The first core was taken in the direction opposite the stem tilting and the second was sampled at 90° from the first one. In total, 25 trees living on the landslide deposit and its crown, 3 trees living on a smaller slide close to the Fossatello ravine and 12 trees in the stable area, outside the main old landslide deposit, were sampled.

The trees living on or very close to the landslide deposit were all bent.

During the field work the location of the trees, the direction and degree of the stem tilting and the direction of the cores sampled were recorded. The direction and intensity of the tilting of the trees seem to be connected to the different landslide zones (see Fig. 4). The trees above the

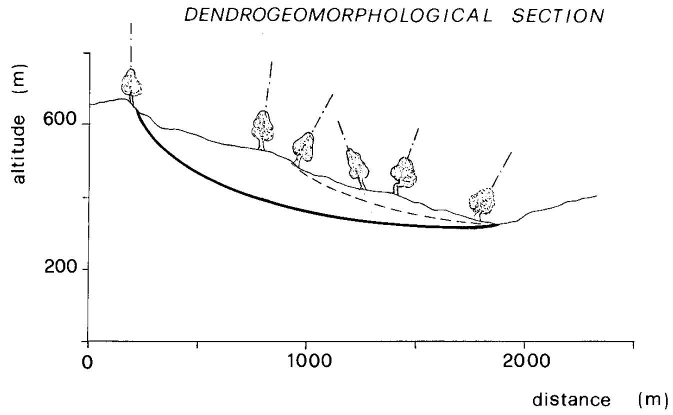


Fig. 4 - Dendrogeomorphological section on the "Fossatello creek" valley. Trees showing different tilting directions according to their location. (The continuous line refers to the hypothetic sliding surface of the ancient landslide while the dashed line to the recent landslide examined).

crown were straight, the ones close to the crown were mostly tilted downhill, others in the middle part of the landslide were tilted downhill as well as uphill and often subject to a complex tilting in different directions because of the numerous movements of the landslide. Instead the last ones on the toe of the deposit were mostly curved downhill. The trees sampled in the stable area all had a vertical stem. Fig. 4 is a dendrogeomorphological section which cross the valley, the old landslide deposit and the recent landslide examined.

All the cores sampled were sanded and crossdated through skeleton plots (STOKES, SMILEY 1968) and then measured with a 0.01 mm. accuracy.

The core measures and dating were controlled with the program COFECHA (HOLMES 1983) to find possible double or false rings and/or reading mistakes.

Once all the samples were dated, they were subject to the visual analysis of the possible abrupt growth anomalies such as decrease or increase (Fig. 5) (SCHWEINGRUBER ET ALII 1990).

The visual growth analysis indicated that most of the living trees on the landslide deposit or near the crown were affected by sudden growth decrease in some periods and that the other trees in the stable area were never affected by these anomalies. The suppression in the plant growth can be related to some disturbances of the root system during the landslide movement. Sometimes, after this sudden growth decrease, the tree had a subsequent sudden release. It could be related to an improvement of the soil properties favourable to the plant growth as better aeration, water and nutrient supply or by a diminished competition because of the death of the adjacent trees. The suppression was already noted in dendrogeomorphological research on landslides as TERASME 1975; STRUNK 1992; DENNELER, SCHWEINGRUBER 1993.

Results

Frequency of the events

The landslide examined was divided into different zones (Fig. 6). Zone H and Zone

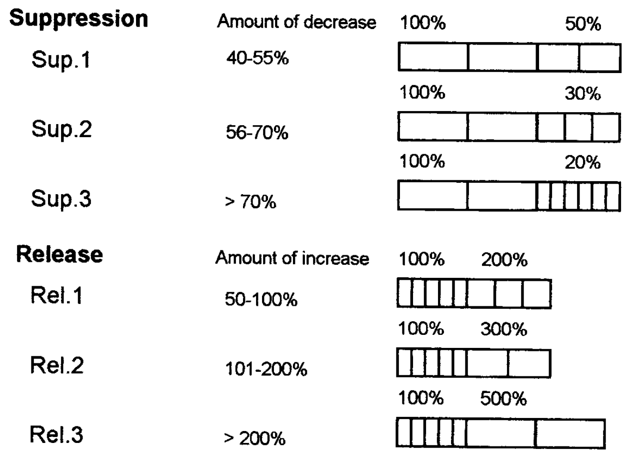


Fig. 5 - Visual growth analysis - sudden growth decrease (suppression) or increase (release) classes.

