OPTIONS FOR RIPARIAN BUFFER TREE PLANTING IN NORTH ALABAMA

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ABSTRACT

We worked with private, State, and Federal agencies to examine one approach of habitat restoration of degraded riparian zones along active agriculture fields in northern Alabama. We wanted to determine which species of high-value timber trees would grow exceptionally well using artificial regeneration (planting) and semi-intensive silviculture (tending activities for competition control). We also examined sediment transport from each block of species to ascertain which blocks provided the highest level of protection to minimize non-point source pollution. We planted eight species, including black walnut (*Juglans nigra*), yellow-poplar (*Liriodendron tulipfera*), green ash (*Fraxinus pennsylvanica*), sweetgum (*Liquidambar styraciflua*), Shumard oak (*Quercus shumardii*), Nuttall oak (*Q. nuttallii*), cherrybark oak (*Q. pagoda*), and loblolly pine (*Pinus taeda*) at two locations. A sediment barrier was used to capture sediment movement off each tree species planting block. After 10 growing seasons, survival across all blocks averaged 78 percent. Loblolly pine was the tallest (34.1 feet) and had the greatest diameter (7.4 inches), followed by green ash. Black walnut had the lowest survival and growth. Over a 5-year period, sediment deposited was related to precipitation, with more sediment in December compared to June for all areas.

INTRODUCTION

Planting trees for profit is common in the South. Planting hardwood trees for profit has a more complicated history, with large-scale restoration and afforestation efforts common in areas such as the Mississippi Alluvial Delta region (Allen 1997, Stanturf and others 1998) and smaller efforts concentrated on private land holdings. Federal and State cost share and assistance programs, including the Environmental Quality Incentives program, Wildlife Habitat Incentives program, and the Wetland Reserve program all support tree planting programs to increase timber production returns and provide environmental benefits (Kennedy 1990). Restoring, enhancing, and maintaining forested riparian zones continues to be of interest to landowners and managers, as these often small but influential areas provide myriad ecosystem functions, including providing a buffer zone that filters sediments and nutrients and potential income from tree harvests (Richardson and others 2007).

We developed case studies and demonstration sites to examine tree planting in areas adjacent to a river that was abutted by cultivation for crops. Although originally designed with three sites, one site experienced tampering that negated its inclusion. These two case studies were designed to assess survival and growth of commonly planted species for riparian areas and to examine natural restoration under no planting scenarios. We also tested the use of sediment barriers to quantify the amounts and change of sediment movement from planted and control areas.

METHODS

Demonstration Sites

Two sites located along the Flint River in northeastern Alabama, Madison County, were used (fig. 1). The northern site, Hazel, was located on the Alabama A&M University's Winfred Thomas Agricultural Research Station and the southern site, Gurley, was located on private landowner property. Both sites have been in various row cropping uses for over 50 years. The Hazel site had two mapped soil series, Abernathy silt loam and Baxter clay loam (Soil Survey Madison County Alabama 1958). Abernathy silt loam is young, local alluvium soil that is the most extensively mapped soil type in Madison County, Alabama. It occurs in narrow strips or bands along drainages and is high in fertility and moisture availability. Baxter clay loam has low fertility and moderate internal drainage. At the Gurley site, most of the soil was Lindside clay loam, alluvium derived from limestone with some sandstone and shale, making it moderate in fertility with productivity limited by slow internal drainage. Lindside is the most extensive soils of first bottoms and occurs along many streams in Madison County, Alabama. The other Gurley soil type was Tyler sandy loam, which is poorly drained with low fertility that is

