The Benefits and Costs of Reforesting Economically Marginal Cropland:

The Case of the Mississippi Delta

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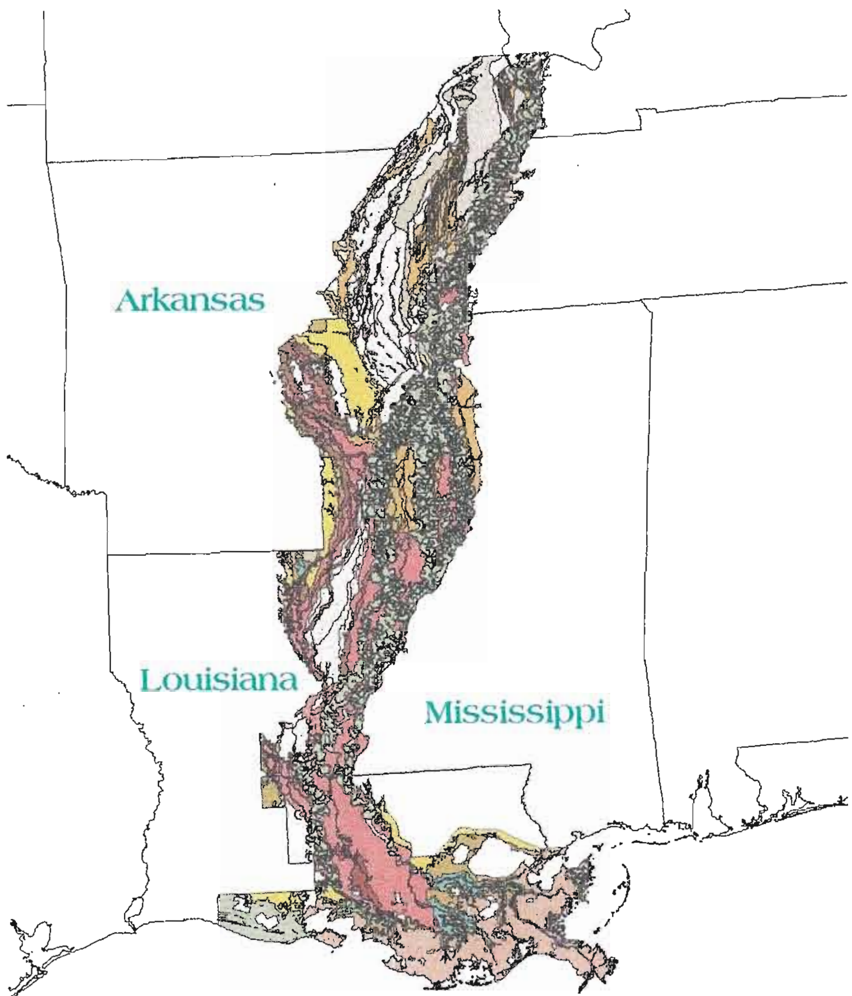

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1. Introduction

Since the 1800s, millions of acres of the swamplands and bottomland hardwood forests that originally covered the area of the Mississippi River flood plain, known as the Delta (Figure 1), have been cleared, drained, and cultivated in corn, cotton, rice, soybeans and other crops. Initially, clearing occurred on lands at higher elevations that were comprised of loamy, well-drained soils. With time, however, clearing progressed to the bottomlands and farmers began to cultivate heavier clay soils that were prone to saturation, slow to dry and of lower potential productivity. These lower elevation fields were particularly susceptible to flooding occurring in the spring and early summer along with the springtime flows of the Mississippi River and its tributaries.

Flooding and soil saturation proved to be significant deterrents to expanding agricultural production. Late spring flooding delayed the planting of crops, resulting in reduced yields or requiring the substitution of a lower-value, later-planted crop. Damages also occurred when flooding destroyed a crop in the field, resulting in a complete loss or requiring the farmer to incur the additional costs of replanting the crop.

Substantial private and government investments have been made in the Delta to reduce agricultural flood damage.[1] Over time, a network of levees, floodgates, diversion channels and other flood control structures have been constructed to prevent the inundation of agricultural fields as well as prolonged periods of soil saturation by minimizing flood elevation and expediting the drainage of flooded fields. While this complex system of flood control structures provided partial protection to some agricultural land, frequent flooding remained a persistent problem in the lower elevations. Nonetheless, clearing of bottomlands for agricultural cultivation continued up through the 1960s and '70s, (even in the most flood prone areas,) encouraged in part by market conditions and government agricultural policies.[2]

An examination of 1989-1999 data in the National Agricultural Census database (USDA 1999) shows how many acres of farmland in the Delta, in any given year, may currently be affected by late floods. By comparing acres planted to acres harvested in soybean, we can roughly judge the number of acres that failed or where crop yields were too low to harvest profitably (McMaster, personal comm.) due primarily to flooding, droughts, or market conditions.[3] Our analysis showed that only a small percentage of farmland in counties lying completely within the Delta remains unharvested after being planted. On average, the number of

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[1] Initially, local drainage districts provided floodwater control structures and channel enlargements to facilitate on-farm drainage systems. Starting in the 1930s, the United States Army Corps of Engineers took on a leading role in the construction of projects to prevent flood damages to existing agricultural activity and to aid in the conversion of wetlands to agricultural production.

[2] In the late 1960s and early 70s, the price of soybeans was quite high, in real terms, relative to current day soybean prices. In 1976, the average annual price per bushel was $6.81. At other times, prices were even higher: $10.00 per bushel in June 1973, $8.99 per bushel in August 1973, $9.05, $9.24 and $8.13 per bushel in April, May and June of 1977 respectively. By contrast, in 1998, the US price for soybeans was $5.30/bu. Consider these prices in real (i.e. inflation-adjusted) terms: the annual price of $6.81 in 1976 would be $17.75 in 1998 dollars (using the GNP implicit price deflator forecasts from WEFA, 1996).

