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Meandering river bank erosion and channel lateral migration recorded in black alder *(Alnus glutinosa)* tree rings

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Introduction

Black alder belongs to pioneer woody species. It prefers area without plants for growing, for example new surfaces occurring after floods (Iversen 1973). Additionally black alder roots are adapted to growing under the water level (van Dijk 1978, Dilly et al. 2000). Therefore black alders often occupance meandering river banks and valley floors in European temperate climates (Grime 1981). Due to bank erosion and lateral channel migration alders are under mechanical stress. Banks upon which they grow are systematically eroded and trees forming different growth forms to survive. Black alders growing on undercutting banks are mostly tilted and their stems are bended, usually they have exposed root systems (Fig. 1A). Clumps of alders growing on the concave banks numbered several stems (Fig.1B), the stems are 1/3 less in diameter than alders growing on straight or convex banks.

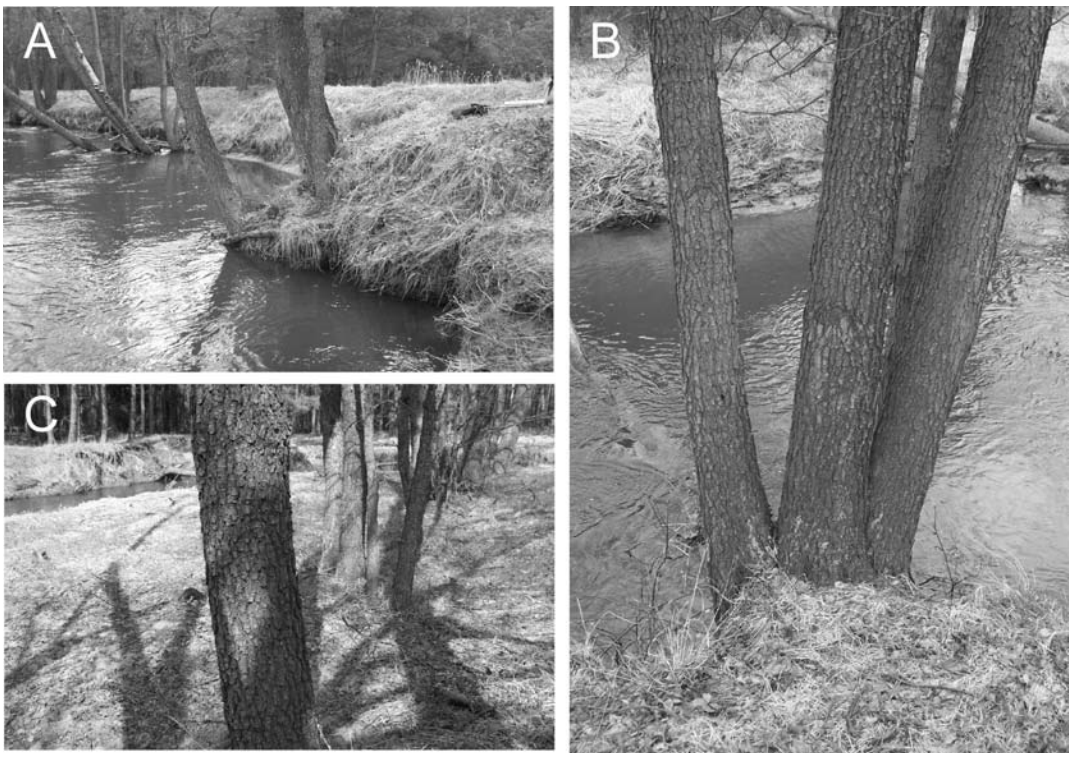


Figure 1: Examples of grow forms of riparian alder. A – alders tilted and advanced due to erosion in respect of river bank; B – clump growing on the river bank; C – alders growing due to lateral channel migration on the old bank line (palaeobank).

Alders are producing clumps with expended root systems because it predisposes the plant to obtain stability in contrast to individual stems. The clumps growing on banks forced by erosion are protruding in the middle of the river channel. The alders growing at some distance from convex banks often have similar shapes to trees observed on the straight and concave bank (Fig.1C). The similarity is caused by progressive lateral erosion and line of trees withdrawn from recent bank.

The aim of this study is to find bank erosion and channel migration records in riparian alder tree rings.

Study area

Study area was selected in the valley of the Mała Panew River runs along an east-west axis through the Opole Plain which forms part of the Silesian Lowland, southern Poland (Fig. 2a). The meandering Mała Panew flows through over 20 kilometres of compact forest complex. Therefore it is one of the few areas in Central Europe Lowlands where the impact of vegetation on river channel formation can be studied. The river is 131 km in length, and drains an area of about 2000 km². The bottom of the valley is covered by poorly sorted sands. Terraces of the Mała Panew River are covered with pine plantations, black alders mostly grow in the floodplain. The monthly precipitation in the study area is between 500 and 700 mm. The mean annual discharge at the Krupski Młyn gauge, 20 km downstream of the study area reaches, is 10 m³/s.

