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Sediment accretion rates and radial growth in natural levee and backswamp riparian forests in southwestern Alabama, USA

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ABSTRACT

Riparian forested wetlands improve downstream water quality by trapping suspended sediment from adjacent waterways. Waters that transport sediment and nutrients into adjacent wetlands also create wet and dry hydrologic periods and thus, have the potential to impact site productivity. In this study, we used a dendrogeomorphic technique with green ash (*Fraxinus pennsylvanica* Marsh.) to estimate sediment accretion for two time periods (1881–2012 and 1987–2012) along a natural levee (35 m from river) and backswamp (75 m from river) and identified the influence of hydrology and climate on radial growth in green ash and water tupelo (*Nyssa aquatica* L.) along the Tensaw River in southwestern Alabama. We detected significantly higher sediment accretion rates for the 1987–2012 time period along the natural levee ($p = 0.00$; 1.6 cm yr^{-1}) and backswamp ($p = 0.03$; 1.2 cm yr^{-1}) than for the 1881 to 2012 period (0.4 and 0.5 cm yr^{-1}). Using previously measured (2010) soil bulk density for the site, estimated mass of sediment trapped per unit area ranged from 55–135 Mg ha^{-1} yr^{-1} for the 1987–2012 period and 17–61 Mg ha^{-1} yr^{-1} for the 1881–2012 period. We identified positive, significant correlations between green ash radial growth and the number of days the backswamp was flooded (1.4 m stage), days the Tensaw River was at bankfull (2.1 m), and average daily river stage during the overall growing season (April to August) and for the month of April. Green ash radial growth also illustrated a positive, significant response to April precipitation totals demonstrating the overall role of moisture availability just prior to the onset of xylem formation. Green ash trees along the natural levee and backswamp were more responsive to hydrology and climate than water tupelo trees located further in the backswamp, illustrating the potential resistance of water tupelo to perturbations. This study illustrates the important role forested wetlands play in improving water quality through quantification of sediment accretion rates and the potential impact that introduced disturbances (i.e., forest harvest-related disturbances) can have on ecosystem services.

1. Introduction

Bottomland hardwoods, a well-known type of riparian forested wetland, provide many ecosystem services to society. Most notably, riparian forested wetlands improve water quality by trapping and storing sediment from adjacent waterways (Boto and Patrick, 1978; Walbridge, 1993). Sediment generated upstream is transported downstream by rivers and eventually released into the ocean unless it is captured and deposited during transport (Walling, 2006). The amount of sediment captured in a riparian forested wetland can change through time if sediment loads in a waterway are altered due to watershed disturbances (e.g., channelization, land use, urbanization) or if trapping efficiency changes due to reasons that increase or decrease surface roughness (e.g., altered vegetation dynamics, microtopography, woody debris dynamics) (Hupp and Morris, 1990; Meade et al., 1990; Hupp and Bazemore, 1993; Kleiss, 1996; Heimann and Roell, 2000; Li and Yang, 2009; Kroes and Hupp, 2010; Ensign et al., 2014). Bottomland hardwood systems are also valued by society as highly productive sites for timber production, wildlife habitat, carbon storage, nutrient cycling, and protection from floodwaters (Walbridge, 1993). Riparian forested wetlands are characterized by hydrologic cycles of wet and dry periods created through variations in onsite flooding, precipitation, and evapotranspiration rates (Broadfoot and Willston, 1973; Wharton et al., 1982; Hupp, 2000; Day et al., 2007). Disturbances which alter the hydrologic regime in a riparian forested wetland have the potential to impact

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functionality of forested wetlands and thus, the ability to provide ecosystem services (Conner and Day, 1976; Mitsch and Rust, 1984; Hunter et al., 2008; Kroes and Hupp, 2010).

Hydroperiod length, flooding occurrence, and streamflow characteristics influence sediment accumulation in forested wetlands (Kleiss, 1996; Hupp, 2000; Hupp et al., 2008). Riparian forested wetlands reduce the velocity and peaks of floodwaters, which transport suspended sediment into adjacent riparian forested wetlands (Kleiss, 1996). As the velocity of the floodwaters is reduced, sediment falls out of suspension and is deposited, thus creating the microtopography associated with bottomlands (Hodges, 1997). Vertical structures such as vegetation, microtopographical features, and woody debris increase surface roughness, contributing to the decreased velocity of floodwaters, and increasing sediment deposition rates (Hupp, 2000; Li and Yang, 2009; Ensign et al., 2014).

Distribution and growth rate of individual tree species varies among microtopographic landforms (e.g., levees vs. backswamps) in bottomland forests due to differences in flood tolerance (Broadfoot and Willston, 1973; Wharton et al., 1982; Hodges, 1997). As a result, forested wetlands along meandering coastal plain rivers in the southeastern United States are characterized by a gradient of less flood-tolerant bottomland hardwood species along elevated natural levee and transitional areas, and by more flood-tolerant species at lower elevations (Wharton et al., 1982; Hodges, 1997; Hupp, 2000; Conner et al., 2014). Changes in hydrologic regime alter spatial and temporal sediment deposition and inflow patterns and, as a consequence, can alter tree growth and productivity in forested wetlands (Conner and Day, 1976; Mitsch and Rust, 1984; Conner et al., 2014).

