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Hydroclimatic effects on the condition of grey alder (*Alnus incana* L. Moench) and European larch (*Larix decidua* L. Mill.) growing in the riparian forest of an incised mountain river

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Introduction

Vertical stability of river channels is a key control on the condition of riparian vegetation communities, including riparian forests. It determines the frequency of inundation of riparian areas (Dufour, Piégay, 2008), and thus the thickness and fertility of soil, as well as the availability of water for root plants. Widespread human impact on river channels in the 20th century has resulted in a common occurrence of river incision (Wyżga, 2008). This phenomenon enlarges the flow capacity of the channel and increases the elevation of floodplain areas over the water level in the river, that may worsen the condition of riparian forest (Dufour, Piégay, 2008) or even lead to its decline (Stella et al., 2013).
The influence of river incision on the condition of riparian forest can be readily demonstrated in the neighbouring incised and vertically stable river reaches. Such variation in the vertical tendencies of channel bed can be observed in the Czarny Dunajec, the upper course of the second largest river of the Polish Carpathians (Zawiejska, Wyżga, 2010). The study was carried out in the middle course of the Czarny Dunajec, in which a wide and shallow, multi-thread channel had existed until the mid-1970s (Fig. 1).

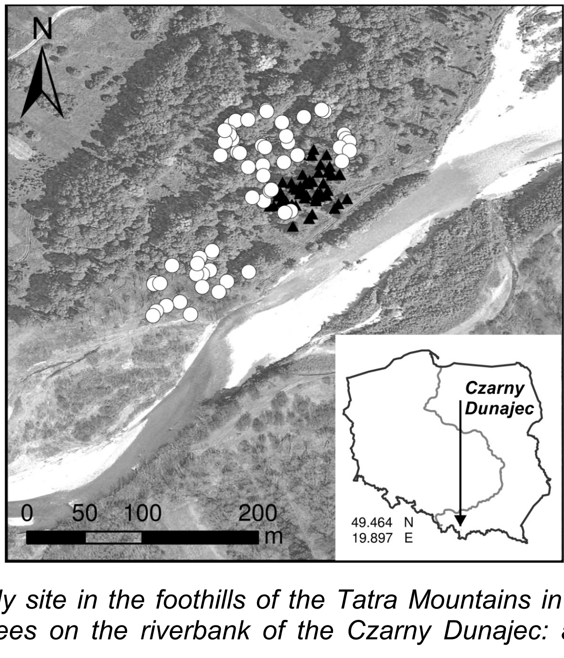

Figure 1: Location of the study site in the foothills of the Tatra Mountains in southern Poland and detailed location of 87 investigated trees on the riverbank of the Czarny Dunajec: alder (white circles) and larch (black triangles).

Along a portion of this reach, the river has remained unmanaged, maintaining the multi-thread channel pattern and vertical stability of its bed. Here, width of the active zone of the river currently exceeds 150 m and the banks are 0.7-1.2 m in height. In the lower portion of the reach, the river was channelized in the years 1974-1976, with the former multi-thread channel replaced by an artificially formed, single-thread channel about 40 m wide. The bed of the regulated channel was positioned about 1 m lower than the bed of the former, natural channel. In response to the increase in transport capacity of the river caused by its considerable narrowing and the concentration of flow in the single channel (Wyżga, 1993, 2008), the bed degraded by further 0.5 m as indicated by a comparison of its elevation in the constructed regulated channel with its current position. A complete lack of the cover of fine-grained, overbank deposits on the gravel bank formed in the course of the river channelization shows that channel incision must have been rapid, lasting only a few years at most. As a result of the mentioned changes, the riparian forest adjacent to the regulated channel ceased to be inundated by flood flows and the height of the river banks increased to 2.4-2.6 m (Fig. 2). The environmental changes were accompanied by modifications of the riparian forest. The systematic tree logging and introduction of a tree species typical of other habitats are two main factors that have influenced the character of the investigated forest.

The aim of this study was to assess the influence of climatic and hydrological factors on two tree species of different origin, which now grow together in the riparian zone of the incised river. Grey alder (*Alnus incana* L. Moench) represents a native species typical of the mineral *Alnetum incanae* riverside forest and is a light-demanding and fast-growing broadleaf tree that prefers moist soil. Alders are actinorhizal trees capable to fix atmospheric dinitrogen due to the symbiosis with actinomycetes (Furlow, 1979). European larch (*Larix decidua* L. Mill.) was introduced in the riparian forest for economical reasons as a good source of timber. The larch is also a light-demanding and fast-growing species but it prefers well-drained soil.