[3] Based on conversation with Larry McMaster, USDA Farm Service Agency, Federal Crop Insurance Corporation, MS.

acres planted not harvested within all Delta counties (Figure 2) was 3,000 acres/year/county for the ten-year period from 1989-1998. The total acreage for individual years ranged from 50,000 in 1994 to 190,000 in 1989. These acreages were typically 1-8% of planted acres within a county and averaged 3% of planted acres over all Delta counties in all years (Table 1). During the ten-year period analyzed, two meteorological events of note were widespread flooding in 1993, and a drought in 1989. The effect of the 1988-89 drought is readily apparent in the yield data for 1989. The 1993 flood does not appear to have resulted in a high rate of failed acres in 1993, but heavy June rains that preceded the flood may have prevented planting on economically marginal farmland (EMF).

Starting in the late 1970s through to present times, however, changes in agricultural market conditions and national agricultural policies began to diminish the profitability of agricultural production on frequently flooded lands and curbed incentives to convert bottomland forests to farmland (Shabman and Zepp 2000, pg. 25). At the same time, recognition was growing for the many environmental services provided by forested wetlands, including wildlife habitat, water quality maintenance, carbon sequestration and floodwater retention. These changes motivated an interest in restoring these frequently flooded areas to their former forested conditions.

A 1997 study (Amacher, et al.) reported that the reforestation of frequently flooded agricultural fields in the Mississippi Delta might not only offer the environmental benefits associated with forested wetlands, but also might provide financial returns to private landowners that are on par with returns currently earned producing soybeans. That study considered several possible revenue sources from reforestation, including the net returns to the sale of timber and pulpwood, the sale of hunting leases, payments from government programs such as the Wetlands Reserve Program (WRP) and payments for environmental services, such as carbon sequestration and the retention of nutrient-laden runoff.

In light of these possibilities, the objectives of this project are to:

- identify the extent of frequently flooded agricultural lands in the Delta area where reforestation is most likely to generate both financial and environmental benefits.
- examine the extent of the possible financial benefits that could be earned by landowners who reforest the lands identified, and
- determine the extent of possible ecological benefits generated by reforestation of the lands identified, including increased wildlife habitat, reduced nutrient runoff, floodwater retention and carbon sequestration.

2. Project Procedures

1. Determine what features characterize EMF in the Mississippi Delta and define spatial variables for identifying EMF.

2. Use the spatial variables and other available data regarding landcover and land attributes to provide an estimate of the total acreage and location of lands that meet these criteria.

3. Develop estimates of the per acre financial returns that landowners could earn by reforesting land under four different forestry scenarios: nuttall oak, seeded nuttall oak, cottonwood and cottonwood - nuttall oak interplanted.

4. Develop estimates of the ecological benefits of reforesting the EMF identified, including increased wildlife habitat, reduced nutrient runoff, floodwater retention and carbon sequestration.

3. Establishing Criteria for Identifying EMF

3.1. Features of EMF

For the purposes of this project, EMF are considered to be fields that are located in bottomland areas and subjected to frequent flooding or soil saturation that results in diminished returns to agricultural production. Generally, agricultural fields with these characteristics are planted to soybeans. Soybeans can be planted later in the season than most other crops and are better suited to the heavy, clay soils than are crops such as cotton or corn.

In this study, a market land value of $400/acre is assumed to be the threshold value for identifying EMF (Black et al. 1997). This means land that would be valued at $400/acre or less is likely economically marginal. Market values for agricultural land can be approximated by capitalizing the average annual net returns earned on the land.[4] The average annual net returns to soybean production are influenced by a variety of features, including flooding regime, production costs, flood-free soybean yields, and the rate used to discount future returns. In order to examine the range of economic and physical features that EMF, the tables below report estimated average annual returns per acre to soybean production under differing assumptions about soybean yields, production costs and discount rates. The estimates of average annual net returns are calculated by a simulation model designed to calculate soybean returns in a two-year flood plain, that is, land with a 50% chance of being flooded in any given year.[5] In calculating average annual net returns, the simulation model accounts for the effects of flooding on annual production costs and harvested yield.

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[4] The market value of these frequently flooded lands is based primarily on the potential income generated by agricultural production, because there is little prospect of development or other forms of land use. This means the market value of the land can be approximated by capitalizing the average annual net returns earned on the land. Capitalizing the net returns requires dividing the average annual net returns by the interest rate.

[5] The simulation model used to calculate agricultural and forestry returns is a modified version of a previous simulation model initially described in a 1997 report published by the Virginia Tech Water Resources Research Center, "Restoration of the Lower Mississippi Delta Bottomland Hardwood Forest: Economic and Policy Consideration" (Amacher, 1997). The simulation model was further refined in a 2000 report prepared by Shabman and Zepp, in cooperation with EPA, Region 4, "An Approach for Evaluation Nonstructural Actions with Application to the Yazoo River (Mississippi) Backwater Area" (Shabman and Zepp, 2000). For the purposes of this report, further adjustments were made to the simulation model, primarily to update prices and costs to current day values and to use the most recent projections available.

