SEDIMENT ACCRETION RATES FOR NATURAL LEVEE AND BACKSWAMP RIPARIAN FORESTS IN THE MOBILE-TENSAW BOTTOMLANDS, ALABAMA

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Abstract—Several methods to quantify sediment deposition patterns in riparian forested wetlands have been used during recent decades. In this study, we used a dendrogeomorphic technique with green ash (*Fraxinus pennsylvanica*) to estimate sediment accretion rates for two time periods (1881 to 2012 and 1987 to 2012) along a natural levee (35 m from river) and water tupelo-baldcypress (*Nyssa aquatica-Taxodium distichum*) backswamp (75 m from river) adjacent to the Tensaw River in southwestern Alabama. Sediment accretion rates were significantly higher for the 1987 to 2012 time period along the natural levee ($p = 0.009$; 1.6 cm yr^{-1}) and backswamp ($p = 0.032$; 1.2 cm yr^{-1}) than for the 1881 to 2012 period (0.4 and 0.5 cm yr^{-1}). We further compared dendrogeomorphic sediment accretion rate estimates along the natural levee and backswamp to rates previously obtained using sediment pin and elevation survey methods at increased distances from the river (160 to 330 m) for the 1987 to 2012 time period. Regardless of method used we identified a negative trend in sediment accretion rates as distance from river increased and elevation decreased. Overall, this study demonstrates effective use of dendrogeomorphic techniques while minimizing site visits, compared to the other methods, to estimate sediment accretion rates across temporal and spatial scales.

INTRODUCTION

Development of methods to estimate the amount of sediment trapped by riparian forested wetlands has followed a recognized need for empirical data on sediment accretion in bottomland systems (Boto and Patrick 1979). Such methods include the use of ^{137}Cesium, feldspar clay marker horizons, sediment pins, elevation surveys, and dendrogeomorphic techniques. Each of these methods has advantages and disadvantages (USACOE 1993). Previous studies that have compared these methods have deemed each method valid for estimating sediment accretion rates in riparian forested wetlands (Cahoon and others 2000, Heimann and Roell, 2000, Kleiss 1996, USACOE 1993).

The dendrogeomorphic technique uses the total vertical depth of sediment accreted and tree age of an immediately adjacent tree to provide sediment accretion rates over the life span of trees used in the estimation technique. This method was validated by Hupp and Morris (1990) and has been used in several studies to provide sediment accretion rate estimates for time periods spanning from 10 to over 100 years across varying topographic positions in bottomland forests (Heimann and Roell 2000, Hupp and Bazemore 1993, Kleiss 1996, Phillips 2001). One major benefit of the dendrogeomorphic technique is the estimates are derived following a single site visit in which measurements are taken.

Sediment accretion rates were previously estimated using sediment pin and elevation survey methods in a water tupelo-baldcypress (*Nyssa aquatica-Taxodium distichum*) backswamp at distances of 160 to 330 m from the Tensaw River in southwestern Alabama (Aust and others 2012, McKee and others 2012). However, sediment pin and elevation based sediment accretion rates only represented a 24-year period (1986 to 2010) and these estimates were derived for only backswamp locations. Therefore, the objectives of this study were to: 1) use the dendrogeomorphic technique to estimate sediment accretion rates along a natural levee (35 m from river) and backswamp (75 m from river) adjacent to the Tensaw River for two time periods (1881 to 2012 and 1987 to 2012), and 2) compare dendrogeomorphic rates with previous sediment pin and elevation survey estimates to determine the influence of distance from river on sediment accretion rates.

MATERIALS AND METHODS

Study Area

This study was conducted along the western bank of the Tensaw River within the Mobile-Tensaw River Delta. The site was located in Baldwin County, Alabama

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approximately 50 km north of the Mobile Bay. Climate in this region is subtropical. On average, 1750 mm of precipitation is recorded annually with the greatest precipitation recorded during July (NOAA, 2011). The mean daily temperature is 19.2° C with the highest temperatures observed during June, July, and August.

