SEDIMENT AND CARBON SEQUESTRATION IN THE LOWER ATCHAFALAYA BASIN, LOUISIANA

EXTENDED ABSTRACT


Background: Sediment and organic material sequestration are important ecosystem functions of forested bottomlands along river systems. This is particularly true along Coastal Plain streams in the southeastern United States as they approach tide dominated estuaries (Hupp, 2000; Ensign et al., 2014). Floodplains along these low gradient systems are among the last places for significant trapping and storage of sediment and associated material, including carbon rich organic material, before they reach highly valued, ecologically and economically critical estuarine systems (Hupp, 2000).

The Atchafalaya River Basin (a distributary of the Mississippi River, Fig. 1) contains the largest relatively intact, functioning riparian area in the lower Mississippi Valley. Approximately 25% of the Mississippi River (drainage area about 3,200,000 km²) and all of the Red River (drainage area about 233,000 km²) flows through the Basin on an annual basis. The entire suspended- and bed-sediment load of the Red River and as much as 35% of the suspended and 60% of the bed sediment load of the Mississippi River (Mossa and Roberts, 1990) are now diverted through the Atchafalaya Basin. As a result, the Basin experiences exceptionally high sedimentation rates at sites with high connectivity to the main river (Hupp et al., 2008).

Recent studies have shown that temperate coastal lowlands may be an important sink for carbon (Ludwig, 2001; Raymond and Bauer, 2001; Noe and Hupp, 2005; 2009; Bridgham et al., 2006; Aufdenkampe et al., 2011) and associated nutrients (Hupp et al., 2008; Noe and Hupp, 2009), which may be stored in these systems as organic rich sediment. Initial results (Hupp et al., 2008) suggest that the central Atchafalaya Basin may conservatively trap 6.7 Tg of sediment annually (approximately 15% of total load entering the Basin), of which over 820,000 Mg are organic material. The temperate lowland trapping function or global service has largely been untested and ignored by many models of global carbon flux (Battin et al., 2008; 2009). Studies of lowland fluvial systems such as the Atchafalaya Basin may be critical towards our understanding of global carbon cycling, which in turn has direct implications for nutrient processing and global climate change. Following initial sediment trapping studies by Hupp et al. (2008), we began a spatially expanded (Fig. 1), ongoing study with the objectives to quantify sediment trapping in range of environments including areas of high deposition rates, which may subsequently allow for quantitative estimates of annual carbon sequestration in the Atchafalaya Basin.

Approach: Sediment deposition rates, in both studies, are determined using artificial markers, feldspar clay pads at stations along transects positioned near waterways/bayous. These pads were/are measured annually for deposit thickness above the clay. We monitored 20 transects located in the central part of the Basin in the 2008 study (Fig. 1). We established an additional 16 transects in the lower (downstream) part of the Basin in 2010 (Fig. 1). Like the earlier study,
Transects are located in a range of depositional environments from sites where new land is accreting in previously open river water (exceptionally high deposition rates) to areas identified as potentially low depositional, hypoxic backswamps with poor connectivity to sediment laden river water. Deposition rates were converted to sediment mass trapping rates using bulk density information from sediment samples collected along the transects. Additionally, the samples were analyzed for loss on ignition (LOI) to determine organic content. In the ongoing study, samples are analyzed for carbon, nitrogen, and phosphorus content, including the determination of the amount of carbon isotopes and ratios $^{12}\text{C}:^{13}\text{C}$ and $^{13}\text{C}:\text{N}$ to infer general carbon sources.

Figure 1 Location of study area in Louisiana. Transect locations in the central (red x’s) and southern Atchafalaya Basin (yellow circles) for original and current studies, respectively, are shown.

**Sediment and Carbon Trapping:** The Atchafalaya Basin traps substantial amounts of suspended sediment annually; many areas have some of the highest documented sedimentation rates in forested wetlands of the United States (Hupp, 2000; Aust et al., 2012). Mean sedimentation rates ranged from about 2 to 40 mm y$^{-1}$ in the central part of the Basin (Fig. 2A). Highest sedimentation rates occur in low elevations that receive sediment-laden water (high connectivity) from two or more sources, which may create slow velocities through hydraulic damming (D, E, and F transects, Fig 2A, Hupp et al., 2008). Mean sedimentation rates ranged from about 7 to greater than 150 mm y$^{-1}$ in the actively aggrading lower part of the Basin (Fig. 2B). The highest sedimentation rates in this area are associated with island building in the main waterways and areas that receive water heavily laden with sediment from nearby channel cuts/canals and other hydrologic diversions (LI, HIS, and FLP, Fig. 2B). Low sedimentation rates throughout the Basin may occur on high levees or on low backswamps, both where there is little connection to river water because of high elevation or stagnant, sediment-depleted flow, respectively.
Organic content in recent deposits is influenced by detrital inputs from on-site (in situ) sources (autochthonous) and from off-site material delivered by stream flow (allochthonous) that may be trapped as deposited sediment. Mean percentage organic material (LOI) was just over 10% and 16% in the central and lower parts of the Basin, respectively. This suggests that the Basin is an important area for organic material trapping (>800k Mg organic sediment of which 40% may be carbon) annually in the central Basin alone, Hupp, et al. 2008). The lower part of the Basin, with a higher mean organic content and order-of-magnitude higher maximum deposition rates than the central part of the Basin, undoubtedly traps substantially more organic material (mass estimates

Figure 2 Sediment deposition rates in A, the central Atchafalaya Basin and B, the lower Atchafalaya Basin. Each bar represents the mean rate for named sites (indicated in Fig. 1).
have not yet been calculated). Studies using stable isotope measurements ($\delta^{13}$C, $\delta^{15}$N) have shown that the source of organic material may be identified (Hackney and Haines, 1980; Craft et al., 1988) based on variance in vegetation utilization of C$_3$ versus C$_4$ photosynthetic pathways (forest vegetation-C$_3$, marsh/grass vegetation-C$_4$) and algal uptake of dissolved inorganic C.

Carbon isotope values ($\delta^{13}$C) in the lower part of the Basin suggest that a range of carbon sources exist (Fig. 3). A large portion of Basin deposited carbon is probably allochthonous as 60% of samples have $\delta^{13}$C values that are closer to that of river suspended sediment compared to forest leaf litterfall values. Thus, our results strongly suggest that the Atchafalaya Basin sequesters substantial amounts of allochthonous carbon (from the watershed) in addition to that produced in the Basin and that lowland alluvial areas (e.g. Lower Mississippi Valley) may be important sinks that should be considered in estimates and models of global carbon cycling.

Figure 3 $\delta^{13}$C values of deposited sediment along a gradient of river-water connectivity to floodplain in the southern Atchafalaya Basin. Sites were categorized into seven classes of connectivity, from high (1) to low (7) with connectivity decreasing from left to right along the x-axis. $\delta^{13}$C of allochthonous, riverine suspended sediment ($\alpha$) and autochthonous forest leaf litterfall ($\Omega$) are included as potential end-members of organic sediment sources.

REFERENCES


