Tree-Ring Dating of Active Faults in Italy and Turkey

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Paleoseismology is of fundamental importance for improving the historical records of earthquakes. Some criteria of the Mercalli scale for classification of earthquakes severity are based on the degrees of tree disturbance (Wood and Newmann, 1931). Tree-ring dating with accurate dendrochronological analysis (Stokes and Smiley, 1968) represent a data source with potential to extend beyond historical records with annual or subannual precision (Jacoby et al., 1997).

Tree-ring analysis is useful in paleoseismology at any location where surface rupture, geomorphic and hydrologic disturbance or acceleration and displacement due to an earthquake can affect tree growth. Earthquakes can produce direct effect on a forest with the displacement of a fault scarp and acceleration of substrate that can broke or rip apart the root system, cut major branch or trunk or tilt trees. These trauma often induce sudden decrease in ring widths (suppression) of few years or a longer period after the event; missing rings, eccentric growth and related reaction wood due to tilting of the stem or to death of tree; more rarely trees react with a sudden increase of growth especially where nearby trees fall down and there is a decrease of competition or increase of nutrient and water supply in soil. Besides the effect of earthquakes activation or reactivation of mass movement many specific studies were carried on dating trees living along active and capable fault lines in the world.

Mapping the extent of disturbed trees could indicate the minimum length of rupture and be used as an index to minimum magnitude. The first studies by McGee (1892) were related to the 1812 New Madrid earthquake (Missouri USA), further studied by Stahle *et al.* (1992). The San Andreas fault were examined firstly by LaMarche and Wallace (1972) dating the 1906 earthquake, then by Miesling and Sieh (1980) that detected the effect of 1857 earthquake of Fort Tejon and from Jacoby *et al.* (1988) that detected again the 1812 earthquake (Mw>7.0) and 1957 earthquake near Wrightwood - California, north east of Los Angeles. Studies in Alaska were made at Ice Cape, related to 1899 earthquake by Jacoby and Ulan (1983); Alaska 1964 earthquake was studied by Yamaguchi (1991) while 1958 earthquake by Page (1971). Sheppard and White (1995) showed that where there is a surface rupture and vertical displacement trees can respond even to events of small magnitude (M 4.6) along a normal fault. More recent tree-ring analysis was made by Bekker (2004) along a normal fault related to the 1959 earthquake near Hebgen lake, southwestern Montana - USA (M 7.5). The same Hebgen fault scarp was investigated by Carrara (2002). In Tibet, Han (1983) sampled trees along a fault in the Damxung district on cypress trees that detected an earthquake occurred in 1951-1952. Lin and Lin (1998) dated the 1930 earthquake (M 8) with a shrub that was cut in two parts due to a dextrally displacement about 11 m along the Fuyun fault in China. In India tree - ring evidence of 1991 earthquake at Uttarkashi, western Himalaya was studied by Yadav and Bhattacharyya (1994). In Almata, Kazakstan, close to the epicentre of 1887 (M 7.5) were examined tree by Yadav and Kulieshius (1992). In the present study tree-ring dating was used as paleoseismological record along fault lines connected to some recent earthquakes in Italia and in Turkey.

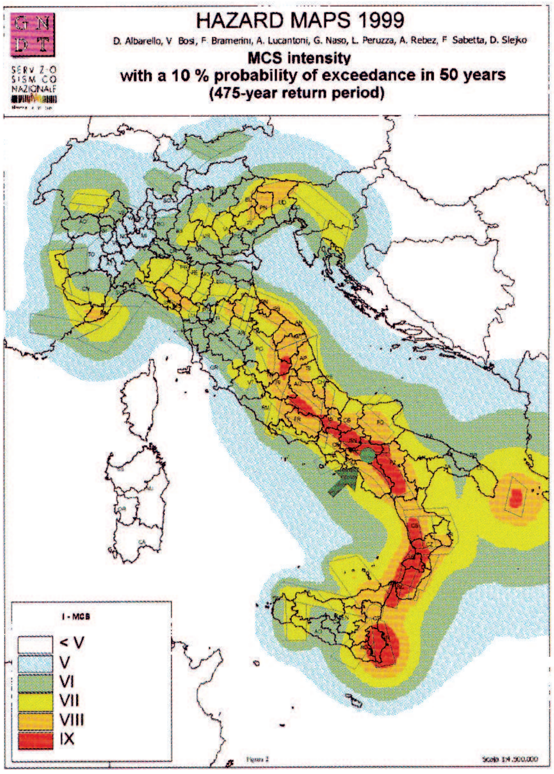


Figure 1: Italian Seismic Hazard Map with study site.