Figure 2: A section of the Czarny Dunajec River channelized in the mid-1970s (photo taken in 2012). The single-thread channel, about 40 m wide and with banks 2.4-2.6 m in height, is the result of the channelization and subsequent channel incision. The investigated riparian forest consists of the introduced European larch (higher trees) and grey alder typical of the riparian habitat.

Materials and methods

The study site was selected according to the results of cartographic analyses and field inspection of the Czarny Dunajec River. The chosen sampling site represents typical channel and riparian zone of the formerly braided mountain river that was modified by channelization. The samples were collected using a standard increment borer at standard height (BH = 1.3m). The cores from 56 larches (LADE) and 60 alders (ALIN) were taken. The cores were prepared for the measurement of ring width using CDendro 7.7 system (Cybis Elektronik & Data AB company). The final preparation of the cores differed between the two species. Larch cores were polished with 500 grid sand paper, whereas much finer (up to 1200 grid) sand paper had to be used to achieve a clear image of the rings of alder. Also acquisition of digital pictures was adjusted to meet the demands of diffuse-porous wood samples of alder. They were scanned with resolution ranging from 2400 to 4800 DPI, whereas 1200-2400 DPI was sufficient to obtain good-quality images of larch samples. The ring width was measured using CooRecorder 7.7 (Cybis Elektronik & Data AB company) software based on digital pictures of cores. Visual examination of actual cores, under a binocular, clarified the doubtful features of digital images. The quality of tree ring width (TRW) series was assessed with Cofecha software (Holmes 1983, Grissino-Mayer 2001). The final cross-dating and the selection of series used for further analyses was performed based on the visual inspection of TRW graphs and occasionally also re-examination of samples. These tree-ring series were detrended to remove the age-related trend and residual chronologies were built using Arstan software (Cook 1985). The cubic smoothing splines with a 50% frequency-response cut off at 200 years were employed and their variance was stabilized over time (Cook, Peters 1997). The main hydrological and climatic factors affecting the growth of the tree species were identified on the basis of correlation analysis between residual chronologies and six series of the following parameters: i) mean temperature, ii) precipitation, iii) monthly PDSI, iv) minimal discharge, v) mean discharge, vi) maximum discharge (all monthly values). Here we present only statistically significant results. The gridded climatic data (CRU TS 3.10) (Jones, Harris 2013) and hydrological data from the Koniówka gauge station located 7 km upstream from the sampling site were used in the analysis.

Results

Both the maximum and average age of sampled trees is similar for the two investigated species. For alder it amounts to 49 and 40 years, respectively, while to 46 and 40 years for larch. After statistical and visual examination of 60 sampled alder trees, 48 were selected to create chronology. Similarly, from the sample of 56 larch trees, 41 were included in the set to compute coherent chronology. The alder showed a slightly lower average growth rate than larch (2.92 and 3.33 mm respectively). Accidentally, the two analysed chronologies reached the threshold of minimum replication of five samples in 1967 (fig. 3).

The raw chronologies showed a similar pattern, revealing strong temporal trend. The main differences are visible in the 1970s and at the end of the 2000s. The first period is that of the channel regulation. Alder showed a decrease in tree-ring widths over several consecutive years, whereas larch did not show a clear reaction. In the last years the two chronologies are out of phase. The main reason is different reaction of alder and larch to the spring flood in 2010. The common minimum of growth was registered in 1987 and 1996.