Table 2. Net Soybean Returns and Approximate Land Values with a flood-free yield of 30 bushels/acre and 7% Discount Rate

	Average per acre annual returns	Approximated Land Value (Annual Returns Capitalized at 7%)
Mississippi	$33.61	$480.14
Louisiana	$56.53	$807.57
Arkansas	$28.25	$403.57

*Results are inflation adjusted and expressed in year 2000 dollars

Table 3. Net Soybean Returns and Approximate Land Values with a flood-free yield of 25 bushels/acre and 7% Discount Rate

	Average per acre annual returns	Approximated Land Value (Annual Returns Capitalized at 7%)
Mississippi	$7.74	$110.57
Louisiana	$30.40	$434.28
Arkansas	$2.19	$31.28

*Results are inflation adjusted and expressed in year 2000 dollars

Table 4. Net Soybean Returns and Approximate Land Values with a flood-free yield of 25 bushels/acre and 4% Discount Rate

	Average per acre annual returns given 2-year flood frequency	Approximated Land Value (Annual Returns Capitalized at 4%)
Mississippi	$8.24	$206.00
Louisiana	$30.72	$768.00
Arkansas	$3.01	$75.25

*Results are inflation adjusted and expressed in year 2000 dollars

3.2. Establishing Criteria for Identifying EMF

The land value estimates reported in Tables 2, 3 and 4 above suggest several possible criteria for identifying the EMF in the Delta, including:

1. **Fields planted to soybeans.** Many of the Delta's lower-elevation, frequently flooded agricultural lands were initially cleared to be planted to soybeans in the 1960s and '70s in

response to elevated soybean prices. Often, these lands remained in soybeans, even after prices moderated because of the constraints presented by flooding and poorly drained, clay soils. Soybeans can be planted later in the cropping season than most other crops, making them best suited crop to plant on fields that remain flooded through spring and early summer.

2. **Land cleared between 1960 and 1980.** For the reasons discussed above, much of the land clearing in the Delta between 1960 and 1980 was occurring in response to a sustained period of high soybean prices in real terms, relative to current day soybean prices. In 1976, the average annual price per bushel was $6.81. At other times, prices were even higher $10.00 per bushel in June 1973, $8.99 per bushel in August 1973, $9.05, $9.24 and $8.13 per bushel in April, May and June of 1977 respectively. By contrast, in 1998, the US price for soybeans was $5.30/bu. Consider these prices in real (i e. inflation-adjusted) terms: the annual price of $6.81 in 1976 would be $17.75 in 1998 dollars (using the GNP implicit price deflator forecasts from WEFA, 1996). The unusually high soybean prices, in combination with federal policies designed at the time to encourage clearing and draining wetlands for cultivation, made the clearing of bottomland areas for soybean production appear profitable to landowners. Under this special combination of market conditions and government policy, many frequently flooded forested bottomland areas that were previously considered worthless for agricultural production were cleared and cultivated in soybeans.

3. **Fields in the 2-year flood plain.** Land falling within the 2-year flood plain has a 50% chance of flooding in any given year. This high risk of flooding means that any type of agricultural activity also stands a good chance of incurring some type of damages in any given year that would diminish the expected net returns to production. Such damages would include reduced yields from planting after the optimal planting date and/or outright plant mortality.

4. **Fields producing a flood-free soybean yield of 25 bu/ac or less.** As is reported in Tables 2, 3 and 4 above, the simulated annual agricultural returns for Mississippi and Arkansas, at an assumed flood-free yield of 25 bu/acre, produced approximate land values that were consistently less than $400/acre, regardless of the production costs or discount rates applied. Only the annual returns calculated using production budgets for the state of Louisiana produced land values that exceeded the $400/acre threshold.[6] In comparison, at 30 bu/ac and a 7% discount rate, approximate land values for all three states exceeded the $400 threshold, ranging from $404 -$808/acre. From the results of the simulation model, 25 bu/ac seems to represent the flood-free yield that best identifies economically marginal farmland under a wide range of different production costs and discount rates.

It is important to note, however, that the flood-free yield selected as the threshold yield for identifying potentially marginal farmland, is sensitive to several economic variables, including the price of soybeans and production costs. The agricultural returns reported in this

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[6] The annual costs of soybean production represented in the Louisiana State budget were approximately $24 less than the annual costs reported in the Mississippi budget, and $29 less than the annual costs reported in the Arkansas budget. Calculating the NPV of these annual cost differences over the 120-year period of analysis at 7%, adds up to a difference of approximately $338 dollars between the NPV of the Louisiana and Mississippi production costs and $418 dollars between the NPV of Louisiana and Arkansas production costs. The NPV of these costs differences almost entirely account for the differences between the annual net returns and approximated land values reported for Louisiana at a flood-free yield of 25 bu/ac, as compared to the annual net returns reported for Mississippi and Arkansas.

analysis assume a current price of $5.31/bu and project a slow decline in prices to $4.87 in the year 2008 (Shabman and Zepp, 2000). Under these price assumptions, the annual equivalent agricultural returns calculated at a 30 bu/ac flood free yield for the state of Mississippi ($33.61/acre, as reported in Table 2), produced a capitalized land value that exceeded the $400/acre threshold used for defining potential EMF. If, however, these assumed prices were to overestimate actual current and future soybean prices by even 75 cents, net returns to soybean production would decrease by a net present value of $119/acre (from an NPV of $480/acre to $361/acre). The new net present value of $361/acre produces an annual equivalent value of $25.26 acre. When capitalized at a 7% rate, $25.26 equals an estimated land value of $361/acre, falling short of the $400/acre threshold defining EMF. In this particular instance, a 30 bu/ac flood-free yield would serve as an accurate indicator of EMF, rather than the 25 bu/ac threshold used in this analysis.