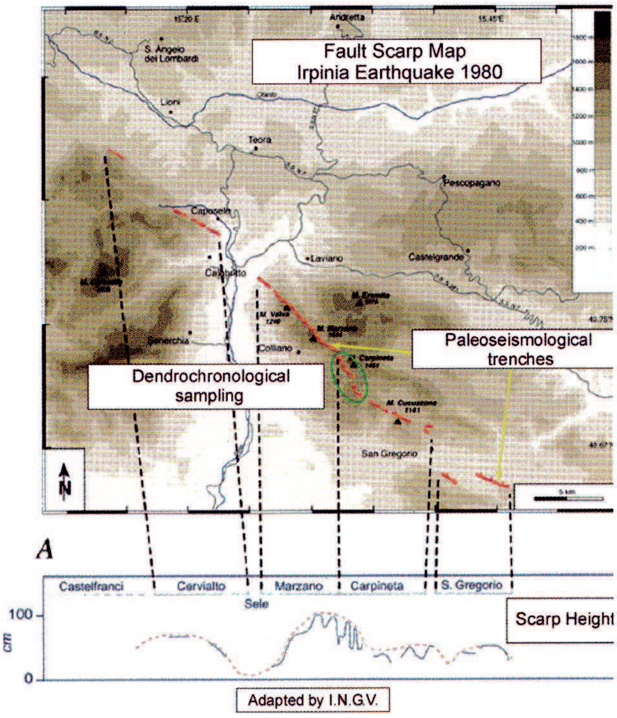


Figure 2: Irpiniafault with sampling locations.

The first site, Irpinia, belong to one of the most hazard zone along the Appennines mountain region in south Italy (Figure 1). This area was affected by many strong and destructive earthquakes in the past. On the 23rd of November 1980 a very strong earthquake hit this area (50-90 km east of Naples) with a maximum intensity of X on MCS scale (Ms 6.9). Its duration was 80 sec which produced a 40 km long northwest trending, northeast dipping normal fault which is referred to as the "Irpinia fault". Dendroseismological analysis was made along a 4 Km length of the 40 Km total length of the "Irpinia" fault, on the north east side of the ridge between Mt. Marzano – Mt. Carpineto, covered by beech forest (Figure 2). The sampling strategy was to collect increment cores using a Swedish increment borer from the beech living along and far from the fault line (as control trees). Overall, during the two samplings in 1993 and 1996, 30 trees were sampled, 20 living just on the fault line, and 10 far from it, used as control ones. Control trees, sampled from 1-2 meters up to 10-20 m from the fault didn't show growth stress (suppression) as those living along the disturbed area. The time span investigated by this research was 120 years. The scarp induced by the 1980 normal fault was at the most 1.0 – 1.2 m high, and most of trees living on it showed disturbance on their root system, often cutting on roots, and sometimes tilting (Figure 3). The aim of the research was to test the effect of the 1980 Irpinia earthquake on trees living along the fault line. It was found that 65% of trees sampled on the fault have recorded growth anomalies, mostly suppression (sudden decrease), that begun the year after the event (1981) or, in some case, the second year after the event (1982). Some trees scattered along the section of the fault line displayed similar growth suppression prior to 1980, probably related to previous earthquakes that occurred in the same region (23rd July 1930, 21st August 1962, 29th November 1971). The 1930 earthquake was recorded only by one tree that with a very strong and long suppression since 1931 (5%);

the 1962 event was recorded by three trees placed in different sections of the fault (15%), while the 1972 event was recorded by two nearby trees. Some additional growth suppressions were recorded on trees living on and outside the fault line but these were not related to earthquake events because they didn't appear on more than on tree (Figure 4).