The study site consisted of a natural levee and water tupelo-baldcypress backswamp (30°57' N, 87°53' W). The natural levee was located parallel to the riverbank and extended approximately 50 m inland until transitioning into the backswamp. The overstory and midstory on the natural levee were characterized by green ash (*Fraxinus pennsylvanica*), overcup oak (*Quercus lyrata*), and water oak (*Q. nigra*) with fewer occurrences of swamp tupelo (*Nyssa sylvatica* var. *bicolor*), black willow (*Salix nigra*), American elm (*Ulmus americana*), and hornbeam (*Carpinus caroliniana*) (Aust and Lea 1991). The backswamp was lower in elevation than the natural levee, which allows overbank floodwaters to pond and persist above the surface into summer months. Change in elevation within the backswamp was initially less than 15 cm (Aust and Lea 1991). Very poorly drained soils of the Levy (fine, mixed, superactive, acid, thermic Typic Hydraquents) series characterized the backswamp (Aust and others 2012). Thus, the backswamp was primarily composed of naturally regenerated flood-tolerant water tupelo and baldcypress, but was also characterized by smaller components of Carolina ash (*Fraxinus caroliniana*), pumpkin ash (*F. profunda*), black willow, red maple (*Acer rubrum*), and water elm (*Planera aquatica*) (McKee and others 2012). Average basal area in the backswamp was initially 75 m^2 ha^{-1} with approximately 85 percent comprised by water tupelo (Aust and Lea 1991). Buttonbush (*Cephalanthus occidentalis*) and dwarf palmetto (*Sabal minor*) were common shrubs in the understory for the backswamp and natural levee, respectively.

Field Methods

Vertical depth of accreted sediment was measured immediately adjacent to 20 green ash trees along transects parallel to the river. Ten co-dominant trees were sampled on the natural levee and ten along the front edge of the backswamp. Using a dendrogeomorphic technique previously validated by Hupp and Morris (1990), the original lateral roots were located on two sides of each ash tree. Once roots were located, the vertical distance between the lateral roots and current ground line was measured to the nearest 0.25 cm. Depths were measured 0.5 m away from the tree base to avoid interference of the base on deposition totals. To determine the time period in which the vertical sediment accumulated, tree cores were extracted below ground level and at DBH (diameter at breast height) for each tree using an increment borer.

Laboratory Methods

Tree cores were air dried and glued to wooden mounts. Cores were sanded with progressively finer sand paper until cellular structures became visible in the cross-sectional view under magnification. A tree-ring chronology was developed using cores extracted at DBH and ground level for the twenty green ash trees. Cores were visually cross-dated using the list method, in which narrow growth rings common among samples were identified and used as signature years to ensure proper alignment of dating (Yamaguchi 1991). Annual tree ring-widths were measured to the nearest 0.01 mm using the LinTab™ 5 RINNTECH® measuring system and TSAP-Win™ software (v. 4.69). Dated tree-ring width measurement values were verified to ensure quality of visual cross-dating using COFECHA software (Holmes 1983). Dating errors detected by COFECHA were corrected.

Data Analysis

The two vertical depths measured at each sampled tree were averaged. Average total sediment deposition values were divided by the respective tree age to estimate sediment accretion rates for the time period in which the tree was living. Average sediment accretion rates were calculated for 1881 to 2012 and 1987 to 2012 time periods along the natural levee and backswamp. Accretion rates associated with green ash trees established from 1881 to 1976 were used to calculate the 1881 to 2012 estimates, while 1987 to 2012 sediment accretion rates were calculated using trees established from 1987 to 1994. Dendrogeomorphic sediment accretion rates were compared between the two time periods along the natural levee and backswamp. Comparisons were made using Wilcoxon-Mann-Whitney tests within the NPAR1WAY procedure in SAS 9.3 (SAS 2012).

