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Using tree rings to estimate the annual carbon sequestration of hardwood floodplain forests along the Middle Elbe

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INTRODUCTION

Anthropogenic land use and landscape change has dramatically decreased the presence of **hardwood floodplain forests** (HFF) globally. In Germany, it is estimated that only 1% of the former HFFs still exist today. Natural HFFs provide an abundance of **ecosystem services** such as the mitigation of climate change through the **sequestration of atmospheric carbon (C)**. However, C sequestration rates may differ for hardwood trees in **different hydro-logical situations** and **developmental stages**. This research focuses on two main questions:

Questions:

1. Does the **hydrological situation** significantly influence the C sequestration rate of hardwood floodplain trees?
2. How does the C sequestration rate of **old trees compare to young trees**?

STUDY SITES

Strata classes

Hydrological situation	Developmental stage		
	Young plantation	Old sparse	Old dense
Deep active floodplain	5x	5x	5x
High active floodplain		5x	5x
Seepage water zone			5x
Tributary			5x

Table 1. Seven strata classes were chosen based on a hydrological gradient and developmental stage. Plot replicates were chosen based on a stratified random sampling design.

Map of MediAN study sites

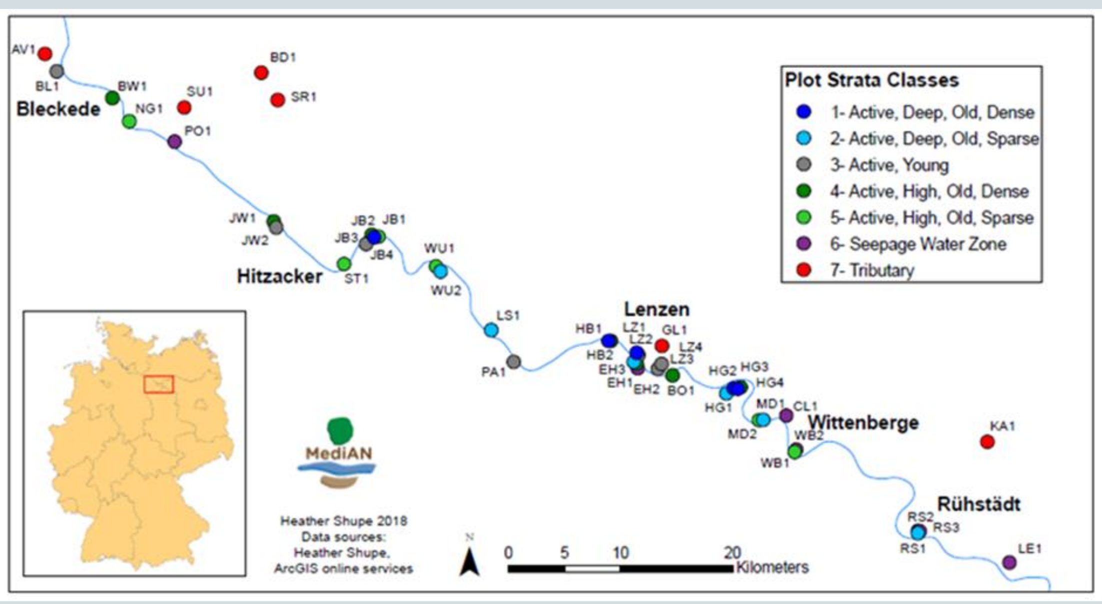

Figure 1. MediAN study sites along the Middle Elbe river, Germany.

Figure 2. Young plantation on the active floodplain

METHODS

Tree inventory: Diameter at breast height (DBH) and height of trees were measured in 2018.

Tree core collection and processing: A 5 mm in-crement borer was used to extract **70 cores** from dominant oaks (10 per strata class). A microscope connected to a **LINTABTM 5** measuring table (RinnTech) and the **TSAP-WinTM** software pro-gram were used to measure the annual tree ring widths (TRW). **Two researchers** compared the TRW measurements and used the **COFECHA** statistical program to ensure proper cross-dating.