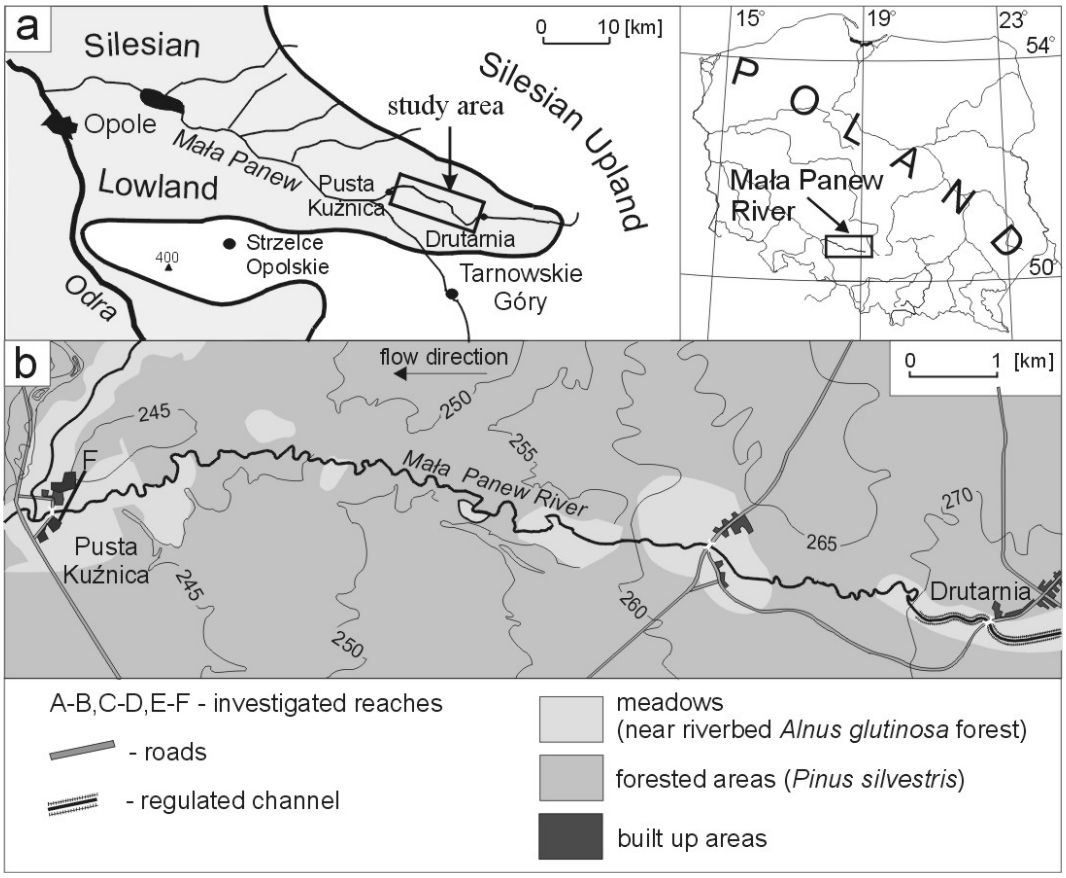


Figure 2: Location of study area.

During the last few decades several peak discharges have been 10-20 times higher, apart from an extraordinary flood event of 3 days in July 1997, when the water rose in same places 6 to 8 m above the flood plain (Malik 2006).

The study sites are located in the 12 kilometres between Drutarnia and Pusta Kuźnica (Fig. 2b). The Mała Panew forming in the study area numerous bends with varying diameters in the river—such features are typical for areas with forested banks. The channel cuts around 0.5–1.5 m deep into the floodplain. The gradient of the Mała Panew valley within the reach examined amounts to 1.2 ‰. The width of the river in forested areas does not exceed 15 m while its depth at average water stage reaches up to 1.5 m. Lateral migration rate of the Mała Panew channel at the studied sites is about 0.2 – 1.5 m/year (Malik 2005, 2006).