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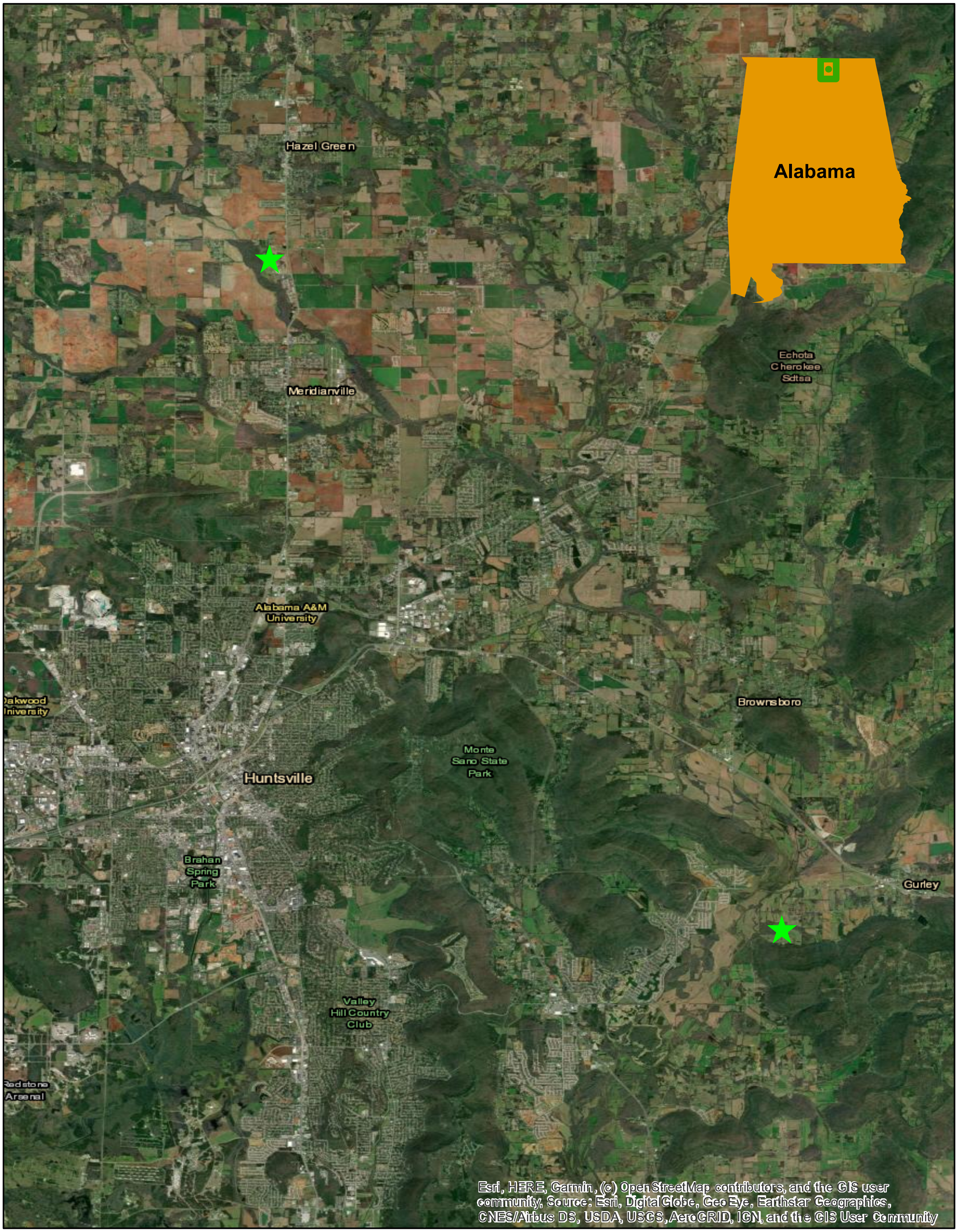

Figure 1—Map of riparian planting sites in Madison County, Alabama. Green stars indicate location of sites, referred to as Hazel (north) and Gurley (south).

mainly under native deciduous forest cover. At each site, the plantings were located between row cropped fields and the Flint River.

Tree Species, Planting Methods, and Measurements

We delineated 10 planting areas that were approximately 0.1 acres each. All planting areas were disked prior to winter 2003 planting, except for one, undisked control. We also had a disked control that was not planted. Eight tree species were tested. These species were chosen based on recommendations from the Alabama Forestry Commission and local forestry consultants and were purchased from ArbonGen (https://www.arborgen.com/hardwood-seedlings-for-revenue-generation). Tree species planted included black walnut (*Juglans nigra* L.), yellow-poplar (*Liriodendron tulipfera* L.), green ash (*Fraxinus pennsylvanica* Marsh.), sweetgum (*Liquidambar styraciflua* L.), Shumard oak (*Quercus shumardii* Buckl.), Nuttall oak (*Q. nuttallii* Palmer), cherrybark oak (*Q. pagoda*Raf.), and loblolly pine (*Pinus taeda* L.). All seedlings were 1-0 bareroot. Seedlings were planted with shovels by a crew of three people in February 2003. Fifty-four seedlings were planted in each area at a 9 x 9-foot spacing. Planted areas were weeded mechanically using a brushcutter with either a line or saw blade in 2003, 2004, and 2005.