Just as soybean prices could prove to be lower than those used in this analysis, future prices could also run higher than projected. In this case, average annual net returns produced at a flood-free yield of 25 bu/ac might be sufficiently high to produce an estimated land value in excess of the $400/acre threshold. Similarly, significant variations in actual current or future production costs from those used in this analysis could have the effect of changing the appropriate flood-free yield for identifying EMF. At the time of the analysis described in this paper, the 25 bu/acre threshold was selected using the best information available concerning current and future production costs, soybean prices and other relevant economic variables.

5. **Fields that are typically flooded through late May or early June.** The optimal planting period for soybeans lasts through June 15th throughout most of the region, although optimal planting dates may end by June 1 in parts of the study area found in northern Arkansas. Soybeans rely on the length of day to initiate flowering. This means that soybeans planted after the planting period are exposed to shorter days before they are fully matured, resulting in early flowering and reduced yields. Additionally, late-planted soybeans tend to have underdeveloped root systems and are vulnerable to drought. In order to plant within the optimal period for soybeans, floodwaters must have receded from a field, and up to ten additional days are required to allow the field to dry out sufficiently to support farm equipment. This means that the timely planting of soybeans will be prevented on fields that tend to remain flooded through late May or early June. Soil data (STATSGO) are available from the USDA that characterize the typical *flood end date* as the, "month in which annual flooding (flooding likely to occur during the year) ends in a normal year" (USDA NRCS 1995).

6. **Fields comprised of hydric soils with high clay content.** Soils found in the sumps and basins that comprise the bottomland areas of the Mississippi Delta are generally hydric soils with high clay content. USDA soil data (STATSGO) include soils rated as hydric.

4. Determining Total Number of Acres and Geographic Location of Lands Suited for Reforestation

This section addresses Task 2: Use the spatial variables and other available data on landcover and land attributes to provide an estimate of the total acreage and geographic location of lands that meet the above criteria.

We employed two different methods to estimate the acreage and spatial distribution of EMF in the Delta. Due to data limitations and methodological uncertainties, we felt a comparison of the two techniques would lead to the best possible estimate of the amount and location of land suitable for reforestation. We describe the methods and comment on the limitations of each.

The Mississippi Delta comprises an area of about 39,000 mi^2 and covers portions of Arkansas, Mississippi, Louisiana, Tennessee and Missouri. For this analysis, we ignored the fairly small portions of the Delta that lay within Tennessee and Missouri. Hereafter we refer to the Delta as the portion of the Mississippi Alluvial Valley that is within the states of Arkansas, Mississippi and Louisiana (Figure 1). We used a geologic data coverage from the US Fish and Wildlife Service (LMV/GIS SC 1996) to delineate the alluvial valley (Figure 3).

4.1. Soil Data (STATSGO) Analysis

Much of the information concerning flooding regime, soils, crop type and crop yield are contained within the STATSGO database maintained by the USDA National Resource Conservation Service. However, these data are less than ideal for our purposes because: 1) data are out of date since they are typically based on soil surveys conducted during the 1940s-1960s, and 2) data are combined over large spatial units which prevents areas with appropriate soil characteristics from being located with a high degree of specificity. The age of the data prevents us from using the crop yield information directly because it underestimates current yield. And, more importantly, the data age prevents us from identifying all the spatial units (polygons) likely to have portions planted in soybeans, since much of the clearing of EMF occurred in the 1970s. The soil surveys and associated agricultural data are based on the area identified as containing crops at the time of the survey and the data do not identify the extent of potential cropland based on soil characteristics. Further, a statistical technique was used to extrapolate from point data, which represents the small areas actually surveyed, to the area (polygon) information represented in the database, so the data do not represent an exact census of the agriculture acreage or location.

STATSGO data are presented in map units which identify characteristics of portions of each mapped polygon in the Geographic Information System (GIS) output (Figures 4, 5, 6 and 7). Since we do not have information about the physical location of the map units with the polygon, each polygon appearing on a map can be defined to represent one map unit at a time, or a sum or other combination of map unit characteristics. Thus, maps generally show values that represent the percentage of the polygon meeting the specified criteria (e.g. percent of the polygon with hydric soils). STATSGO data were not intended to be used for fine scale analysis, and therefore, are useful for generalizing over areas and roughly estimating acreage, but not for detailed spatial analysis.

The STATSGO database included a wide variety of data fields including basic soil characteristic measurements (e.g., percent clay content) as well as information on typical crops grown, yield characteristics of those crops on particular soils, average flooding regime, and whether the soils are hydric. To select the areas (polygons) that were likely to EMF, we selected polygons that had some percentage of any of the following characteristics:

- Hydric soils (Figure 7)
- Soybean yields in the 10-25 bushel/acre range[7] (hereafter referred to as marginal soybean yields)
- Average annual flood end date of May or June
- Soil drainage class of C or D

Although the STATSGO data are organized so that we could select soil components (portions of map units) that share characteristics (e.g., units that contain both hydric soils and soybean yields in the 10-25 bu/ac range), missing data and other data errors resulted in very few polygons being selected through this method. Instead, we compared the acreage estimates for the various characteristics that would tend to identify EMF.

This STATSGO data analysis yielded estimates of 1.5-1.9 million acres of EMF based on flood end dates and soybean yields respectively (Table 5). These values are well below the 9.2 million acres of hydric soil since much of this land is not farmable. This estimate of EMF is likely to be low compared to current EMF because the data on agricultural crop patterns and yields were collected prior to major clearing of EMF, as discussed above.