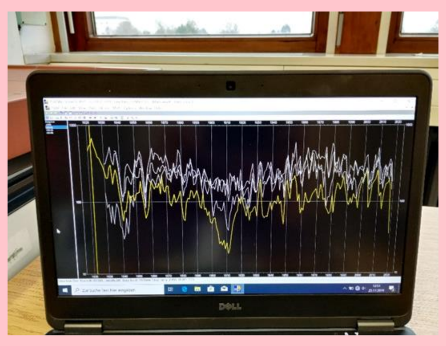

Figure 3. Tree ring width measurements in the TSAP program

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*****************************************
*C* Number of dated series        51 *C*
*O* Master series 1830 2018  189 yrs *O*
*F* Total rings in all series   5728 *F*
*E* Total dated rings checked   5715 *E*
*C* Series intercorrelation    0.518 *C*
*H* Average mean sensitivity   0.281 *H*
*A* Segments, possible problems   15 *A*
*** Mean length of series      112.0 ***
*****************************************
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Figure 4. COFECHA output for dominant oaks shows an acceptable series intercorrelation

FIVE step C sequestration rate computation

1. at each annual timestep, multiply TRW by 2 to estimate **change in diameter**
2. for each core, **input DBH at year 2018** and subtract change in DBH for every following year
3. **reconstruct heights** by using the DBH:height cubic equation (see below)
4. **reconstruct annual C stocks** using the allometric equation for oaks using DBH and height as input parameters (Ziannis 2005)
5. estimate annual **change in carbon stocks** (and the decadal average change in carbon stocks). This output is then the average annual carbon sequestration per tree.