Each seedling was assessed for survival and health status (any noticeable damage was recorded) following each growing season from 2003 to 2012. We used calipers to measure basal diameter to the nearest 0.01 inch immediately after planting, and then following each growing season. If trees reached 6 feet in height, we then measured diameter at breast height (d.b.h., measured at 4.5 feet above ground level) using a diameter tape, to the nearest 0.1 inch. Seedling heights were measured with a height pole to the nearest 0.1 foot.

Sedimentation Estimation

We used a ditch witch to create a 12-inch furrow around each of the 10 areas. We installed aluminum flashing in these furrows and connected the flashing to a sheet-metal gutter that was the only outlet for any sediment flow from each area (Carter 2013). Attached to each gutter using metal clips was a felted fabric bag, approximately 18 x 22 inches in which deposited sediment was captured. Bags were weighed prior to field installation, collected monthly, oven dried at 221 ^{0}F for 48 hours, and then reweighed to obtain an estimate of deposited sediment. An Onset RG3 HOBO data logging rain gauge was installed on a specially built wooden platform at each site (Onset Corporation, Cape Code, MA) and data was downloaded bi-monthly. Deposited sediment was collected from 2004 through 2009.

Statistics

Sites were analyzed separately and considered fixed. We used analysis of variance to determine differences among survival, diameter growth and height growth, as well as deposited sediment amounts, all random variables. If significant differences were found, Duncan's Multiple Range Test was performed post hoc to measure specific difference among means. All analyses were performed in SAS PROCMIXED in SAS 9.4 (SAS Institute 2013).

RESULTS

Tree Survival and Growth

Survival after 10 years was higher at the Gurley site at 91.7 percent compared to the Hazel site at 64.4 percent. At the Gurley site, survival ranged from 100 percent for green ash to 75.9 percent for black walnut (fig. 2). Green ash also had the highest survival at the Hazel site at 92.6 percent and yellow-poplar had the lowest survival at 14.8 percent (fig. 2). After one growing season, there were no differences in survival by species at each site. By 2012 at the Gurley site, green ash had significantly greater survival compared to Shumard oak, loblolly pine, and black walnut ($F_{6,33}$, P<0.0001). At the Hazel site, three groups of survival emerged ($F_{21,37}$, P<0.0001) with green ash, loblolly pine, Nuttall oak, and Shumard oak greater than black walnut, sweetgum, and cherrybark oak, and all were greater than that of yellow-poplar.

At the time of planting, seedlings at the Gurley site had root-collar diameters that ranged from 0.42 inches for green ash to 0.18 inches for cherrybark oak. Nuttall oak and yellow-poplar root-collar diameters were 0.31 and 0.29 inches, respectively, with the remaining seedlings at 0.20 inches. After 10 growing seasons, some seedlings were large enough to record d.b.h. and some were not. For the seedlings with a root-collar diameter, green ash seedlings were the largest at 2.10 inches, followed by Shumard oak (2.04 inches), cherrybark oak (1.70 inches), and black walnut (1.69 inches). There were significant differences in the d.b.h. of trees at the Gurley site ($F_{70,81}$, P<.0001), and they were separated into four distinct groups. The largest diameter trees were loblolly pine (7.9 inches) followed by sweetgum (4.3 inches). The third group contained yellow-poplar (3.5 inches), Nuttall oak (3.5 inches), green ash (3.2 inches), and cherrybark oak (3.2 inches). The smallest diameter was for Shumard oak at 2.2 inches d.b.h.

Hazel site seedlings also had a range of root-collar diameters at planting, from 0.38 inches for green ash to 0.18 inches for Shumard oak. Root collars were not significantly different for the five trees with measurements for root collar at year 10 (i.e., not large enough to have d.b.h.) ($F_{1,30}$, P=0.2784). Three species—loblolly pine, green ash, and yellow-poplar—had trees large enough to have only d.b.h. measurements. At year 10, d.b.h. was significantly different among species ($F_{6,99}$,

$P<0.0001$), with loblolly pine (6.8 inches) greater than all others except cherrybark oak (5.14 inches). Cherrybark oak d.b.h. did not differ from the remaining species, green ash (3.3 inches), black walnut (2.8 inches), Nuttall oak (2.6 inches), Shumard oak (2.4 inches), and yellow-poplar (2.2 inches).