Table 5. Area (1000s of Acres) with various soil properties (from STATSGO)

	Hydric	Average Flood End Date of May or June	Soy Yields of 10-25 bu/acre
	1000 acres	1000 acres	1000 acres
Arkansas	4890	900	626
Louisiana	3010	800	906
Mississippi	1340	180	404
Total	9250	1900	1540

[7] We used the 10-25 bu/acre range that would be considered EMF by today's standards. However, since the yield data are predominantly from the 1940s and 1950s, these yields would translate into 1990 yields of as much as 30-60 bu/acre. Therefore, much of this acreage would not be considered EMF today. These adjusted yields are based on a 3-5% annual average growth rate in soybeans in Mississippi from 1954-99. Historical records of soybean yields are available from the National Agricultural Statistical Service http://www.nass.usda.gov:81/ipedb/.

4.2. Technique Using FWS Land Use Coverages: Landcover Change Analysis

The best data that we were able to obtain for spatially locating marginal soybean farms was landcover data from the USFWS (LMV/GIS SC). A GIS coverage of 1950s forest cover data[8] was generously provided to us by USFWS (Uihlein, personal comm.). This spatial data allowed us to compare areas that were identified as forest in the 1950s and were no longer mapped as forest in a 1992 land use coverage (LMV/GIS SC) (Figure 8). The forest coverage within the Delta is dominated by bottomland hardwood forested wetlands (Twedt and Uihlein 1999), so we assumed all forest cover represented wetlands. Since significant clearing of forested wetlands to create EMF took place during the 1960s and 70s (see Introduction and Table 6), differences in the extent of forested wetlands before and after this period should reveal the location of current EMF in soybeans, in addition to areas deforested for all other reasons since the 1950s.

Table 6. Total Acreages of Bottomland Hardwood Forest (1,000 acres) for portions of Mississippi, Louisiana, Arkansas and Tennessee included in the Mississippi Alluvial Plain (US FWS, November 1979)

Land Use Class	Dates of Estimates and Data Sources					
	U.S. Forest Service Data			**PI/ Planimetered data**		
	1937	1947	1957	1957	1967	1977
Mississippi	1764.0	1619.0	1566.0	1514.1	1179.8	931.3
Louisiana	5270.5	5072.1	4682.6	4320.3	3738.5	3000.1
Arkansas	3947.3	3715.6	3437.7	2083.0	1326.8	1015.1
Total Forest Land	10981.8	10406.7	9686.3	7917.4	6245.1	4946.5

U.S. Forest Service data provides an estimate of both bottomland and upland forest area combined
Adapted from US DOI 1979

The analysis was straightforward, except for determining the proportion of deforested land that should be considered to be EMF. A GIS analysis allowed us to identify which of the ~2 acre grid cells in the GIS coverage had primarily been forest in the 1950s *and* were classified as land converted to farming or other developed uses in the 1992 USFWS land cover data (Figure 9). The 1992 land use of all regions deforested over this period, according to the data, is shown in Table 7. The portion of the deforested area that was also in soybean farms in the 1992 land use coverage was 1.7 million acres (Figure 10) and the total of deforested land in all cropland was 3.4 million acres. These estimates were somewhat consistent with the estimate of EMF from STATSGO data since the 1.7 million acre estimate for soybeans was the mean value between the two STATSGO estimates of 1.5 and 1.9 million acres (Table 5). However, the STATSGO and the 1.7 million acre estimates are all likely to be underestimates as we discuss in the next section.

[8] The coverage was digitized from paper maps (NWI, Circular 39).

4.3. EMF Area Results and Discussion

The estimate of 1.7 million acres, which were identified as EMF in the land use change analysis above, is likely to be an underestimate of total EMF in the Delta. The reasons have to do with potential errors in and limitations of the 1992 USFWS land use coverage, many of which originate from the fact that land was classified into use categories based on data from a single year. Since farmers on EMF can rotate soybeans, cotton milo and other crops, any of these crops may potentially represent EMF.[9] Further, in any given year, a certain percentage of farms will not be planted, particularly since farms only need to be planted once every 5 years to retain USDA status as active farmland. The classification process is also subject to significant error since satellite imagery for spring and fall was the primary data set used, making crop identification difficult.

A comparison with another recent (MRLC) land use analysis[10] shows that the 1992 USFWS landcover map has significantly less cropland than this more recent analysis. It is important to note that the MRLC land use data exclude roughly 2.5 million acres of the southern portion of Louisiana's Delta or 10% of the USFWS data (compare Figures 8 and 11). The MRLC data show that all crops (row crops and small grains) cover 14 million acres or 66% of the land within the alluvial valley only.[11] In comparison, the U.S. Fish and Wildlife Service land cover data show soybeans covering 5.4 million acres (22%) and total crop coverage covering 11 million acres or 46% of the Delta area. So the USFWS has 3 million fewer acres of cropland in an area that is 2.5 million acres *larger* than the more recent MRLC data. Therefore, the USFWS coverage provides 20% less cropland relative to the MRLC.

So, while the total amount of land deforested, gives us a rough upper bound EMF (3.6 million acres), the total of land deforested and classified as soybean (1.7 million acres) is probably an underestimate of EMF. Given that the MRLC data are more recent and indicate more overall farmland in the Delta, it seems likely that some of the deforested areas that are currently EMF were not identified as being in soybeans on the 1992 USFWS coverage. Therefore, we need to include more than just land classified as soybean in the USFWS coverage in order to provide an accurate estimate of EMF. Of the total deforested acreage from the USFWS data, 3.4 million is in crops. While the 3.4 million acres includes some farmland that generates normal yields, we feel an estimate between 1.7 and 3.4 million acres, such as the mean of 2.6 million, is more representative of total EMF acreage in the region than the 1.7 million acres classified as soybean.