M refer to the crown of the landslide and to the main track of the deposit respectively, while Zone T refers to the toe of the landslide. Zone S concerns a very recent slump along the Fossatello gully. Zone U, instead, concerns the stable area surrounding the ancient landslide, near the wathershed divide.

The results of visual growth analysis in the cores taken from the trees living on or close to the landslide were used to create some graphics of the growth anomalies related to the different zones of the studied site.

Index I_t (%) (suppression and release) was calculated at year t:

$$It = \left(\sum_{i=1}^{t} Ri\right) / \left(\sum_{i=1}^{t} Ai\right) \times 100$$

(adapted from Shroder, 1978)

where:

R_i: cores that have shown the anomalies in the year t

A_i: total number of cores sampled for the year t

The values of It % were calculated for each class of the negative (suppression) and positive (release) anomalies and a graph was composed for each zone examined (Fig. 7).

The graph regarding landslide (Fig. 7) is the sum up of all the suppression and release anomalies of the sampled trees on the main landslide examined.

During the investigation period 1880-1994 some peak anomalies were found. They are typical of the landslide area and did not appear in the stable areas so are most probably related to the mass movement activity. The two zones more affected by the landslide activity are Zone H and Zone M while Zone T was less interested by anomalies. Zone S was interested by anomalies too, while the stable Zone U did not show growth anomalies.

The suppression growth anomalies appear to be directly connected to the disturbance events due to landslide movement, while the release seems to be a subsequent consequence only, so the anomalies of the

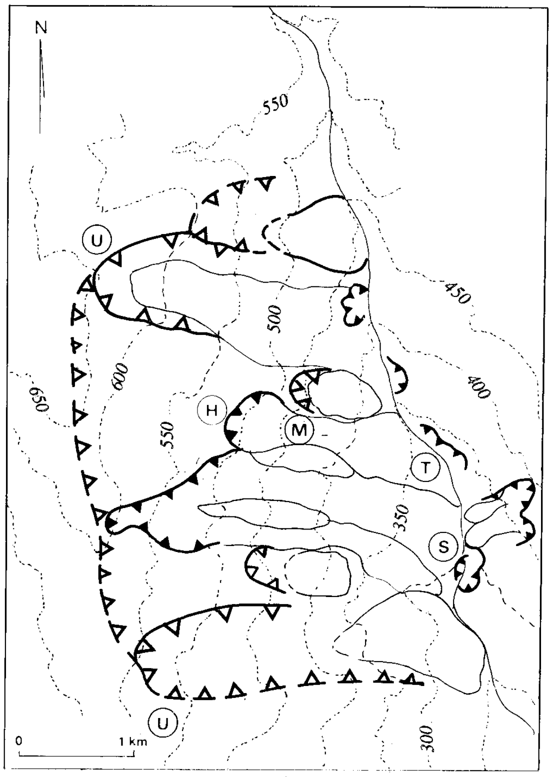


Fig. 6 - Map of the complex landslide area with the zones investigated: Zone H, M and T pertain to the recent landslide, Zone S to a small slump along the Fossatello creek and Zone U to the geomorphological stable areas.

first only were considered as a sign of landslide movement events.

The main events noted occurred in: 1894, 1903, 1915-16, 1922, 1928, 1937, 1940, 1945, 1963, 1972, 1986. As shown by the landslide graph, the intensity of the anomalies increased from the '60. There were also two periods not affected by disturbances between 1909-1914 and 1948-1961.

The most important event is that of 1963 which interested more than 70% of the sampled cores on the landslide. The small slump along the Fossatello creek (Zone S) was affected by anomaly on 100% of the trees during the year 1986, so this can be considered the exact dating of this mass movement.

Correlation between growth anomaly and climate

Some authors related the tree-ring growth anomaly to annual flood record (HUPP 1983) or tree-ring width to rainfall (KASHIWAYA ET ALII 1989) in landslide prone areas.

