**Advancing the Use of Artificial Intelligence and Machine Learning in the Development of Useable Tree-ring Proxy based Reconstruction of Streamflow**

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Water resources and planning management decisions are generally based on observed historical records. Therefore, it is crucial to investigate historical streamflow in order for water managers and planners to make better decisions on water resources. Although the Southeast United States is known to have more abundant water quantity than other regions in the US, having a long period of historical record can help stakeholders evaluate certain climatic factors that influence irregular periods of streamflow and water availability variability (Anderson et al., 2019). Our NRT project aims to develop streamflow reconstructions using both traditional regression techniques using tree-ring-based proxies and innovative AI/ML approaches and evaluate extreme events, particularly in the southeast US as agencies such as TVA are stakeholders in the findings of the studies. After performing a preliminary literature review, we have determined multiple studies using tree-ring chronology-based proxies for paleo streamflow reconstruction in both the continental United States and parts of Europe. A study focusing on the Sava River Basin in Europe utilized tree-ring proxies and the Old-World Drought Atlas (OWDA) to reconstruct seasonal streamflow data for approximately 2000 years. It identifies both drought and pluvial periods in the reconstructed historical record, with a significant decrease in pluvial periods compared to the paleo record, likely due to increased human activities like the construction of water control structures. This knowledge is of paramount importance for water managers and planners seeking practical solutions for sustainable water resource management (Tootle et al., 2023). Additional studies were conducted in the US, including the Tennessee Valley which successfully utilized tree-ring proxies for paleo streamflow reconstruction (Anderson et al., 2019), and for summer streamflow of the White River in Arkansas (Cleaveland et al., 2000). Knight (2004) reconstructed the Flint River streamflow, Crockett et al. (2010) analyzed tree ring chronologies for streamflow reconstruction in Florida, Harley et al. (2016) rebuilt the Suwannee River streamflow, and Stahle et al. (1988) reconstructed the North Carolina drought.

Bald cypress trees and oak trees are moisture-sensitive indicators for precipitation and streamflow, with rings and flood rings being anomalous growth patterns. These growth anomalies can be used to investigate past hydrological and climate conditions. Healthy oak trees have cylindrical, uniform vessels that facilitate efficient water transport, but environmental stresses like flooding can cause vessel deformation, twisting, or misshapening, negatively impacting growth and health (Meko & Therrell, 2020). Bald cypress trees produce one growth ring per year, but can temporarily reduce or cease growth in flood-prone areas (Therrell & Bialecki 2015). These growth anomalies offer insights into patterns of long-term climate trends and high-flow periods.

Gaps in streamflow records and short records can make predicting water difficult for managers and decision-makers. There have been some efforts to use machine learning techniques to fill in these gaps and to reconstruct records from other sources like tree-ring proxies. The MissForest algorithm (Arriagata et al., 2021) is an implementation of the random forest algorithm and uses the existing data to predict the missing data. This method works with large datasets with multiple variables. There have also been efforts to extend streamflow records using machine learning tree ring data and the random forest algorithm. In the Kazakh Uplands they were able to reconstruct streamflow from 1788-2016, even reconstructing extreme periods of drought and high precipitation (Zhao et al., 2022). Machine learning seems to have some advantages over traditional linear regression methods due to the amount of and differing data that can be used and its ability to identify non-linear relationships.

In conclusion, these articles provide historical context and accurate reconstructions of streamflow data, which are valuable for guiding water resource management in regions facing complex challenges due to climate change and human interventions. Having accurate and complete time series for hydrological data is crucial to making decisions about water resources. Our NRT project aims to extend historical streamflow records with tree-ring proxies, provide past information on water availability and variability, and assist water managers in making better water resource decisions in the southeast United States.

**References**

Anderson, S.; Ogle, R.; Tootle, G.; Oubeidillah, A. Tree-Ring Reconstructions of Streamflow for the Tennessee Valley. Hydrology 2019, 6, 34.<https://doi.org/10.3390/hydrology6020034>

Arriagada, P., Karelovic, B., Link, O., 2021. Automatic gap-filling of daily streamflow time series in data-scarce regions using a machine learning algorithm. Journal of Hydrology 598, 126454.<https://doi.org/10.1016/j.jhydrol.2021.126454>

Cleaveland, M. K. (2000). A 963-year reconstruction of summer (JJA) stream flow in the White River, Arkansas, USA, from tree-rings. *The Holocene*, *10*(1), 33-41

Crockett, K., Martin, J. B., Grissino‐Mayer, H. D., Larson, E. R., & Mirti, T. (2010). Assessment of Tree Rings as a Hydrologic Record in a Humid Subtropical Environment 1. JAWRA Journal of the American Water Resources Association, 46(5), 919-931.

Harley, G. L., Maxwell, J. T., Larson, E., Grissino-Mayer, H. D., Henderson, J., & Huffman, J. (2017). Suwannee River flow variability 1550–2005 CE reconstructed from a multispecies tree-ring network. Journal of Hydrology, 544, 438-451.

Knight, T., Policy, G., & Center, P. (2004). Reconstruction of Flint River streamflow using tree-rings. Water Policy Working Paper, 5.

Meko, M. D., & Therrell, M. D. (2020). A record of flooding on the White River, Arkansas derived from tree-ring anatomical variability and vessel width. Physical Geography, 41(1), 83-98.

Patskoski, J., Sankarasubramanian, A., & Wang, H. (2015). Reconstructed streamflow using SST and tree-ring chronologies over the southeastern United States. Journal of Hydrology, 527, 761-775.

Stahle, D. W., Cleaveland, M. K., & Hehr, J. G. (1988). North Carolina climate changes reconstructed from tree rings: AD 372 to 1985. Science, 240(4858), 1517-1519.

Therrell, M. D., & Bialecki, M. B. (2015). A multi-century tree-ring record of spring flooding on the Mississippi River. Journal of Hydrology, 529, 490-498.

Tootle, G., Oubeidillah, A., Elliott, E., Formetta, G., & Bezak, N. (2023). Streamflow Reconstructions Using Tree-Ring-Based Paleo Proxies for the Sava River Basin (Slovenia). *Hydrology*, *10*(7), 138.

Zhao, X., Zhang, R., Chen, F., Maisupova, B., Kirillov, V., Mambetov, B., Yu, S., He, Q., Dosmanbetov, D., Kelgenbayev, N., 2022. Reconstructed summertime (June–July) streamflow dating back to 1788 CE in the Kazakh Uplands as inferred from tree rings.Journal of Hydrology: Regional Studies 40, 101007.<https://doi.org/10.1016/j.ejrh.2022.101007>