Figure 3 (a): Beech trees sampled along the Irpinia fault (tilted stems)

Figure 3 (b): Beech trees sampled along the Irpinia fault (roots damaged).

The second dendroseismological research was conducted as a test along different zones in Turkey in June 2004. The aim of this test was to collect samples from different tree species (i.e. oriental plane-tree, sweet chestnut, black pine) living in various environments (i.e. flood plain, mountain region) along some segments of the North Anatolian fault (Düzce and Mudurnu). The aim of the test was to investigate the potential use of dendrochronology in paleoseismological analysis in Turkey (Figure 5).

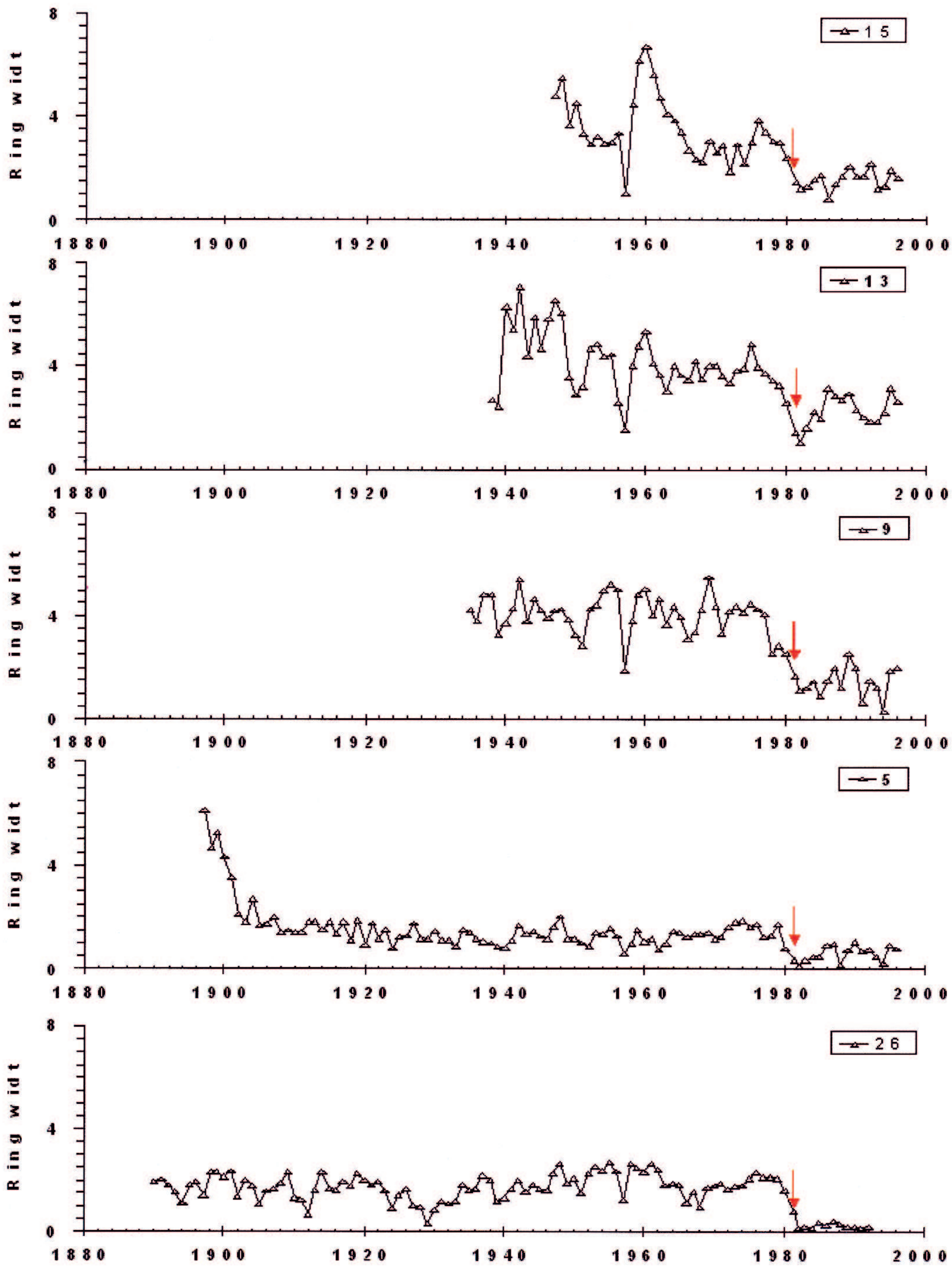


Figure 4 (a): Tree-ring anomalies after 1980 Irpinia (Italy) earthquake.