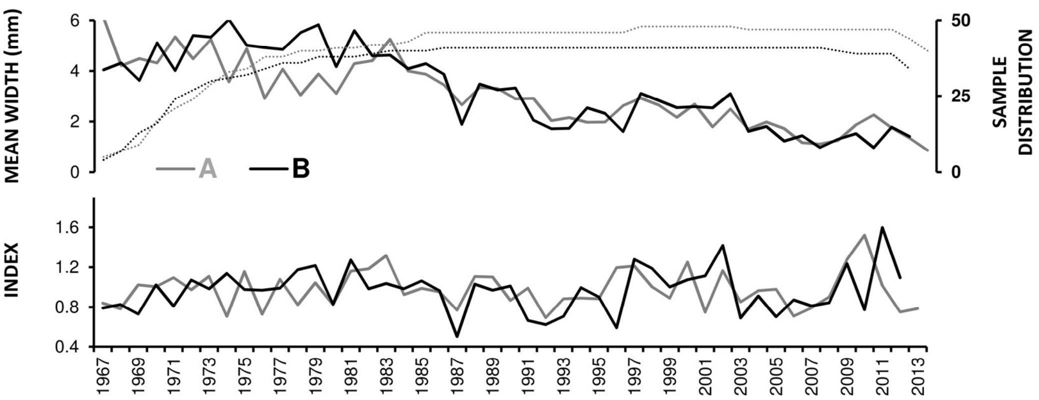

Figure 3: Raw (upper diagram) and residual (lower diagram) chronology of grey alder (A) and European larch (B) for the common period of 1967–2013. The sample distribution is displayed as a dotted line in respective colour.

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We computed correlation between residual chronologies and monthly (from January to October), seasonal and annual averages of climatic and hydrological data (Fig. 4). Additionally, to determine the autocorrelation, the similar calculation was done for chronologies lagged by 0, +1 to +5 years (Fig. 5).

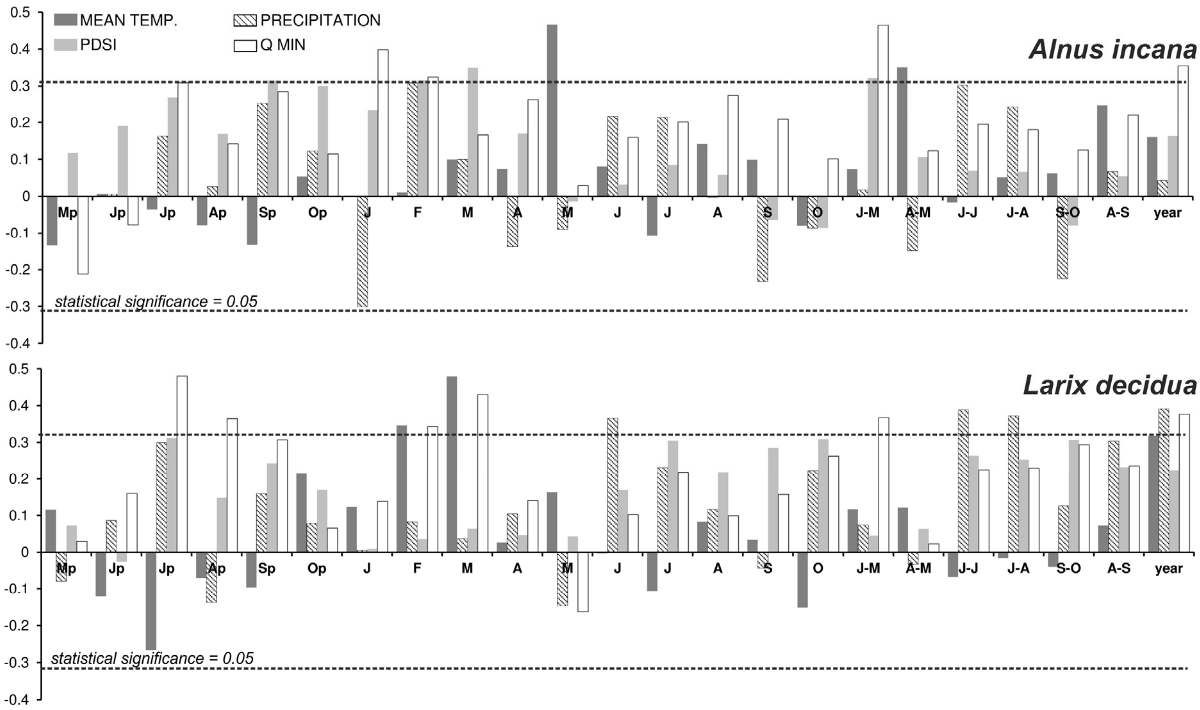

Figure 4: TRW response to mean monthly temperature, precipitation, PDSI and minimal monthly discharge calculated for the period 1973–2009.