Periodic sediment accretion data were available from previous periodic sediment pin (70 to 81 pins) measurements and repeated elevation surveys between 1986 and 2010 at distances of 160, 250, and 330 m from the river (Aust and others 1991, Aust and others 1997, Aust and others 2012, Gellerstedt and Aust 2004, McKee and others 2012, Warren 2001). Sediment pin measurements and elevation surveys were conducted across the backswamp on 20 x 20 m grids. To identify the influence of distance from river on sediment accretion rates, differences among dendrogeomorphic rate estimates at 35 and 75 m and sediment pin measurements at 160, 250, and 330 m were evaluated using a Kruskal-Wallis test. If significant, pairwise Wilcoxon-Mann-Whitney tests were conducted between the distances. Differences among all five distances using the dendrogeomorphic and elevation survey data were evaluated in an identical method. Exact methods were specified for all nonparametric tests. All statistical analyses were performed at a significance-level $\alpha = 0.05$.

RESULTS AND DISCUSSION

Dendrogeomorphic Sediment Accretion Rates

Mean sediment accretion rates on the natural levee were significantly higher (124 percent, $p = 0.009$) for the 1987 to 2012 time period (1.6 ± 0.2 cm yr^{-1}) than the 1881 to 2012 time period (0.4 ± 0.0 cm yr^{-1}) (fig. 1). Similarly, sediment accretion rates were significantly higher ($p = 0.032$, 72 percent) along the backswamp for the 1987 to 2012 time period (1.2 ± 0.2 cm yr^{-1}) than the 1881 to 2012 time period (0.5 ± 0.1 cm yr^{-1}) (fig. 1). Differences in sediment accretion rates between the two time periods were attributed to altered sediment trapping efficiency due to changes in the dynamics of ground flora and understory vegetation following an adjacent forest harvest disturbance in 1986. This disturbance likely increased levels of light penetration and thus, initially resulted in increased ground flora and understory vegetation densities (Aust and others 1997). An initial increase in low, dense vegetation is likely the main reason for higher sediment accretion rates during the 1987 to 2012 time period. Similar increases in sediment trapping efficiency with increased vegetation have been noted following altered vegetation dynamics following harvesting disturbances (Aust and others 2006, Perison and others 1997). Other studies that have identified temporal patterns in sediment accretion have attributed differences to changes in upstream land use and channelization (Heimann and Roell 2000, Hupp and Morris 1990, Kleiss 1996). While upstream land use could have potentially impacted sediment accretion rates in this study, the localized impacts of the adjacent harvesting disturbance are most likely the reason for the differences. Another potential influence on the longer term (1881 to 2012) sediment accretion rates is erosion. Differences between gross and net sediment accretion rates have been reported in wetlands adjacent to the Olentangy River in Ohio (Mitsch and others 2014). In our study, sampled areas were in direct contact with overbank floodwaters which could have potentially eroded exposed portions of the natural levee and backswamp through time.

Sediment Accretion Rates With Increased Distance

Mean sediment accretion rates decreased as the distance from the river increased from 35 m to 330 m for the 1987 to 2012 time period (fig. 2). Dendrogeomorphic sediment accretion rate estimates for the natural levee and backswamp were higher than in the water tupelo-baldcypress backswamp stand at distances of 160 to 330 m from the river. A Kruskal-Wallis test indicated sediment accretion rates estimated from dendrogeomorphic and sediment pins were significantly different ($p < 0.001$) for at least one distance (35, 75, 160, 250, and 330 m from the river). Pairwise Wilcoxon-Mann-Whitney tests confirmed dendrogeomorphic estimates at 35 m (1.6 ± 0.2 cm yr^{-1}; $p = 0.034$) and