Methods

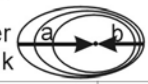
Firstly, 20 stems of alders growing on today undercutted bank with well visible formed growth transformation (bending, tilting, clumps forming) were selected for sampling. Twenty alder stems growing on the old bank line and 10 alder stems representing carr formation were selected to compare alder tree-ring series transformed by bank erosion and ring series not transformed. Two cores were sampled from individual 50 alders. The sampling level on each tree was about 0.5 metres above ground. Trees growing on undercutted banks and palaeobanks were sampled on the maximum tilt axis of the alders in a plane perpendicular to the riverbed. The first core was sampled from a location facing the riverbed, while the second faced the flood plain. Finally tree ring series from every tree and site chronology ware constructed and cross-dated to find bank erosion and lateral channel migration records. Additionally stem circumference and mean ring width from every stem were calculated.

Results and Discussion

Erosion records in the tree rings of tilted and bend alders

Tree rings formed by alders growing on undercutted banks are considerably thinner than rings formed by alders growing in the some distance form banks (Tab. 1).

Table 1: Ring width and eccentric growth in different types of alders form growth

	mean ring width (mm)	degree of eccentric (%) river bank  riverbed	
		a	b
tilted alders growing on the river banks	2.56	145.7	100.0
alders growing on the river banks in clumps	2.90	124.6	100.0
alders growing on the palaeobanks	2.45	100.2	100.0
alders growing in carr formation	3.80	-	-

Alder stems undercutted by erosion produce eccentric tree rings. In individual tilted stems, rings facing the flood plain are 50% wider than rings facing the riverbed. After titling during the period without great erosion events alders gradually straighten stems, finally alders become hook shaped (Fig. 1A and 3).

Similar effects were observed for trees growing on continually creeping slopes by Patrizek and Woodruff (1957). The authors suggest the trees had been bowed because only the apical part of stem is able to grow vertically. Trees changing stem shape after soil creeping were also described by Schmid and Schweingruber (1994). Trees incline towards the slope after the event, while next years without soil creeping events overcompensation occurs and trees start to grow vertically again.

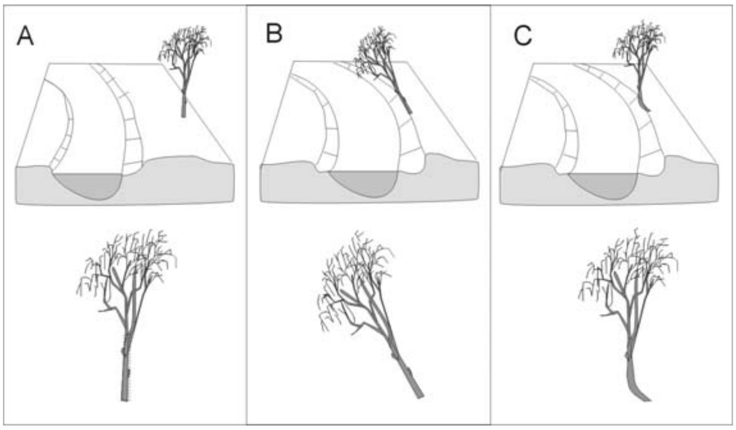


Figure 3: Riparian alders tilted and bend as a result of bank erosion. A – straight alder stem not transformed by erosion, B – tilted alder stem transformed by erosion, C – bend alder stem as a result of periods without erosive episodes.

Finally trees are S-shaped. Tilting and bending of alder stems are well recorded in tree rings. Alder tilting makes the width of the first ring facing the floodplain decrease and simultaneously the same ring facing the riverbed increases (Fig. 4, years 1987 and 1997).

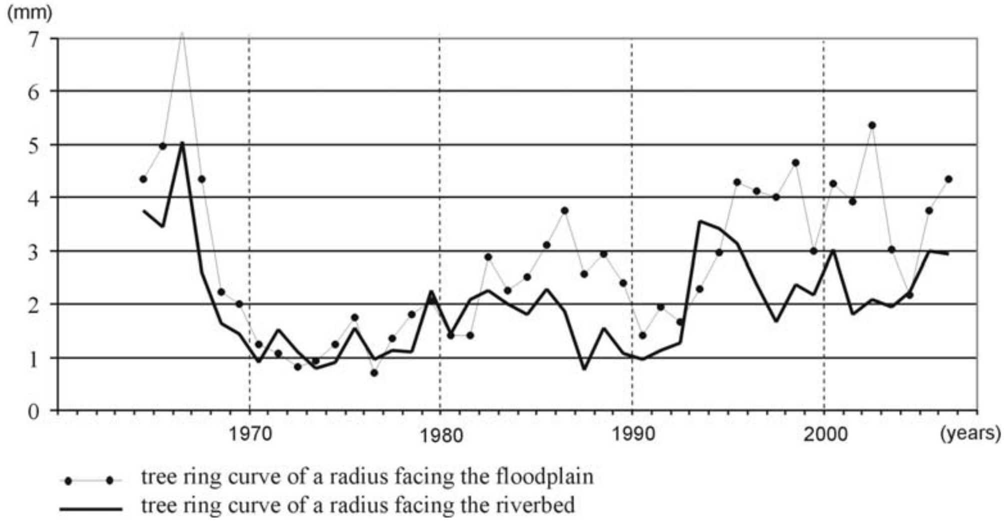


Figure 4: Example of tilted and bend alder tree ring series.