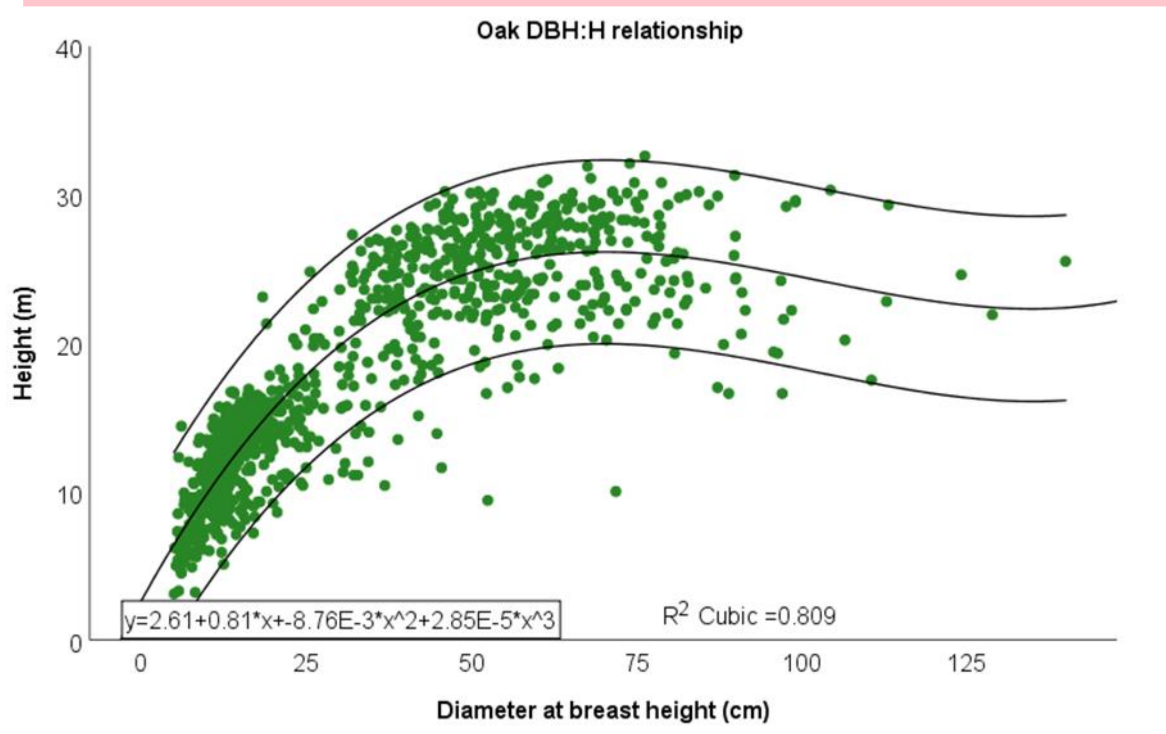

Figure 5. This DBH:height relationship was calculated using the inventory data collected in the 35 plots for all oaks.

Equation 1:

$$CS=((D^{2.00333} \cdot H^{0.8925} \cdot \exp(-2.86353))/1000)*WD*CC$$

Equation 1 measures the carbon stock (CS) of an oak tree in tons. The allometric equation to estimate the volume (V) of Oak is taken from Appendix C of Zianis et. al. (2005). The parameter D is the diameter at breast height in cm (1.3 m above ground surface) while H is tree height in meters. The specific wood density (WD) for oak is 0.56 (from the wood density database). The carbon content (CC) is assumed to be 0.47 (UNFCC 2015).

RESULTS

Average annual C sequestration rate for different strata classes over the decades

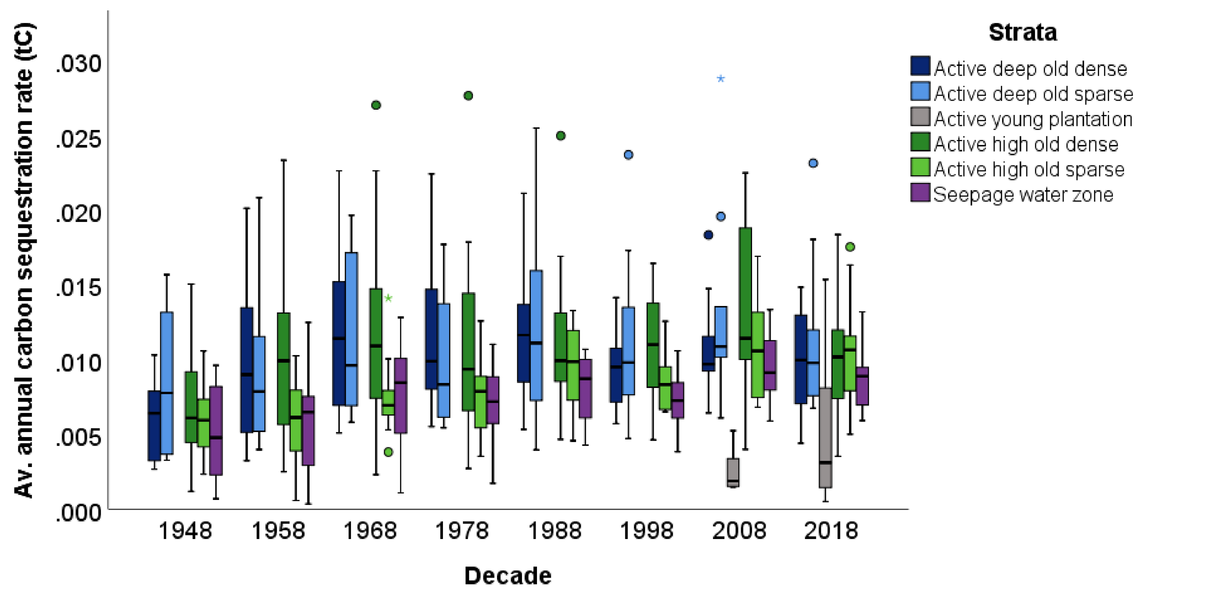

Figure 6. The average C sequestration rate in tons carbon per tree per year is estimated by averaging the annual sequestration rate over the decade. Error bars show standard deviations.

