Trees
https://doi.org/10.1007/s00468-023-02437-x

ORIGINAL ARTICLE

Conifer quantitative wood anatomy as proxy data: application in agricultural yield reconstruction

Elena A. Babushkina[1,3] · Dina F. Zhirnova[1,3] · Liliana V. Belokopytova[1,3] · Nivedita Mehrotra[2] · Dmitry R. Dergunov[3] · Santosh K. Shah[2] · Eugene A. Vaganov[3,4]

Received: 22 March 2023 / Accepted: 12 July 2023

Abstract

Key Message **The principal components of tree-ring anatomicalchronologies of Scots pine proved to be much better proxy than its tree-ringwidth for reconstruction of climate-driven component in the regional yield ofcereals**

Abstract Tree-ring records are often used as a proxy not only for climate, but also for other related variables. One of such applications is the reconstruction of crop yield, since both are indicators of productivity in the respective ecosystems. Recently, finer parameters of wood structure were applied to enhance the sensitivity and temporal resolution of the registered climatic signal and thus to improve the quality of tree-ring based reconstructions. This pioneering study tests cell-scale quantitative wood anatomy (QWA) of conifer tree species as a proxy for crop yield in the moisture-limited plains of Khakassia (South Siberia). Spring wheat, oats, and barley yield series generalized for rain-fed (north of the region) and irrigated (central part) fields in the steppes were compared with long-term (1807–2018) QWA series of the Scots pine (*Pinus sylvestris* L.) from the forest-steppe in the foothills. Chronologies of the cell radial diameter and cell wall thickness, describing the tree ring separated into 15 sectors, were obtained and indexed to remove their common exponential dependence on the number of cells per radial row in the ring. The tree-ring width alone could explain only 16.0 and 5.3% of yield variation for rain-fed and irrigated crops, respectively. Whereas, the multifactor linear regressions with stepwise inclusion of QWA chronologies explained 48.4 and 16.1%. The implementation of principal components for QWA in the models further increased the fitness to 48.9 and 23.0%. These reconstructions have climatic responses during the vegetative season similar to ones of the respective actual yield series. The reconstructed history of the low-yield years is supported by documented evidence of crop failures, droughts, and other related events.

Keywords Conifer quantitative wood anatomy · Agricultural crop yield · Semiarid climate · Principal component analysis · Reconstruction model

Introduction

Climatic variability influences human society on many levels, more evidently as its extreme manifestations such as heat waves, droughts, frosts, floods, etc. (Camenisch and Rohr 2018; Degroot et al. 2021). According to the climate–society interaction model by Krämer (2012), this influence includes prices of resources, diseases and demography, conflicts, and consequent cultural responses. But all of this is initiated by the climatic impacts on the biomass productivity of ecosystems. The most extensive types among terrestrial ecosystems, according to FAO statistics, are forests and territories usable for agriculture, i.e., grasslands / pastures and croplands (Ritchie and Roser 2013a; https://www.fao.org/faostat/en/#data/LC, accessed on March 20, 2023). Therefore,

Communicated by A. Bräuning.

✉ Liliana V. Belokopytova
white_lili@mail.ru

1 Khakass Technical Institute, Siberian Federal University, 655017 Abakan, Russia

2 Birbal Sahni Institute of Palaeosciences, 226007 Lucknow, India

3 Institute of Ecology and Geography, Siberian Federal University, 660041 Krasnoyarsk, Russia

4 Department of Dendroecology, V.N. Sukachev Institute of Forest, Siberian Branch of the Russian Academy of Science, 660036 Krasnoyarsk, Russia

Published online: 20 July 2023