Seedling height varied greatly among species. For both sites, green ash seedlings were the tallest at the time of planting at 2.4 feet tall, and loblolly pine seedlings were the shortest, at 1.0 foot tall. The remaining seedlings averaged 1.4 feet tall at planting, except black walnut, which was 2 feet tall. After 10 years loblolly pine was significantly taller than all other species at both sites, 33.7 feet tall at the Hazel site ($F_{161.31}$, $P<0.0001$) and 34.5 feet tall at the Gurley site ($F_{160.65}$, $P<0.0001$). At the Hazel site, green ash and sweetgum ranked second in height (23.8 feet and 22.5 feet), and Nuttall oak was the shortest (9.3 feet). At the Gurley site, sweetgum (28.6 feet) and yellow-poplar (27.9 feet) ranked second in height, and black walnut was the shortest (8.1 feet). Although we did not make comparisons among sites, there were some interesting trends (fig. 3). Nuttall oak, cherrybark oak, Shumard oak, and yellow-poplar had greater height on the Gurley site, and black walnut and green ash were taller on the Hazel site compared to the Gurley site.

In the control sites that were disked but were not planted and did not receive any weed control, we tallied 15 species on the Hazel site and 17 on the Gurley site. Eight of these

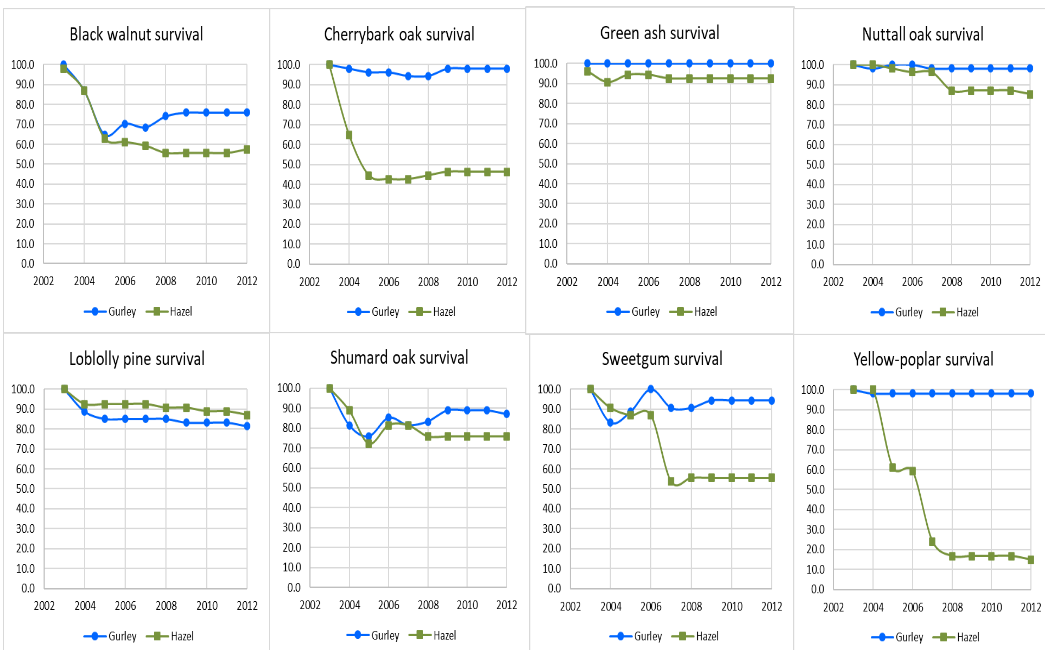

Figure 2—Tree survival over 10 years for eight species planted in two riparian areas in Madison County, Alabama.