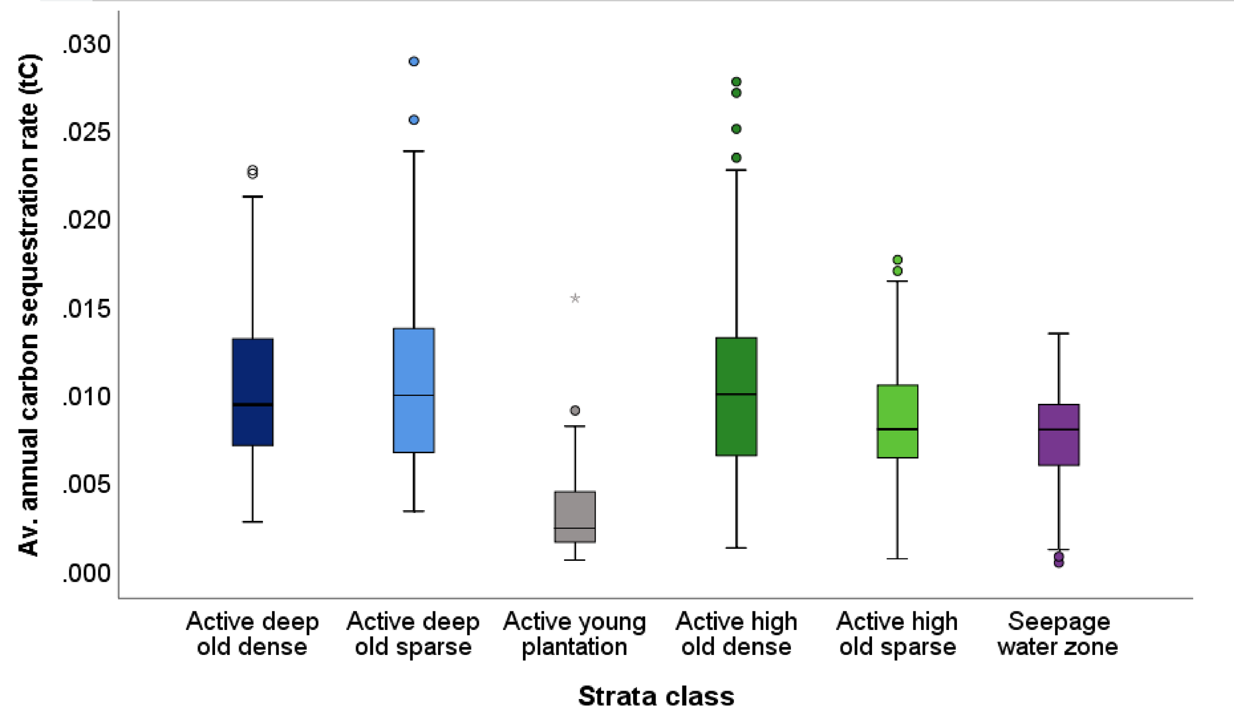

Figure 7. Average annual C stocks are shown for individual dominant trees in the different strata classes. Error bars show standard deviations.

CONCLUSIONS

- **Old oaks** in sparse and dense forests on the deep active floodplain sequester comparable amounts of C as old oaks on the high active floodplain and seepage water zone (on average **9.6 kg C per tree per year** +/- 4.81 sd).
- **Young oaks** in plantations on the active flood-plain sequester significantly less C than old oaks (**3.8 kg C per tree per year** +/- 3.71 sd).

Old trees (up to 200 years old) continue to sequester C at a high rate and provide ecosystem services which help to decrease atmospheric C concentration and mitigate climate change.

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Find out more at: MediAN website

MediAN

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