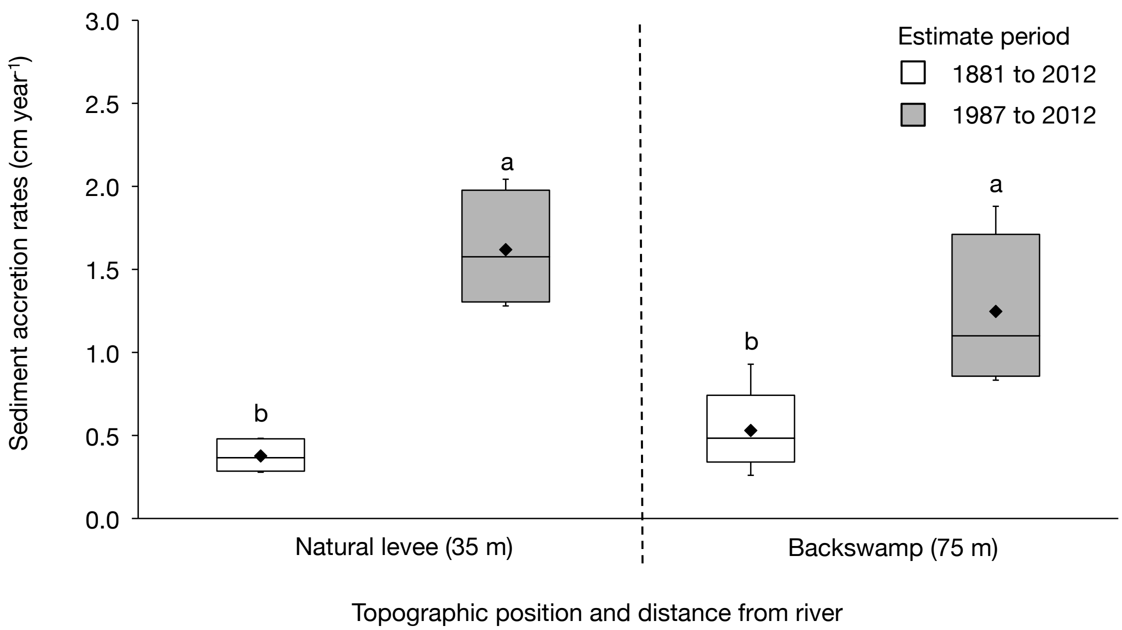

Figure 1—Sediment accretion rates (cm yr^{-1}) estimated using a dendrogeomorphic technique on green ash along a natural levee (35 m from river) and backswamp (75 m from river) adjacent to the Tensaw River. Estimates were derived for different time periods: 1881 to 2012 (tree ages ranged from 60 to 131 years) and 1987 to 2012 (tree ages ranged from 20 to 25 years). Mean estimates are indicated by closed markers. Different letters indicate estimates are significantly at $\alpha = 0.05$ based on Wilcoxon-Mann-Whitney tests.

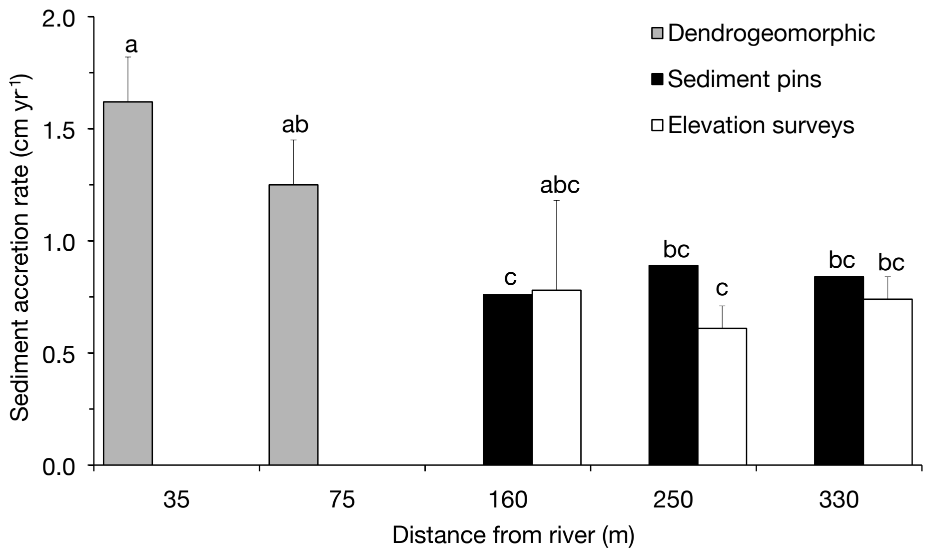

Figure 2—Mean sediment accretion rates (cm yr^{-1}) for the 1987 to 2012 time period as distance from the Tensaw River increased from the natural levee (35 m) across the mature tupelo-cypress backswamp (75 to 330 m) based on dendrogeomorphic estimates, previous sediment pin measurements, and elevation surveys. Different letters indicate estimates are significantly at $\alpha = 0.05$ based on Wilcoxon-Mann-Whitney tests.