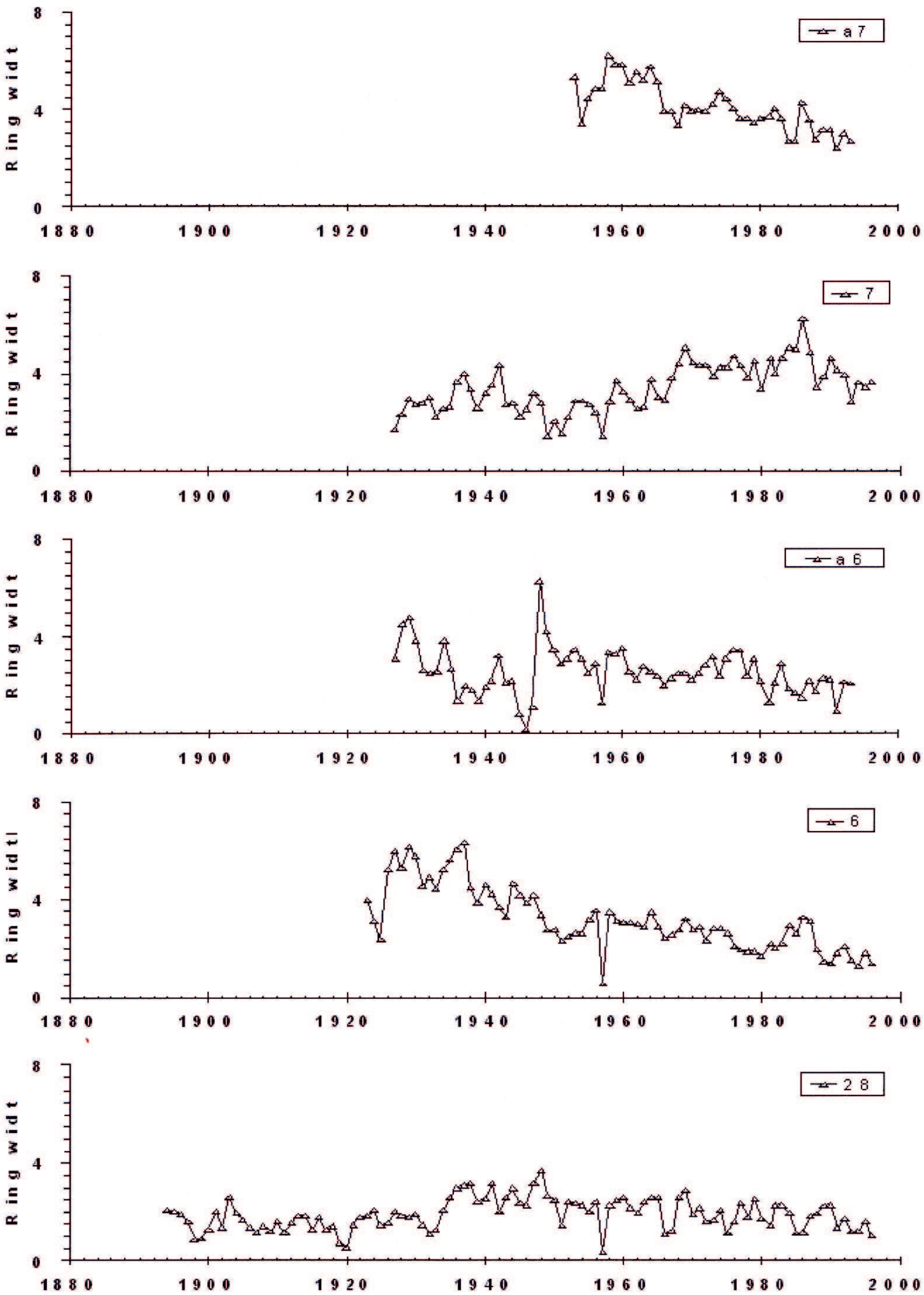


Figure 4 (b): Regular tree-ring growth (control)

In this study were sampled 41 trees belonging to many different species. Most of trees have recorded the 1999 earthquake disturbance in Düzce plain as sudden growth suppression starting in 2000 or 2001; in some oriental plane-trees in the same area was recorded also the previous 1967 earthquake (Fig.6). From dendrochronological point of view these trees growing on Düzce alluvial plain can be classified as complacent (with a wide and regular ring growth due to the favourable site conditions) with a medium tree-ring 10-15 mm/year, usually considered not useful for this kind of research. When trees were disturbed by an earthquake, which provoked stress on the root system and or on the stem, they have shown sudden growth decrease (1-2 mm/year) lasting for some years, recovering later their regular growth (Figure 6).

In the second fragment of the fault, Mudurnu area, trees have shown besides the usual cut of roots and tilting another specific anomaly in the stem, not recorded along other faults in the bibliography as well as in the research made in Irpinia (south Italy). This is a kind of compression crush detected at some meters of high along the stem that is typical of this fault (Figure 7). In the site were not found tree-ring anomalies connected to 1957 and 1967 earthquake. Some other disturbance have been recognized (i.e. 1885, 1902, 1919, 1947, 1951-52 (Figure 8), 1973-75) but more investigations are need for an interpretation of these few and sparse sampling.

Moreover this zone has a great potential for dendrochronological analysis because of the diffuse forest.