In this study the tree-ring growth anoma-

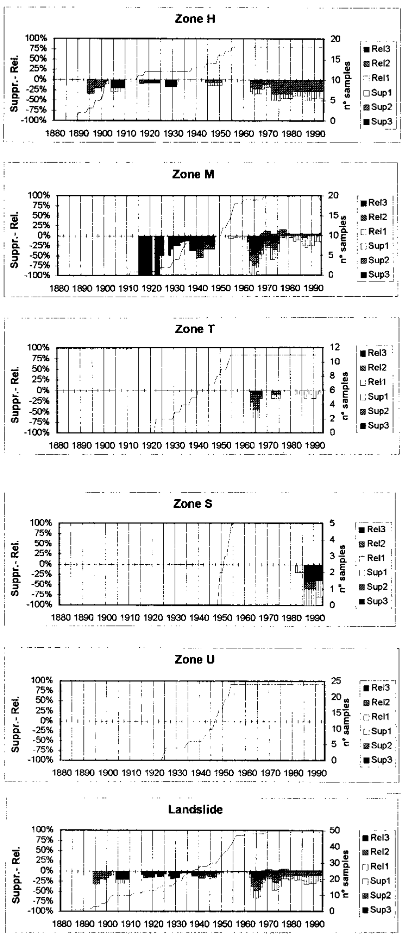
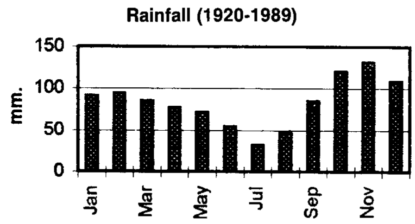


Fig. 7 - Anomaly growth (It%) graphs (negative values for suppression and positive values for release) relative to the Zones of Fig. 6. The Landslide graph refers to the anomalies of Zones H, M and T of the recent landslide examined.

lies are associated to the rainfall data (seasonal precipitation) of the closest gauge station (Acquapendente - altitude 425 m. - distance from the site 4 km). The few missing data of the gauge station were estimated through three other close meteorological stations, whose homogeneity was tested with the Mann-Kendall test. The meteorological data where thus divided into four seasons starting from the winter (previous december - current february). For each season the mean and MSR (Mean Square Residuals) of the precipitation record time period 1920-1989 was calculated. This was used to recognise the season dates with particular high precipitation values. In the graph in fig. 8 all the seasonal rainfall data above 1.5 MSR, together with the dates of the main growth anomalies events were plotted. The mean precipitation from 1920-1989 was 997.49 mm.



The rainfall distribution is a Mediterranean climate kind with a summer minimum and a autumn - winter maximum. The mean and MSR data for the seasons are:

Season	Mean	MSR
winter	295.65 mm.	93.12
spring	232.61 mm.	86.55
summer	134.04 mm.	62.29
autumn	336.36 mm.	137.10

The graph in Fig. 8 shows that more than 75% of the growth anomalies events are

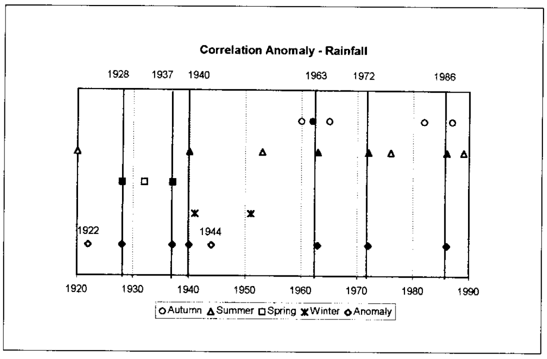


Fig. 8 - Anomaly dates and seasonal rainfall peaks (>1.5 MSR). Solid symbols for years in which growth anomaly and exceeding rain coincide.

well related to some particular wet periods which occurred during the growing season (spring 1928-1937, summer 1940, 1963, 1972, 1986) or during the previous vegetative rest season (autumn 1962).