75 m (1.2 ± 0.2 cm yr^{-1}; p = 0.036) were significantly higher than sediment pin accretion rate estimates at 160 m (0.8 ± 0.0 cm yr^{-1}). Dendrogeomorphic sediment accretion rates at 35 m were significantly different from sediment pin estimates at 250 m (0.9 ± 0.0 cm yr^{-1}; p = 0.034) and 330 m (0.8 ± 0.0 cm yr^{-1}; p = 0.047). Analysis of the dendrogeomorphic and elevation survey estimates among the same five distances indicated values for at least one distance were significantly different (p = 0.043). Additional pairwise comparisons revealed dendrogeomorphic estimates at 35 m were significantly different from elevation survey estimates at 250 (0.6 ± 0.1 cm yr^{-1}; p = 0.047) and 330 m (0.7 ± 0.1 cm yr^{-1}; p = 0.047). Sediment accretion rates estimated from the dendrogeomorphic technique at 35 and 75 m were higher than the elevation survey estimates at 160 (0.8 ± 0.4 cm yr^{-1}), but were not statistically different (p = 0.250 for both distances) due to an elevated value at the 160 m distance (fig. 2). As expected, dendrogeomorphic sediment accretion rate estimates at 75 m were significantly higher than elevation survey based estimates at 250 m (p = 0.036) but not at 330 m (p = 0.140).

In our study, as distance from the Tensaw River increased, sediment accretion rates for the 1987 to 2012 time period decreased. At our study site, elevation also decreased with increased distance from the river. Trends in sediment deposition with changes in distance from river and elevation both agree (Asselman and Middlekoop 1995, Johnston and others 1984, Kesel and others 1974) and disagree (Hupp and Bazemore 1993, Hupp and Morris 1990, Kleiss 1996) with our results due to differences among studies in site characteristics and connectivity to sediment-laden waters (Hupp and others 2015). Decreased sediment accretion rates at increased distance in our study may have been influenced by the size of particles deposited. Larger particles generally fall out of suspension first, as overbank floodwater velocity decreases (Boto and Patrick 1979). Therefore, particle size could have influenced total vertical deposition values with change in distance from the river. Along the Mississippi River, the percentage of sand (0.063 to 2 mm) particles that were deposited on the natural levee (68 percent) and the levee backslope (47 percent) were greater than in the backswamp (3 percent) (Kesel and others 1974). Smaller silt (0.002 to < 0.063 mm) and clay (< 0.002 mm) particles made up particles in the backswamp than along the natural levee and levee backslope (Kesel and others 1974). Similar findings in the distribution of particles by size have been reported along transects extending from natural levees into backswamps in the Atchafalaya Basin in Louisiana (Hupp and others 2008) and in floodplains along Long Brank Creek in Missouri (Heimann and Roell 2000).

CONCLUSION

Riparian forests have the capacity to trap and store significant amounts of sediment from adjacent waterways. This study used a dendrogeomorphic technique, which minimized visits, to illustrate temporal patterns in sediment deposition. Further, this study identified spatial patterns of sediment deposition; specifically, decreased sediment accretion rates with increased distance from river and decreased elevation. Trends in repeated sediment deposition have numerous implications on successional pathways in riparian forested wetlands. Overall, the dendrogeomorphic technique was effective in supplementing sediment accretion rate estimates derived from sediment pin and elevation survey methods to quantify the amount of sediment being trapped through time and space.

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