The riverbank on which the trees grew was undercut in 1987 and 1997 (Fig. 4). In these two years, water stages recorded at the nearby gauge were extremely high in June and July respectively. About 5 to 10 years after the tilting episode floodplain and riverbed facing tree rings reach gradually even widths. It means, the stem grows upright again after several years but the straightening period depends on the erosion episode frequency.

Lateral migration records in the tree rings of alder growing on palaeobanks

River channel may shift it's course during one flood. As a consequence, lines of alders are documenting old river channels after such a big flood (Fig. 5). Trees growing on palaeobanks gradually loose their bendiness and tiltness and start growing upward. When a channel has been shifted alders produce about 50% thinner tree rings than before shifting.

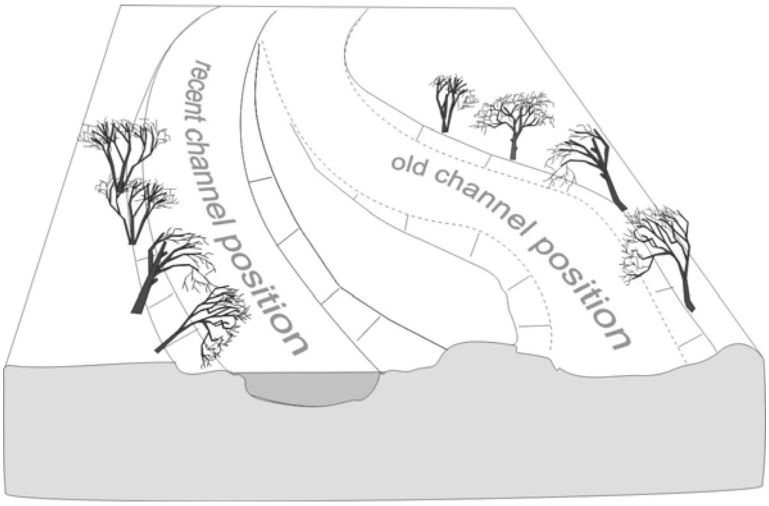


Figure 5. Alders growing along recent and old channels within a floodplain

Figure 6 reveals clearly visible growth reduction in alder stems when the river channel changed it's course in 1966 at this site. Probably the growth reduction results from a decreasing of water level after river channel shifting.

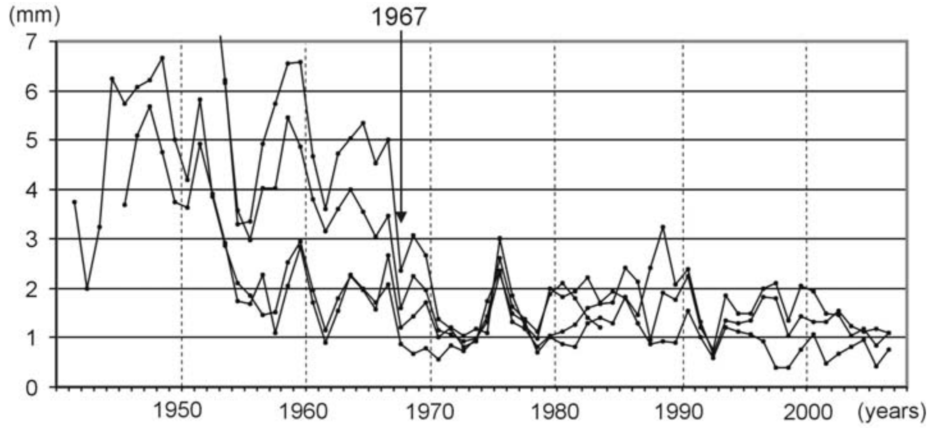


Figure 6. Example of ring curves of alders growing along palaeochannel at one site (ring reduction in 1967 showing year when the channel was shifted)

Conclusions

1. It is possible to reconstruct bank erosion and river channel migration by using riparian alders. Bank erosion and channel shifting are clearly reflect in riparian alder ring series.
2. After erosion episodes alders growing directly on the udercut bank are often tilted. The trees produce eccentric tree rings. Rings facing the floodplain are strongly wider than rings produced on the other side. After several years without any erosion episode alders begin grow straight again. A stem results hook shaped.
3. As soon as a channel has shifted it's course, alders established on an abandoned bank reduce growth ubruptly.

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