Fig. 8 shows the seasons in which the rainfall exceeded the 1.5 MSR and the dates of the main anomalies. It was observed that usually the particularly wet seasons connected to the growth anomalies were preceded by a particularly drier season. Indeed, the graphs (Fig. 9) for the events in 1928, 1937, 1963 and 1972 indicate that in all these cases a drier period occurred before. The 1928 and 1937 events seem to be related to a wet spring in the same year. The 1940, 1972 and 1986 events could be related to wet summer periods. The strongest event was the 1963 one which could be related to the particularly wet autumn of 1962 or the wet summer of 1963, which followed a dry period longer than one year (Fig. 9-10). There is also evidence that the particularly wet autumn in 1962 had induced many landslides on a regional scale (AVI - CNR 1994).

In Fig. 9 the seasonal MSR of rainfall before and during the events is indicated. The presence of a drier period before the anomaly event is well evidenced. The most apparent case occurred in 1963, which is connected to the wet autumn of 1962, followed to a long dry period.

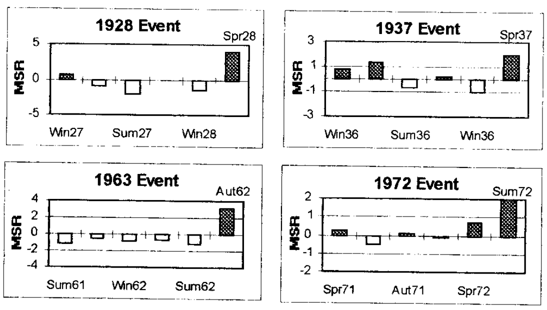
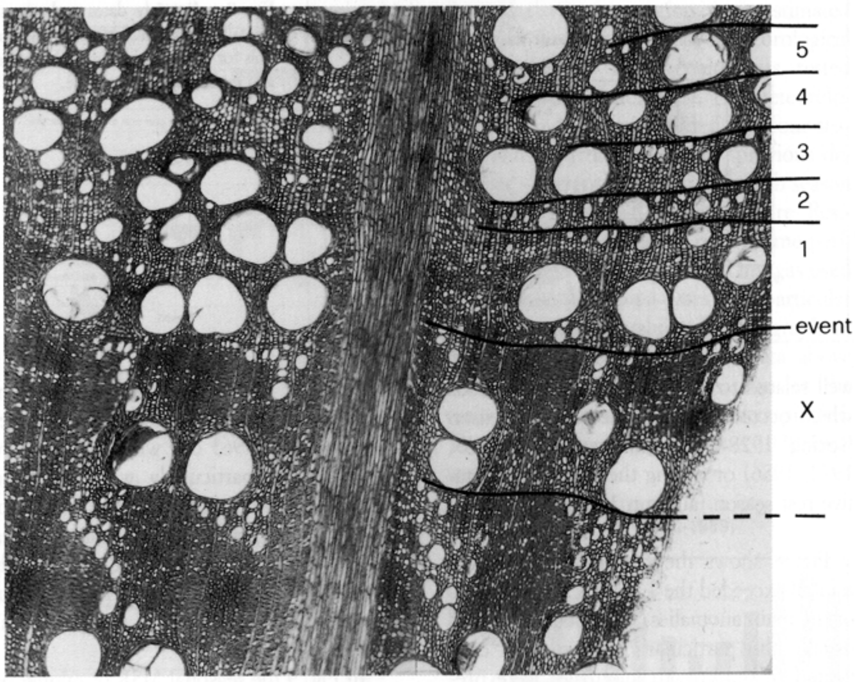


Fig. 9 - MSR seasonal rainfall before and during the growth anomaly event.



Quercus cerris L. 30x.

Fig. 10 - Microphotograph representative of the 1963 event (occurred in the 1962 autumn). The ring structure after the event is abnormal. The thick fibers are missing. The rings get abruptly small. The second ring after the event has partially very narrow vessels. Rings on the left side are difficult to distinguish.

To understand the correlation between rainfall data and anomaly events better some microphotographs from the cores which clearly showed the growth anomaly in 1963 were taken. The microphotograph in Fig. 10 indicates that the disturbance of 1963 occurred during the previous vegetative rest period . The 1962 ring is, in fact, complete and not disturbed so the event can be well dated to the 1962 autumn after the growing season (Fig. 10). This kind of analysis was extremely useful to individualise the season in which the landslide event occurred.

Spatial analysis of the landslide activity

The time period 1890-1994 was subdivided into decades; for each one a map was made showing the zone of the landslide examined which were affected or not by growth anomalies related to the landslide movement (Fig. 11).