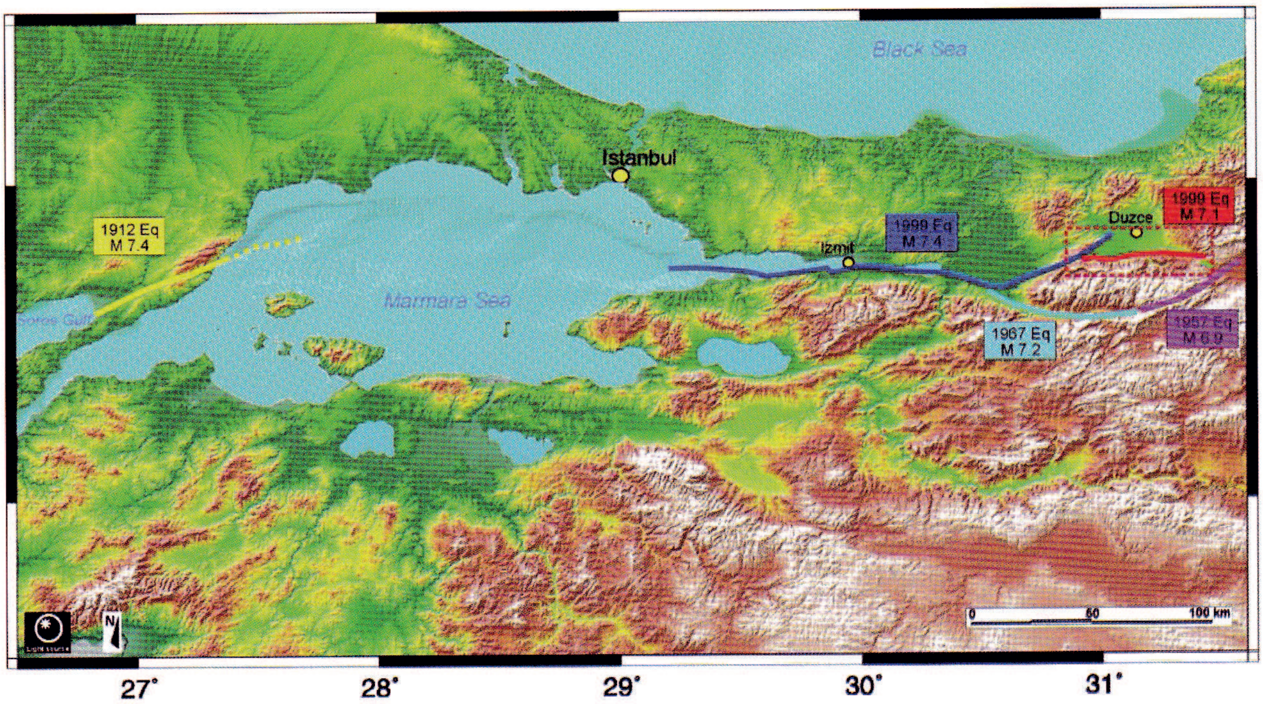


Figure 5: North Anatolian Fault with sampled zone in Düzce - Mudurnu zone.

Figure 6 (a): Oriental plane tree