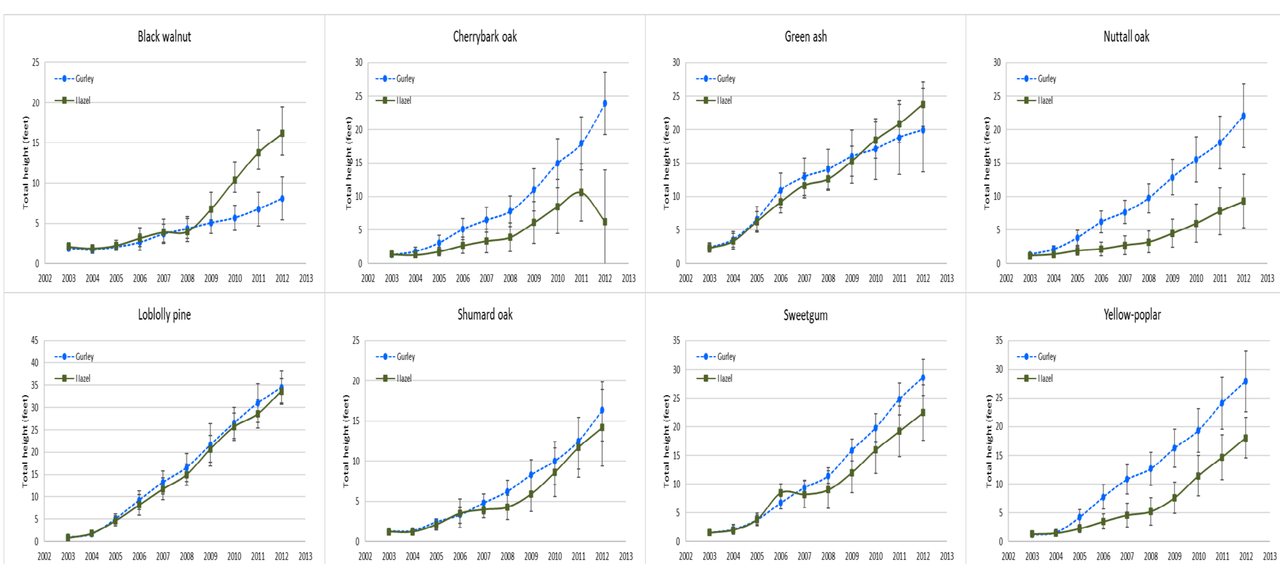

Figure 3—Total tree height over 10 years for eight species planted in two riparian areas in Madison County, Alabama.

species were found on both sites, including black cherry (*Prunus serotina* Ehrh.), boxelder (*Acer negundo* L.), Eastern redcedar (*Juniperus virginiana* L.), privet (*Ligustrum vulgare* L.), red maple (*A. rubrum* L.), sweetgum, water oak (*Q. nigra* L.), and winged elm (*Ulmus alata* Michx.). In 2012 on both sites, the majority of the volunteer trees were greater than 4 feet tall but less than 1.5 inches d.b.h. Volunteer woody species in this predominant size class had densities of 850 stems per acre (SPA) out of a total 1,358 SPA on the Hazel site and 1,775 SPA out of a total of 2,233 SPA at the Gurley site. By species for stems greater than 4 feet tall but less than 1.5 inches d.b.h., privet (242 SPA), winged elm (175 SPA), and sweetgum (142 SPA) had the highest densities at the Hazel site, and red maple (1,175 SPA) and green ash (117 SPA) had the highest densities at the Gurley site. Trees that were greater than 1.5 inches d.b.h. included Eastern redcedar (83 SPA) and winged elm (50 SPA) at the Hazel site, and red maple (83 SPA) and sycamore (*Platanus occidentalis* L.) (83 SPA) at the Gurley site. Species unique to the Hazel site included hophornbeam (*Ostrya virginiana* K. Koch.), black oak (*Q. velutina* Lamarck), *ilex* spp., pignut hickory (*Carya glabra* Sweet), scarlet oak (*Q. coccinea* Muench.), willow oak (*Q. phellos* L.), and yellow-poplar. Species unique to the Gurley site included flowering dogwood (*Cornus florida* L.), green ash, honeylocust (*Gleditsia triacanthos* L.), persimmon (*Diospyros virginiana* L.), plum (*Prunus americana* Marsh.), slippery elm (*U. rubra* Muhl.), sycamore, and winged sumac (*Rhus copallina* L.).