Only the living trees sampled in the examined period are plotted in the temporal maps. These maps are useful in identifying the main landslide reactivation periods and the zones affected by the movement. As is

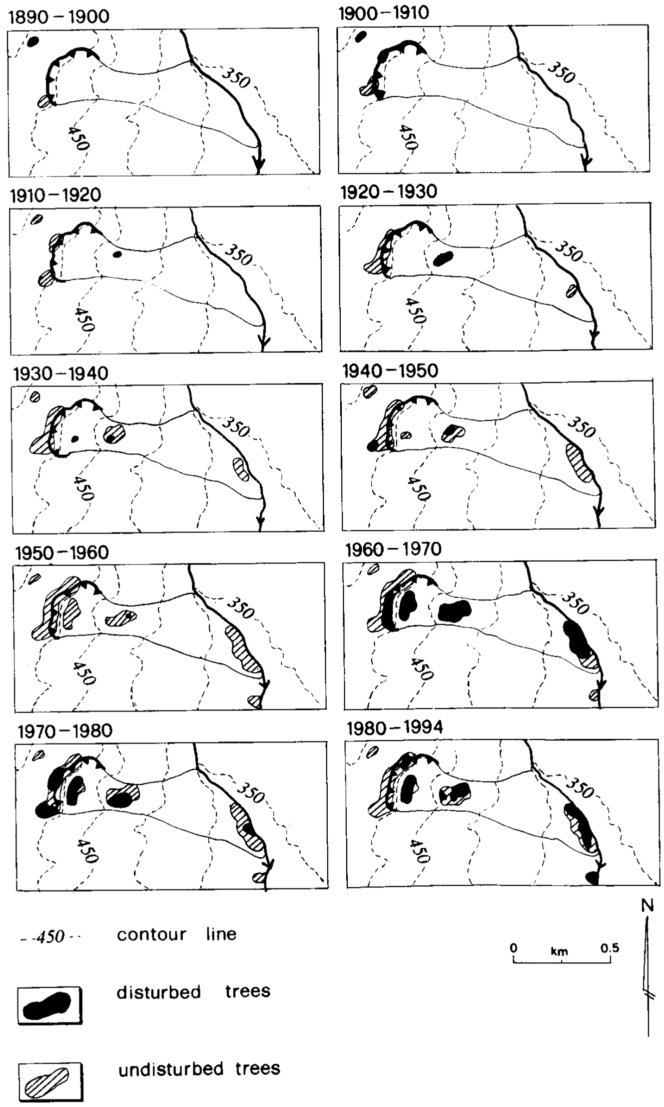


Fig. 11 - Landslide temporal maps between 1890-1994. They show different behaviour according to the period of landslide activity or inactivity. The increase of mass movement activity since 1960 is evident.

shown in Fig. 11, in the maps 1890-1900 and 1900-1910 the only living and disturbed trees were in the old landslide deposit above the crown area. In the maps 1910-1920 and 1920-1930 some trees appeared for the first time in the landslide body starting from the middle-upper part and most of them were affected by some disturbances. In the time interval between 1930 and 1960 there was generally no disturbance due to the landslide activity. In the 1960-1970 period, instead, most of the trees were interested by an event (the 1963 one). This movement reactivation interested all the landslide body from the crown to the toe zones. In the 1970-1980 map, instead, only the middle-upper part of the landslide was affected by disturbance (1972 event).

By comparing the two maps of 1960-1970 and 1970-1980 it can be noticed that the zone affected by disturbance close to the crown retreated uphill in the more recent map. This could be related to the formation of a secondary scarp (surveyed during the field work) behind the main crown, during the 1972 event.

Another period of landslide movement occurred during 1986 when some of the trees on the deposit were disturbed. This corresponds with the dating of the small slump along the Fossatello gully (Zone S in Fig. 6).

Conclusion

The dendrogeomorphological analysis was a very useful approach in the examination of this mass movement. The trees living on or close to the landslide body have been affected by the mass movement activity. The disturbances found were evident both in the morphology of tree stem (simple or complex tilting) as well as in the sudden growth anomalies (suppression), found in other previous studies as OROMBELLI, GNACCOLINI (1972); TERASME (1975); CLAGUE, SOUTHER (1982); JIBSON, KEEFER (1988); STRUNK (1992); DENNELER, SCHWEINGRUBER (1993). The growth anomaly could be connected to more or less strong damages to the root apparatus during the landslide reactivation.