in Düzce with growth suppression due to 1967 and 1999 earthquakes.

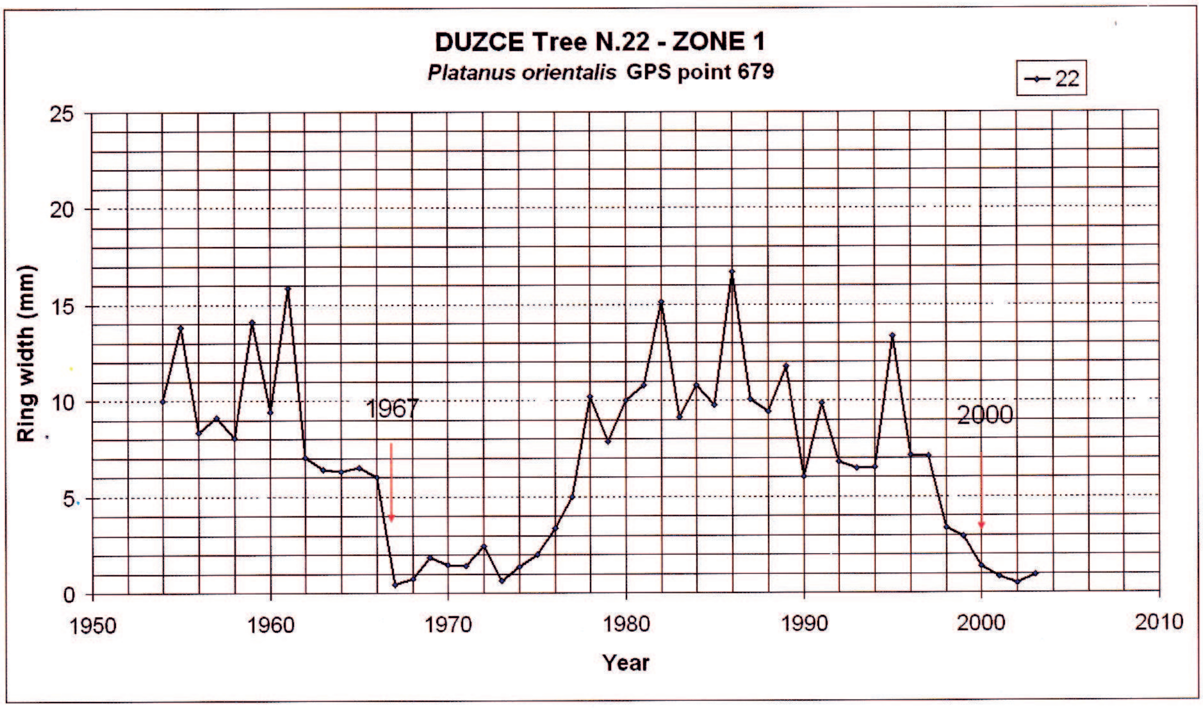
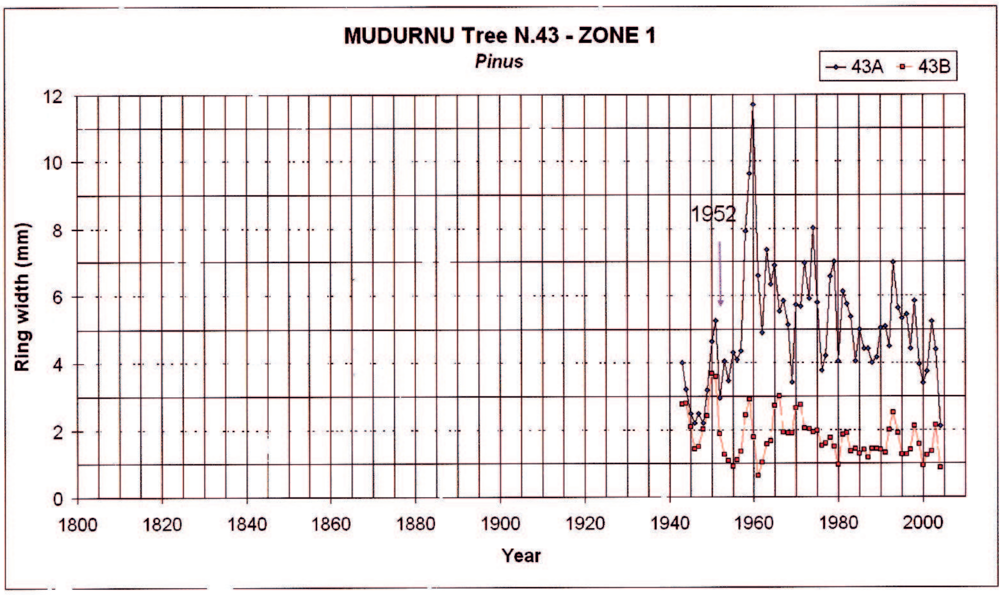