Precipitation and Sediment Movement

We measured precipitation on each site from 2003 until 2009. For the Gurley site, total annual precipitation amounts, ranked from highest to lowest were 2009 (67.2 inches), 2004 (64.3 inches), 2003 (61.3 inches), 2008 (48.6 inches), 2005 (45.6 inches), 2006 (37.5 inches), and 2007 (22.3 inches). Over these 7 years, December was the wettest month (averaged 6.3 inches), and June was the driest (3.0 inches). We had rain every month of the year during the 7 years that data were collected except March 2007. At the Hazel site, total precipitation amounts were (highest to lowest): 2004 (61.2 inches), 2009 (59.4 inches), 2003 (53.8 inches), 2008 (51.1 inches), 2005 (35.8 inches), 2006 (31.8 inches), and 2007 (28.2 inches). Rain was recorded every month over the 7-year period, and the wettest month was December (averaged 5.9 inches), and the driest month was June (2.8 inches).

The amount of deposited sediment from each area was heavily influenced by precipitation. June consistently had the lowest accumulated sediment and December had the highest. The amount of sediment collected over the 4 years of the study remained consistently related to precipitation. For example, at the Hazel site the most sediment was collected in the wettest year of 2004 (average of 53.77 grams across all areas) and the least was collected in the driest year of

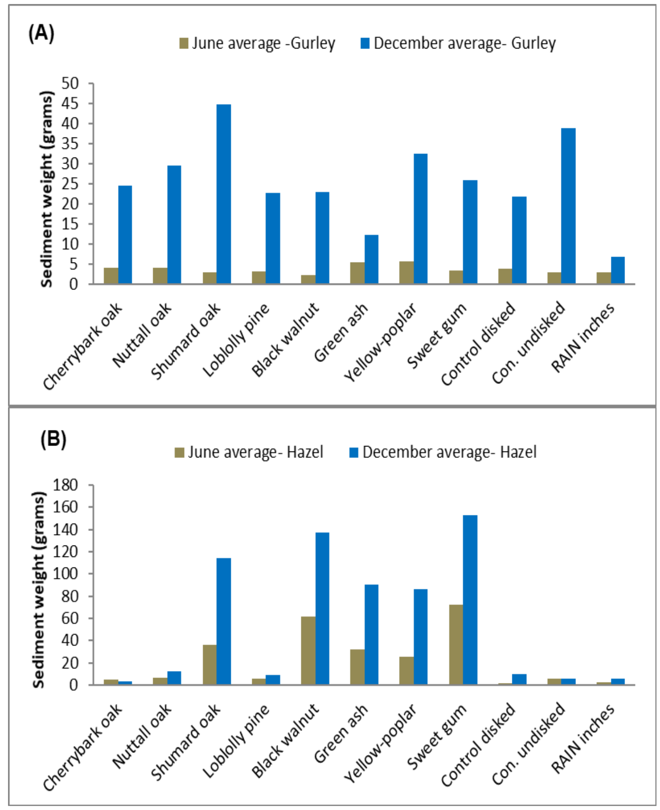

Figure 4—Average deposited sediment weights collected from two sites planted with eight different species and two unplanted control areas, one disked at the time of planted and one left undisturbed (A) Gurley site; (B) Hazel site. Data presented for 2 months that represent the average highest precipitation (December) and lowest (June) from 2004 to 2009.

2007 (5.29 grams). Damage to the sampling areas ended our collection after 6 years. For both June and December, the sediment deposited on the bags from all planted areas was higher at the Hazel site (30.68 grams in June and 75.59 grams in December) compared to the Gurley site (3.88 grams in June and 26.87 grams in December). At the Gurley site, more sediment was collected from Shumard oak, black walnut, green ash, yellow-poplar, and sweetgum planted areas (fig. 4A) in both June and December. There were no discernable trends in the sediment deposited by area (planted or controls) at the Hazel site (fig. 4B).

DISCUSSION

Demonstration areas allow landowners and practitioners to observe management practices. Planting marginal agricultural lands with hardwood species continues to be of interest to landowners, and this case study was designed to examine species success on specific sites, as well as attempting to quantify potential ecosystem benefits related to control of sediment movement. We solicited input from foresters in species selection, obtained seedlings from a local commercial nursery, and used common planting and tending methods. Predicting which species would provide maximum profit at some future date is unreliable, but all species planted have commercial value that fluctuates with changes in markets and consumer demand. Exports of important eastern hardwoods includes oaks, ashes, and walnut, supporting the inclusion for this assessment (Luppold and Bumgardner 2021). An extensive history of planting loblolly pine in the South supports its inclusion (Zang 1998).