Aboveground productivity in forested palustrine wetlands is dependent on several factors including: silvical characteristics for individual species, hydrologic regime, nutrient availability, edaphic conditions, and previous disturbance history (Broadfoot and Willston, 1973; Conner and Day, 1976; Reily and Johnson, 1982; Wharton et al., 1982). Floodwaters transport suspended sediment and additional nutrients into adjacent forested wetlands and thus, are one of the main hydrologic drivers influencing productivity in forested wetlands (Conner and Day, 1976; Hunter et al., 2008). Sediment deposited from floodwaters provides an allochthonous, external source of nutrients, to forested wetlands (Johnston et al., 1984). These additional nutrients enhance aboveground productivity, allowing individual species to achieve maximum growth (Keeland and Shartiz, 1995). Furthermore, these sediments alter microtopography and species distribution over time by filling abandoned river channels, creating and adding to the occurrence of natural levees (Hodges, 1997).

Dendrochronological techniques can be used to estimate sediment accretion rates (Shroder, 1980; Hupp and Morris, 1990) and to assess the impacts of altered hydrology through examination of the variation in annual tree-ring growth patterns (Fritts, 1976). A dendrogeomorphic approach that incorporates total vertical sediment deposition and total age of an immediately adjacent tree can be used to estimate sediment accretion rates following one site visit (Hupp and Morris, 1990; USACE, 1993). For instance, this dendrogeomorphic technique has been used to: characterize spatial and temporal sediment deposition patterns (Hupp and Morris, 1990); quantify the influence physical (e.g., elevation, microtopography, distance from waterway or channel, flood duration) and ecological (e.g., vegetation density, stand structure, species composition) factors have on sediment accretion rates (Hupp and Morris, 1990; Kleiss, 1996; Heimann and Roell, 2000; Phillips, 2001; Hupp et al., 2008); and determine the impact of upstream disturbances (e.g., channelization, dam construction, hydrologic alterations, land use) on short- and long-term sediment deposition and subsidence rates (Hupp and Bazemore, 1993; Heimann and Roell, 2000; Kroes and Hupp, 2010). Analysis of the variation in tree ring widths among calendar years has proven useful in identifying environmental influences (e.g., flooding, streamflow, precipitation, temperature) on annual tree growth (Fritts, 1976). Growth rates and aboveground productivity in response to hydrologic regimes have been demonstrated for a variety of tree species through utilization of tree-ring analyses (Reily and Johnson, 1982; Mitsch and Rust, 1984; Anderson and Mitsch, 2008; Predick et al., 2009; Gee, 2012; Keim and Amos, 2012).

Riparian forested wetlands located adjacent to rivers in the coastal plains of the southeastern United States are at an increased risk to changes in hydrologic regime and sediment deposition patterns due to their downstream location relative to anthropogenic influences and proximity to oceanic disturbances (Doyle et al., 2007; Stanturf et al., 2007; Conner et al., 2014). Quantification of the amount of sediment being trapped in riparian forested wetlands and impacts of hydrologic fluctuations in response to disturbances through time can aid predictions of future impacts of disturbances on forest productivity, regeneration, carbon storage, bottomland restoration, and water quality (Conner and Day, 1976; Hodges, 1997; Hunter et al., 2008). Therefore, the objectives of this study were to: (1) use the dendrogeomorphic method to compare estimated sediment accretion rates and mass per unit area of sediment trapped between two time periods (1881–2012 and 1987–2012) along a natural levee and backswamp in a riparian forest adjacent to the Tensaw River in southwestern Alabama, and as a result of the occurrence of flooding in this freshwater tidal system, (2) identify the impacts of hydrology and climate on radial growth in green ash (*Fraxinus pennsylvanica* Marsh.) and water tupelo (*Nyssa aquatica* L.), two species of differing flood-tolerance that are commonly found in bottomland hardwood systems.

2. Materials and methods

2.1. Study area

This study was conducted along the western bank of the Tensaw River within the Mobile-Tensaw River Delta at approximately 1 m asl (Fig. 1). The Mobile-Tensaw Delta is formed by the Mobile, Tensaw, and Middle Rivers and is the second largest delta system in the United States (Smith, 1988). This delta contains approximately 43,000 ha of wetlands, with 75% forested (Smith, 1988). The Mobile-Tensaw Delta is located within the Mobile River Basin, situated below the confluence of the Alabama and Tombigbee River Basins. The Alabama and Tombigbee River Basins combined contain approximately 11.6 million ha (Smith, 1988). Drainage from this area contributes to the estimated 4.3 million Mg yr^{-1} of suspended sediment that is transported downstream into the Mobile Bay and then potentially into the Gulf of Mexico (Fig. 1; Ryan and Goodell, 1972).

The study site consisted of a natural levee, a ridge of sediment along the riverbank, and a water tupelo-baldcypress (*Taxodium distichum* (L.) Rich.) backswamp (30°57′N, 87°53′W) located in Baldwin County, Alabama. This site is approximately 4.5 km southwest of the community of Stockton and 50 km north of the Mobile Bay (Fig. 1). Very poorly drained soils of the Levy (fine, mixed, superactive, acid, thermic Typic Hydraquents) series characterize the site (Aust et al., 2012). Due to its proximity to the river, the natural levee receives greater sand deposition and thus, provides microsite conditions favorable to vegetative species that are less flood-tolerant and survive and grow better in better drained soils. The overstory and midstory on the natural levee are characterized by green ash, overcup oak (*Quercus lyrata* Walt.), and water oak (*Q. nigra* L.) with fewer occurrences of swamp tupelo (*Nyssa sylvatica* var. *bicolor* (Walt.) Sarg.), black willow (*Salix nigra*