The trees sampled in the stable geomorphological zone were not, on the contrary, affected by any growth anomaly and stem bending. This confirms that the disturbances found on the trees living on or close to the landslide were due to the mass movement reactivations.

This research investigated the dynamic landslide activity underlining the following aspects:

- Dating of the main mass movement reactivation periods.
- Identification of the most disturbed zones of the landslide.
- Identification of the activity and inactivity periods of mass movement with the temporal maps.
- Correlation between growth anomalies and rainfall data.
- Use of cores'microphotographs to evidence the seasonal dating of growth anomaly events.
- Relationship between growth anomalies events and historical data of regional landslide reactivation periods.

The dating of the main mass movement reactivation periods was indicated through the growth anomaly (suppression) detected in the samples.

The visual growth anomaly technique introduced by SCHWEINGRUBER ET ALII

(1990) and utilised in research on conifer species (DENNELER, SCHWEINGRUBER 1993) was found to be very useful even for the deciduous tree species as in this study (*Quercus Cerris* L.).

The division of the landslide area examined in different zones was very important to evidence which parts have been more disturbed by landslide activity (Zone H and M in Fig. 6).

The temporal maps (Fig. 11) concerning the decades of the period examined (1890-1994) have shown the landslide reactivation periods and those of landslide inactivity. This kind of analysis can be very useful to understand the dynamic evolution of a mass movement. A previous use of spatial maps was introduced by SHRODER (1978) to point out the tracks of different debris avalanches in a complex rock glacier-like boulder deposit on the Table Cliffs Plateau, Utah (U.S.A.).

The correlation between tree-ring data and rainfall data was used by SHRODER (1978) who tried to correlate the mass movement event-response index It to the mean annual precipitation. The spectral analysis suggested a possible relation between precipitation and slope movement. Another study was made by KASHIWAYA ET ALII (1989) to relate heavy rainfall in the Kobe district, Japan, to the tree-ring width. They found a 25-30 years dominant periodicity both in the tree-ring width as well as in the heavy rainfall.

In this research the main peaks of seasonal precipitation data were related with the main growth anomalies detected in the cores. In this way it was possible to correlate 75% of the anomalies to some particular wet season (Fig. 8). In the case of the most important growth disturbance event of 1963 there were two possible seasons that could have induced the slope movement: the previous autumn (1962) or the current summer (1963). In this case, the use of some microphotographs of the cores which revealed that the landslide event happened during the previous vegetative rest period, in 1962 autumn, were very useful (Fig. 10). In fact, the core shows a complete normal ring (1962) before the one after the event whose structure is abnormal. Many rings following the events get abruptly small. Moreover, november 1962 was recorded as a period of regional landslide crisis (AVI - CNR 1994). This kind of analysis was previously done on a conifer species which revealed a dating of landslide on mount Clayley, British Columbia, (U.S.A.) in the 1963 growing season (CLAGUE, SOUTHER 1982).

A more detailed analysis of rainfall data was done for those years in which there is a coincidence between growth anomaly and wet season (Fig. 9). The relationship between the rainfall data and the growth anomaly seems to point out that the reactivation of this slide-flow type landslide mainly concerns some dry periods followed by intense rainy ones. This can be related to the increase of the secondary hydraulic conductivity in the clayey material during the long drought because of the clay shrinkage and tension cracks formation that favour the infiltration in the following rainy periods; this decrease the shear strength of the slope material so that the movement of the landslide can be reactivated.

The dating of growth anomalies could also be documented as periods of historical regional scale landslide reactivation crisis (1928, 1937, 1962, 1963, 1986) (AVI - CNR 1994). This relationship is a further support to the results of the research data.

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LITERATURE

ALESTALO J., 1971. Dendrochronological interpretation of geomorphic processes. *Fennia*, 105: 1-140.

AVI - CNR, 1994. Prog. CNR G.N.D.C.I. - Censimento delle aree italiane vulnerate da calamità geologiche. Catalogo delle calamità geologiche nelle regioni Lazio, Toscana ed Umbria.