The correlation analyses reveal the hydroclimatic controls exerted on both species. The highest correlation (r=0.49) was derived between larch chronology and the minimum discharge in March of the previous year (lag+1). The similarly high correlation was obtained between TRW and the temperature in March of a given year (lag=0). The growth rates show a significant ($p < 0.05$) response to hydroclimatic conditions during summer (July and August) of the previous year. The amount of available water, regardless of its source (river-derived groundwater or rain), controls the larch growth in the next year. The high correlation between TRW and water discharge in February and March extends this important period to several months before a growing season. During the vegetation period, tree growth depends more on precipitation (June, June-July, June-August) than on the discharge in the adjacent river. The analyses of autocorrelation reveal strong carryover effect. The correlation between TRW and lag+2 February discharge was one of the highest obtained from the analyses (r=0.49). The alder TRW chronology correlates strongly with the temperature in May (r=0.47) and the discharge during January-March of a given year (r=0.46). The availability of river-derived groundwater seems to be more important for this species, whereas no significant correlations with precipitation in all analysed periods were obtained. The growth of alder is driven by groundwater during end of winter and beginning of spring (January-March) and also by spring (April-May) temperature.

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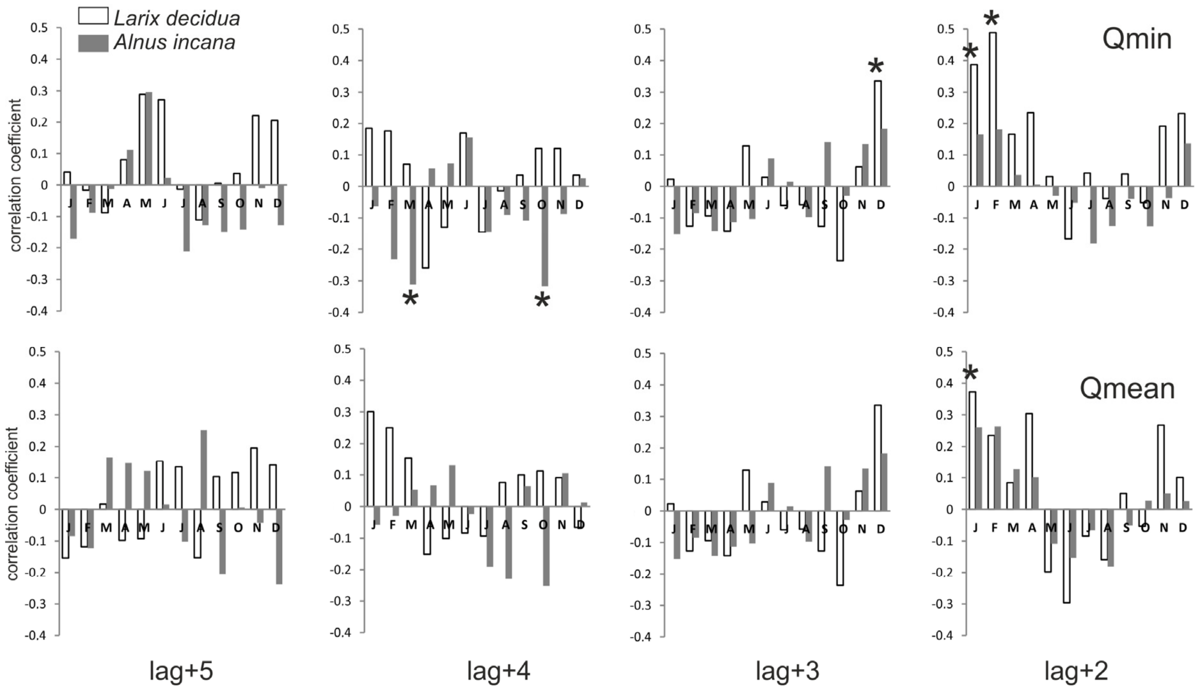

Figure 5: TRW response to mean and minimal monthly discharge calculated for the period 1973–2009. The stars indicate the results significant at level p=0.05.

This species also showed a statistically significant correlation with spring drought, expressed by PSDI index (Palmer Drought Severity Index) (Palmer 1965). Similar relation to available groundwater was observed for other riparian species (Mahoney, Rood 1991, Vreugdenhil et al. 2006). The soil moisture is important for the actinomycetes living in symbiosis with alder and responsible for fixing atmospheric nitrogen (Kaelke, Dawson 2003). Alder is also less dependent on the conditions in the previous year. Only winter discharge (last December-February) showed a significant influence on TRW. The analyses of autocorrelation derived also a correlation of -0.30 between TRW and lag+4 March and October discharge. The results of the analyses helped to understand the mechanisms responsible for the development of particularly narrow rings in 1987 and 1996. Short growth depressions are common for alder and larch. 1987 was one of the coldest years in the analysed period, and the water discharge in 1986 was significantly below the average. In 1996 the summer was also colder than usually but during that and the previous years, the river discharge was near to average. These hydroclimatic conditions resulted in a narrow ring of larch and an average one of alder.