If we compare our estimate to available literature estimates of related acreage, we do not find anything that would contradict an estimate of 2.6 million EMF acres. The area we identified as EMF is larger than any estimated area that is currently slated to be reforested, but well below the total area previously in forest. One study (US DOI 1979) estimated the amount of land deforested between 1957 and 1977 as 2.97 million acres (Table 6). About 2.5 million acres

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[9] Based on conversation with Bill Maily, Hinds County Cooperative Extension Service.

[10] The more recent land cover data set was extracted from the Federal Region 4 portion of the satellite-derived land-cover data set currently being produced through a cooperative project between the U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS), as part of the Multi-Resolution Land Characteristics (MRLC) Consortium activities.

[11] For the analysis the land cover data were clipped to include only the portion within the alluvial valley and not the wider area seen in Figure 11).

within the alluvial valley are available for reforestation in Bird Conservation Regions according to one study (Twedt and Uihlein 1999). Acreage enrolled in the Wetland Reserve Program, which converts EMF to wetlands, totals 140,000 acres for all counties partially or completely within the 3-state Delta. Land in the Conservation Reserve Program, which also EMF totals 11,000 acres of new trees planted for those counties (Table 8). The total of all acres in soybean farms for counties completely within the Delta is 36 million acres (based on National Agricultural Statistical Survey, USDA 1999).

4.4. Summary of Findings

Through analysis of the two distinct data sets, we were able to create a likely range of EMF acreage within the Delta area of Arkansas, Mississippi and Louisiana as 1.5- 3.4 million. Given points raised regarding data limitations, we feel the most reliable estimate is the mean of this range, or 2.6 million acres based on an analysis of land deforested between the 1950s and 1992. This breaks down to $950,000 acres in Arkansas, $670,000 in Louisiana, and $980,000 in Mississippi if we assume a proportional distribution of the 2.6 million acres of EMF. The total cropped area identified as marginal is 7% of the mapped soybean cropland in Delta (based on USFWS coverage) and 48% of land identified as being deforested between 1950s and 1992 (Table 7). The estimate of 2.6 million acres is generally supported by an independent landuse cover dataset and by available literature values.

5. Examining the Financial and Environmental Benefits of Reforestation

The previous section summarized our assessment of the extent of EMF in the Delta. This section summarizes our assessment of the economic and environmental benefits of reforesting this EMF. For purposes of our analysis the overall economic benefits of reforestation, including those associated with improved environmental conditions, are distinguished from the economic benefits that are likely to accrue to landowners as financial returns. The results of this analysis will help determine the financial incentives private landowners would need to switch land use from crops to forests, and the extent of the public benefits that would result.

5.1. Reporting the Financial Benefits of Reforestation

Reforestation of EMF provides landowners the opportunity to earn revenues from timber harvests and the sale of wood products, including sawtimber and pulpwood. Net revenues earned from the sale of wood products equal the difference between the revenues received and the financial outlays required to establish and maintain a forest stand on former agricultural fields. A simulation model was used to calculate the possible financial benefits to reforestation in the form of net returns earned from the sale of timber and pulpwood under four different reforestation scenarios:

1. cottonwood (*Populus deltoides*) for pulpwood,
2. nuttall oak (*Quercus nuttallii*) for sawtimber and pulpwood production,
3. seeded nuttall oak (planted from seed) for sawtimber and pulpwood production,
4. cottonwood/nuttall oak interplanted with cottonwood for sawtimber and pulpwood production

The tree growth rates, rotation lengths and establishment costs used in the simulation model are selected based on the assumption that reforestation is occurring on economically marginal agricultural lands, as they have been defined in this study. This means that returns are calculated for reforestation occurring on hydric soils. Additionally, the model accounts for the effects of flooding on timber stand establishment for sites located in the 2-year flood plain. The net returns are calculated over a 120-year period, discounted and summed to produce a net present value (NPV) estimate of returns. Annual equivalent value is reported for each NPV estimate, and results are reported using both a 4% and 7% discount rate. (See Tables 9 and 10)

Table 9. Net Returns from the Sale of Wood Products: 7% Discount Rate

Reforestation Scenario	Net Present Value per acre	Annual Equivalent Value per acre
Nuttall Oak	$-85.06	$-5.96
Seeded Nuttall Oak	$-18.43	$-1.29
Cottonwood	$-35.09	$-2.46
Cottonwood – Nuttall Oak interplanted	$-73.70	$-5.16

*Results are inflation adjusted and expressed in 2000 dollars

Table 10. Net Returns from the Sale of Wood Products: 4% Discount Rate

Reforestation Scenario	Net Present Value per acre	Annual Equivalent Value per acre
Nuttall Oak	$123.72	$4.99
Seeded Nuttall Oak	$162.18	$6.55
Cottonwood	$42.35	$1.71
Cottonwood – Nuttall Oak interplanted	$121.90	$4.92

*Results are inflation adjusted and expressed in year 2000 dollars

One consideration landowners face when deciding whether or not to reforest their EMF, is the extent to which the revenues they would earn from reforestation will exceed or fall short of the revenues they would earn if they were to keep the same land in soybean production. This would mean comparing the net returns earned from the sale of wood products, as reported in Tables 9 and 10 above, with the forgone net returns to soybean production.

Tables 3 and 4 suggest the range of average annual soybean returns that a landowner might earn on EMF (assuming a 25 bu/ac flood-free yield) over the 120-year period of analysis. As an example, consider a landowner that expects to earn an average annual soybean return of $3.01/acre, equivalent to the returns reported for Arkansas at a 4% discount rate (see Table 3). Under the seeded nuttall oak scenario, at the same 4% discount rate, this landowner would expect to earn an annual equivalent value of $6.55/acre from the sale of wood products. In this instance, the annual equivalent returns from reforestation would exceed the average annual returns from continued soybean production by $3.54/acre.