BÉGIN C., FILION L., 1988. Age of landslides along the Grande Rivière de la Baleine estuary, easter coast of Hudson Bay, Québec (Canada). *Boreas*, 17: 289-298.

BRAAM R.R., WEISS E.E.J., BURROUGH P.A., 1987a. Spatial and temporal analysis of mass movement using dendrochronology. *Catena*, 14: 573-584.

BRAAM R.R., Weiss E.E.J., Burrough P.A., 1987b. Dendrogeomorphological analysis of mass movement: A technical note on the research method. *Catena*, 14: 585-589.

BUONASORTE G., CATALDI R., CECCARELLI A., COSTANTINI A., D'OFFIZI S., LAZZAROTTO A., RIDOLFI A., BALDI P., BARELLI A., BERTINI G., BERTRAMI R., CALAMAI A., CAMELI G., CORSI R., DACQUINO C., FIORDELISI A., GHEZZO A., LOVARI F., 1988. Ricerca ed esplorazione nell'area geotermica di Torre Alfina (Lazio - Umbria). *Boll. Soc. Geol. It.*, 107: 265-337.

CLAGUE J.J., SOUTHER J.G., 1982. The Dusty Creek landslide on Mount Cayley, British Columbia. *Can. J. Earth Sci.*, 19: 524-539.

CORONA E., 1972. L'abete affiorato nella zona del Falterona (Toscana). *Monti e boschi*, III: 35-38.

DENNELER B., Schweingruber F.H., 1993. Slow mass movement. A dendrogeomorphological study in Gams, Swiss Rhine valley. *Dendrochronologia*, 11: 55-67.

FILION L., QUINTY F., BÉGIN C., 1991. A chronology of landslide activity in the valley of Rivière du Gouffre, Charlevoix, Quebec. *Can. J. Earth Sci.*, 28: 250-256.

HEIKKINEN O., 1994. Using dendrochronology for the dating of land surfaces. In: Beck C. (ed.) *Dating in exposed and surface contexts*. Albuquerque, Unit of New Mexico Press, 213-235.

HOLMES R.L., 1983. Computer-assisted quality control in tree-ring dating and measurements. *Tree-Ring Bulletin*, 43: 69-78.

HUPP C.R., 1983. Geo-botanical evidence of late quaternary mass wasting in block field areas of Virginia. *Earth surface processes and landforms*, 8: 439-450.

JIBSON R.W., KEEFER D., 1988. Landslide triggered by earthquakes in the Central Mississippi valley, Tennessee and Kentucky. *U.S. Geological Survey Professional Paper 1336-C.*

KASHIWAYA K., OKIMURA T., KAWATANI T., 1989. Tree-ring information and rainfall characteristic for landslide in the Kobe District, Japan. *Earth surface processes and landforms*, 14: 63-71.

LOCARDI E., LOMBARDI G., FUNICIELLO R., PAROTTO M., 1976. The main volcanic groups of Latium (Italy): relations between structural evolution and petrogenesis. *Geologica Romana*, vol. XV: 279-300.

OROMBELLI G., GNACCOLINI M., 1972. La dendrocronologia come mezzo per la datazione di frane avvenute nel recente passato. *Boll. Soc. Geol. It.*, 91: 325-344.

SCHWEINGRUBER F.H., ECKSTEIN D., SERRE-BACHET F., BRÄKER O.U., 1990. Identification, presentation and interpretation of event years and pointer years in dendrochronology. *Dendrochronologia*, 8: 9-38.

SHRODER J.F., 1978. Dendrogeomorphological analysis of mass movement on Table Cliffs Plateau, Utah. *Quaternary Research*, 9: 168-185.

SHRODER J.F., 1980. Dendrogeomorphology: review and new techniques in tree-ring dating. *Progress in Physical Geography*, 4: 161-188.

Shroder J.F., Butler D.R., 1987. Tree-ring analysis in the earth sciences. Proceedings of the International Symposium on Ecological Aspects of Tree-Ring Analysis, August 17-21, 1986 - Marymount College - Tarrytown, New York: 186-212.

Stokes M.A., Smiley T.L., 1968. An introduction to tree-ring dating. The University of Chicago Press, Chicago.