Figure 6 (b): Graph showing tree-ring growth in Düzce since 1950s.

Figure 7: Pines in Mudurnu area with compression on the stem and cut roots.



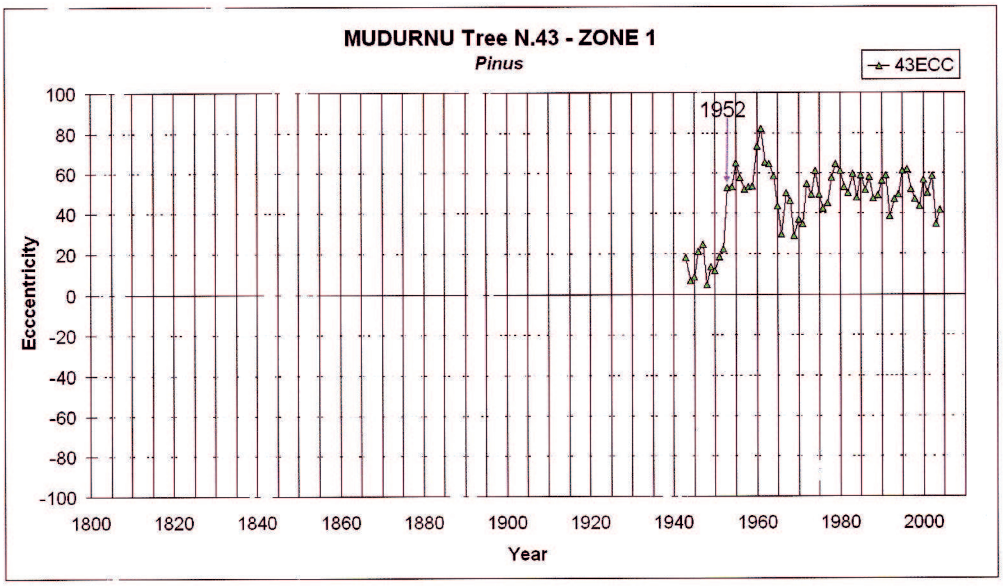


Figure 8: Growth eccentricity of a pine tree (No: 43) in Mudurnu area since 1952.

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