In another instance, a landowner may find that the annual equivalent forestry returns would fall short of the average annual return to continued soybean production. Again, consider the landowner in Arkansas that expects to earn an average annual return of $3.01/acre (at a 4% discount rate) from continued soybean production. Under the cottonwood reforestation scenario at a 4% discount rate, the landowner would only realize an annual equivalent return of $1.71/ac, $1.30/acre less than the returns earned under continued soybean production.

While in some instances, the net returns earned from the sale of wood products may fall short of the net returns earned from soybean production; reforestation offers landowners a wide range of income opportunities. Additional income sources available to owners of EMF who reforest are revenues from hunting lease sales and payments received through government programs that pay landowners to idle environmentally sensitive agricultural lands, such as the Wetlands Reserve Program (WRP) or Conservation Reserve Program (CRP).

Hunting lease revenues can increase the returns to reforestation significantly. Hunting lease revenues are highly variable and very sensitive to habitat, local market and other conditions. Hunting leases can be sold for agricultural lands as well as forested lands; however, it is generally true that the highest value hunting leases in the study area are for waterfowl, deer and turkey hunting in bottomland hardwood forests.

Suppose, for example, a landowner could earn an annual return of $10/acre from the sale of a hunting lease on his reforested EMF, while he could only earn a $5/acre return for the hunting rights to his land when still in soybean production. In this case, the landowner would expect to earn an additional $5/acre yearly from reforesting, above the revenues earned from soybean production. This additional annual amount of $5/acre, if earned over the entire 120-year period considered in this analysis, would be equivalent to an additional net present value of $123.87/acre at a 4% discount rate, and an additional net present value of $71.41/acre at a 7% discount rate. If this $5/acre premium for forest land hunting leases were doubled to $10/acre, the net present values at 4% and 7% would likewise double to $247.74/acre (4%) and $142.82/acre (7%).

It is also important to note the sensitivity of the calculated returns from the sale of wood products to the rate used for discounting future values. Given the longer time horizon for timber production, the more a dollar is forecast to be worth in the future – as indicated by a higher discount rate – then the lower the NPV of future timber revenues. That means that, when discounting the net returns earned over the length of one tree rotation (from the time of initial stand establishment to the harvest of the stand) the reforestation NPVs will be higher at a lower discount rate. As seen in Section 5.2, it is also likely that reforested land will command a premium (versus soybean land) in emerging environmental services markets such as nutrient and sediment reduction, carbon sequestration and wetlands.

5.2. Identifying the Environmental Benefits of Reforestation

For the purposes of evaluating environmental benefits, we considered 4 scenarios for reforesting EMF which would result in land being placed in the following four categories:

1. cottonwood on 10-year rotations for pulpwood
2. cottonwood/nuttall oak interplant with cottonwood on 10-year rotation
3. nuttall oak for sawtimber and pulpwood production on 60-80 year rotations
4. bottomland hardwood (*Quercus spp.*, *Fraxinus spp.*, etc.) with no commercial production

The different scenarios are expected to create different levels of benefits due to differences in growth rates, harvesting frequencies and tree characteristics. Cottonwood plantations have high survival rates and fast growth leading to rapid establishment of stands that provide minimal wildlife habitat requirements and aesthetic benefits. When cottonwoods are interplanted with oak, cottonwoods provide the benefits of a fast growing species while the oaks mature more slowly providing the more diverse habitat structure and additional food resources favored by wildlife. The cottonwoods may act to increase oak survival by altering the microclimate (Schweitzer et al. 1997) adding another benefit of interplanting the two species. The nutall oak scenario alone, assuming high survival, would provide many of the same environmental benefits as the cottonwood-oak interplant over the long term, but would not provide these benefits as quickly. The bottomland hardwood scenario assumes a return to the pre-deforestation state, with its associated hydrological conditions, and would result in many benefits associated with the native ecosystem, once the trees were established.

Knowing only the overall acreage of reforested land allows us to make rough estimates of expected benefits. However, the actual distribution of any level of reforestation can lead to higher or lower benefits. For example, increased forest cover in riparian areas can have a larger impact on sediment and nutrient removal from runoff than the reforestation of land farther from streams. On the other hand, reforestation may lead to increased floodwater retention if it takes place further from rivers and streams. In terms of distribution pattern of forest on the landscape, forest added so as to increase the core (interior) forest area, or so that it links together adjacent forested wetlands, can disproportionately increase the quantity of rare habitat, especially for flora and fauna that require more specialized habitat (Rudis 1995, Bender et al. 1998). A series of interconnected patches, versus isolated patches is thought to contribute to long-term species survival (Gibbs 2000).

5.2.1. Sources of Reforestation Benefits

Terrestrial Habitat Improvement

While soybean production offers cover and a growing season food source for deer and small mammals, reforestation will increase and improve cover, nesting sites and brood-rearing habitat (Wesley et al. 1981). Also, newly established forests can act as corridors connecting existing forest habitat, increase edge, and eventually forest interior habitat (Peterken and Hughes

1995). However, variation in stand composition associated with different reforestation scenarios will affect relative habitat suitability for different game and non-game species. Cottonwood plantations show rapid biomass growth resulting in rapid stand closure, thereby quickly providing interior habitat. Although fast –establishing, these cottonwood stands would tend to provide lower overall benefits than scenarios with hardwood species. Oak plantings, unlike cottonwood, produce potentially large quantities of hard mast in the form of acorns in stands aged 20 years and greater. Hard mast is a preferred food source for both wild turkey and deer (Wesley et al. 1981). Nuttall oak is considered to provide excellent terrestrial habitat compared to many other bottomland hardwood species (Appendix A). For the above reasons, bottomland hardwood forests in the Yazoo River Basin of the Mississippi can provide habitat for a variety of game species, including whitetail deer, wild turkey, rabbit, bobwhite quail, mourning dove, squirrel and waterfowl (Figure 12, Woolfolk 1997).