Strunk H., 1992. Reconstructing debris flow frequency in the southern Alps back to AD 1500 using dendrogeomorphological analysis. *Erosion, Debris flows and Environment in Mountain Regions* (Proceedings of the Chengdu Symposium, July 1992). IAHS Publ. 209: 299-307.

Terasme J., 1975. Dating of landslide in the Ottawa river valley by dendrochronology - a brief comment. Mass wasting Proceedings, 4th Guelph Symposium on Geomorphology, 1975: 153-158.

SUMMARY

Reconstruction of landslide dynamic with dendrocronological methods

The dynamic of a recent slide-flow landslide which belong to a complex landslide in the Mt. Rufeno Natural Park (in the province of Viterbo - Latium - Italy) was studied through dendrochronological methods. 40 *Quercus cerris* L. trees were sampled: 25 from the recent landslide, 3 from a small slump along the Fossatello creek and 12 from the surrounding geomorphological stable areas. The samples taken from the landslide deposit were affected by growth anomalies such as suppression or release, while the samples from the stable areas did not show growth anomalies. The visual growth anomaly analysis (Shweingruber et alii 1990) was made on the samples. This analysis evidenced, during the investigation period 1890-1994, noumerous peak- anomaly which are connected to mass movement reactivation events. The most important was the 1963 one. Some microphotographs were very useful to detect the season in which the event occurred (vegetative rest period in 1962). The seasonal rainfall data and the hystorical regional landslide crisis data confirmed the date of the event in the 1962 autumn. Other mass movements events were recorded in 1894, 1903, 1915-16, 1922, 1928, 1937, 1972, 1986; most of them are well connected to the seasonall rainfall peaks, often preceeded by drier periods. Spatial analysis of the mass movement was made through decade temporal maps, starting from the 1890. These have shown a strong increase of landslide activity since the '60.

RIASSUNTO

Ricostruzione di una dinamica franosa tramite metodologia dendrocronologica

L'analisi dell'attività di una frana recente del tipo scorrimento-colamento, appartenente ad una frana complessa, sita nel territorio della Riserva Naturale di Monte Rufreno (provincia di Viterbo - Lazio - Italia) è stata esaminata tramite l'utilizzo della metodologia dendrocronologica. Sono state campionate n. 40 piante della specie *Quercus cerris* L. di cui n. 25 viventi sul deposito franoso in esame, n. 3 provenienti da un piccolo smottamento verificatosi lungo il fosso Fossatello e n. 12 provenienti da zone geomorfologicamente stabili adiacenti la zona in esame. I campioni legnosi provenienti dagli alberi su frana hanno mostrato evidenti segni di anomalie nell'accrescimento quali improvvise riduzioni di crescita ed in minor misura improvvisi aumenti di crescita. Gli alberi campionati in zona stabile non hanno mostrato invece anomalie di accrescimento. Le anomalie sono state esaminate tramite l'analisi visiva (Shweingruber et alii 1990). I risultati hanno mostrato, nell'intervallo di tempo esaminato 1890-1994, alcuni improvvisi picchi di anomalie. Questi periodi corrispondono ad eventi di riattivazione del movimento franoso, il principale dei quali è databile al 1963. L'ausilio di microfotografie eseguite in campioni con disturbi di crescita si è rivelato molto utile nell'individuare la stagione in cui si è verificato il disturbo e quindi la riattivazione del movimento franoso (periodo di riposo vegetativo 1962). Le elaborazioni dei dati meteorologici relative ai dati stagionali di piovosità oltre ai dati storici, relativi ai periodi di crisi franose a diffusione regionale, hanno confermato la datazione della riattivazione franosa nell'autunno del 1962. Oltre a questo evento di riattivazione del movimento franoso ve ne sono stati altri durante il periodo esaminato nelle seguenti date: 1894, 1903, 1915-16, 1922, 1928, 1937, 1945, 1972, 1986, la maggior parte dei quali è correlata a periodi

di particolare piovosità, spesso preceduti da periodi siccitosi. L'analisi spaziale dell'attività franosa ricostruita tramite mappe decennali a partire dal 1890, ha mostrato un notevole incremento dell'attività franosa dagli anni '60.

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