We had high survival rates for most species on the Gurley site, from a low of 76 percent of black walnut to a high of 98–100 percent for green ash, Nuttall oak, cherrybark oak, and yellow-poplar. We also had high growth on this site, with an increase of almost 20 feet of height growth for Shumard oak, green ash, and Nuttall oak, and over 21 feet of growth for cherrybark oak, yellow-poplar, sweetgum, and loblolly pine. On the Hazel site, both green ash and Nuttall oak had high survival, but only green ash displayed good growth, increasing by almost 22 feet in height. Nuttall oak seedlings grew much more slowly at the Hazel site, increasing by 8 feet in 10 years. The selection of these bottomland species was aligned with natural species-site relationships. Green ash is common on both major and minor bottoms, and is successionally replaced by sweetgum, Nuttall oak, cherrybark oak, and Shumard oak, depending on elevation and successional stage. Yellow-poplar can be found on better drained bottoms (Hodges 1997). These single-species plantings were an initial step in creating restoration demonstration sites for landowners to observe. Following these preliminary results, a next phase would be to examine mixed species plantings with those species deemed most desirable (Lockhart and others 2008).

Black walnut only increased by 3.8 feet, and that coupled with low survival are indicative of unfavorable suitability to this site. A desire to plant black walnut may be predicated on the idea that, black walnut trees, when planted to maximize tree growth, can grow as much as 3 to 4 feet per year in good soil, reaching a mature height of over 100 feet and 30 to 40 inches in diameter, with 16-inch diameter saw logs ready to harvest in 30 years. However, the area of greatest commercial importance for the species is limited to the central part of its range, particularly the States of Missouri, Iowa, Illinois, Indiana, Michigan, Ohio, West Virginia, Kentucky, and Tennessee (Landt and Phares 1973). Black walnut is sensitive to soil conditions and develops best on deep, well-drained, nearly neutral soils that are generally moist and fertile (Brinkman 1965). Walnut has best growth in its natural range along streams. Other benefits of including black walnut include both promoting biodiversity and producing mast for wildlife, and its inclusion in mixed plantings for alternative benefits may be considered. The Hazel site also had low black walnut survival and growth.

Yellow-poplar survival was low on the Hazel site, with only eight seedlings surviving. They grew 17 feet in 10 years, compared to 98 percent survival at the Gurley site with 27 feet of height growth. Both sweetgum and cherrybark oak had low survival at the Gurley site and surviving sweetgum seedlings grew 20 feet and cherrybark oak seedlings only grew about 12 feet in 10 years.

Green ash, Nuttall oak, and loblolly pine experienced high survival and growth on both sites. Planting green ash is questionable given that the emerald ash borer (EAB) (*Agrilus planipennis*) has killed millions of ash trees in the Eastern United States. The remaining regeneration cohort is often not in competitive recruitment positions, hence green ash fate remains uncertain (Siegert and others 2021). However, establishing green ash in riparian plantings may be one way to safeguard this species, especially in areas of none to low EAB invasion, and these trees may also serve a future seed source.

We tried to quantify potential sediment deposition as a surrogate for erosion mitigation impacts under different species plantings. Because our design did not measure actual runoff (water), we were left to examine some general trends. Unfortunately, damage to our sampling system truncated our study. We found that there were differences among sites and species, but all were related to the amount of precipitation. We were unable to explain the small amount of collected sediment from the Hazel control site, which was not found on the Gurley site. Both sites had high levels of volunteer species and were quickly colonized by woody species.

Removing the main disturbance (soil cultivation for agriculture) allowed these sites to colonize with many native species, and one non-native invasive. While invasive privet plants can develop into dense thickets, competition with other fast-growing volunteer trees may diminish this response. Desirable timber species, such as the oaks, were part of the volunteer cohort, but not in sufficient numbers to result in a fully stocked stand and thus potential to provide future timber revenue would be low. These demonstration sites allowed us to examine restoration techniques that are commonly used by landowners. Planting desirable tree seedlings in these riparian areas will result in stocked stands as survival is generally high, especially for loblolly pine, green ash, and Nuttall oak. Future management that addresses tree density, tree form, and other issues, such as non-native invasive species will be needed.

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