Conclusions

The river channelization performed in the years 1974–1976 and the resultant channel incision have significantly changed the conditions for riparian forest growth. The channel regulation caused both immediate and subsequent changes of the valley-floor environment. The age of the trees of both examined species does not allow to assess these changes by a simple comparison of pre- and post-regulation periods. Therefore, further studies focused on control (natural) sites are needed. The growth of larch and alder is driven by climate and hydrological conditions of the riparian zone. The relation between tree growth and hydroclimatic conditions is complex. It was difficult to identify the main factor controlling growth of these species as both temperature and soil moisture (related to precipitation and high river discharge) are equally important for their vitality. Alder, the species typical of riparian habitat, and larch, introduced by man, react positively to warm spring and negatively to dry periods. Further channel incision and climate warming will have a negative influence on the conditions of the riparian forest. Alder trees, more sensitive to drought, may not survive. The larch, also sensitive to the lack of soil moisture, is not a good substitute for them.

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References

Dufour, S., Piégay, H. (2008): Geomorphological controls of Fraxinus excelsior growth and regeneration in floodplain forests. Ecology, 89: 205-215

Cook, E.R. (1985): A time series analysis approach to tree-ring standardization. Lamont-Doherty Geological Observatory, New York, pp 171

Cook, E.R., Peters, K. (1997): Calculating unbiased tree-ring indices for the study of climatic and environmental change. The Holocene 7: 361–370

Furlow, J. (1979): The systematics of the American species of Alnus (Betulaceae). Rhodora 81, 1–121; 151–248

Holmes, R. (1983): Computer Assisted Quality Control in Tree-Ring Dating and Measurement. Tree-Ring Bulletin 44: 69-75

Grissino-Mayer, H.D. (2001): Evaluating crossdating accuracy: A manual and tutorial for the computer program COFECHA. Tree-Ring Research 57: 205-221

Kaelke, C.M., Dawson, J.O. (2003): Seasonal flooding regimes influence survival, nitrogen fixation, and the partitioning of nitrogen and biomass in Alnus incana ssp. Rugos. Plant and Soil 254: 167–177

Mahoney, J.M., Rood, S.B. (1991): A device for studying the influence of declining water table on poplar growth and survival. Tree Physiology 8: 305-3 14

Palmer, W.C., (1965): Meteorological drought. Weather Bureau Research Paper No. 45, U. S. Dept. of Commerce, Washington, DC, pp58

Stella, J.C., Riddle, J., Piégay, H., Gagnage, M., Trémélo, M-L., (2013): Climate and local geomorphic interactions drive patterns of riparian forest decline along a Mediterranean Basin river. Geomorphology 202: 101‐114

University of East Anglia Climatic Research Unit (CRU). [Phil Jones, Ian Harris]. CRU TS3.21: Climatic Research Unit (CRU) Time-Series (TS) Version 3.21 of High Resolution Gridded Data of Month-by-month Variation in Climate (Jan. 1901 - Dec. 2012), [Internet]. NCAS British Atmospheric Data Centre, 2013

Vreugdenhil, S.J., Kramer, K., Pelsma, T. (2006): Effects of flooding duration, frequency and depth on the presence of saplings of six woody species in north-west Europe. Forest Ecology and Management 236: 47–55

Wyżga, B. (1993): River response to channel regulation: case study of the Raba River, Carpathians, Poland. Earth Surface Processes and Landforms, 18: 541-556

Wyżga, B. (2008): A review on channel incision in the Polish Carpathian rivers during the 20th century. [In:] H. Habersack, H. Piégay, M. Rinaldi (Eds), Gravel-Bed Rivers VI – From Process Understanding to River Restoration, Elsevier, Amsterdam, 525-556

Zawiejska, J., Wyżga B. (2010): Twentieth-century channel change on the Dunajec River, southern Poland: Patterns, causes and controls. Geomorphology, 117: 234-246