Recreational hunting is a popular pastime in Mississippi and a significant source of economic income for the region. For example in each of the three States in 1996, 433,000 recreational hunters in Mississippi spent an estimated $576.3M on hunting activities; in Arkansas, 379,000 recreational hunters spent $338.9 M on hunting activities; and in Louisiana, 352,000 recreational hunters spent $577.1 M on hunting activities (DOI 1997). With significant demand for suitable hunting sites, the sale of hunting leases provides landowners with a non-timber source of income from reforested land. A 1997 survey of private landowners in 66 Mississippi counties reports an average annual hunting lease value of $31 per acre. (Jones et al. 1999) In general, wetland areas that are well suited for waterfowl draw significantly higher lease values, ranging from $49 – $98/acre (Jones et. al. 1999). "All-purpose" hunting leases can range from $1.50 to $25/acre annually (Woolfolk 1997

A 1995 study quantified the potential habitat gains from reforestation of bottomland hardwoods in the Yazoo River basin (Wakeley 1996), which is part of the Mississippi Delta. That study defined habitat improvements in terms of net change in average annual habitat units (AAHUs), where one HU is equivalent to one acre of optimal habitat. The six evaluation species were gray squirrel, barred owl, Carolina chickadee, pileated woodpecker, wood duck, and mink. In the study, 100 acres of cleared land was restored to bottomland hardwoods under various management plans and the benefits were assessed over a 50-year period.

The results were consistent for the barred owl (34.35), the Carolina chickadee (46.80) and the pileated woodpecker (27.00) for all six of the management plans. The results for the gray squirrel differed between the plans. For the three management plans that left the area to naturally revegetate, the increase in the AAHU was 25.95, but was 47.85 for the three management plans that required active reforestation of the area. Wood duck results were either 37.77 or 62.70 depending on the plan, and mink results ranged from 10.89 - 55.65.

With the reforestation of 2.6 million acres, under the no-harvest scenario, we would expect to see over 25,000 times the number of habitat units created in the Wakeley (1996) study after the same 50-year period. The amount and type of habitat created would vary based on land configuration, as discussed below, since each marginal farm parcel we are evaluating covers approximately 2.5 acres, compared to the 100 acre unit used in the Wakeley study. However, since much of the EMF is adjacent to existing forest, we would expect reforestation to result in increasing forest patch size. Timber harvests would result in recreated edge habitat, which is preferred by some species.

In general, forests at various stages of growth and with different dominant tree species can support different animal species (Figure 12). Therefore, some species could be expected to benefit from scenarios involving harvesting at the expense of other species. A diversity of habitats would generally produce the greatest diversity of species, especially if rare habitat were included. We would expect cottonwood harvested on 10-year rotations, for example, to provide less interior habitat area than the no-harvest bottomland hardwood scenario given the disruptions due to harvesting such as the removal of cover. The nuttall oak scenario should provide a fairly high level of habitat over the long term, although not as much rare habitat as the no harvest or oak/cotton wood scenarios since harvested areas would be unsuitable for many interior-dwelling species and would remain unsuitable for many years. On the other hand, the oak/cottonwood interplant should provide a similar level of interior habitat and more edge habitat than the natural reforestation scenario, since the cottonwood grow quickly to allow recovery from harvest, and the oaks, which mature later, provide the preferred canopy structure and food source for many species.

Forest Core Area Improvements for Habitat

Almost any level of reforestation offers an opportunity to improve forest habitat, and in particular interior forest habitat, because much of the EMF is adjacent to forested wetlands. Population density of many birds and mammals is a function of habitat patch size (Bender et al. 1998). Specialist species that require undisturbed forest interior habitat or rare vegetation benefit from reforestation that connects forest patches into larger, more continuous patches than current conditions. Tree species richness in southern bottomland forests was shown to increase with forest fragment size at small to intermediate patch sizes (Rudis 1995), demonstrating that even modest increases in forest patch area can lead to greater diversity of species.

We conducted an analysis to quantify the additional rare habitat that might be added to existing forest under the 100% reforestation plan. Our spatial analysis quantified the percent of the landscape in forest, the increase in forest patch size,[12] and core area (interior) of each forest patch both before and after reforestation (Figure 13). Each reforestation scenario, regardless of the percent of forest included, could disproportionately increase this rare interior habitat through careful allocation. An analysis of bird habitat in the region (Twedt and Uihlein 1999) demonstrated some of the potential benefits of such an approach.

Using the 3-state area of the Delta (AR, LA, MS), we evaluated the configuration of forest patches under current conditions and compared those values to the scenario of 100% reforestation of our most conservative estimate of 1.7 million acres of EMF (Section 4.2 and Table 6). We divided the landscape into two scenes at a natural break in the forest patches, which was close to the northern border of Louisiana with Arkansas. This allowed us to characterize changes to both the less densely forested northern portion of the region and the more densely forested southern region of the Delta.

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[12] A forest patch is an area that appears contiguous in forest at the scale of the GIS coverage. Patches may have interior parcels in a non-forest coverage, but can not be completely separated from the patch by non-forested areas.

We examined the following indicators: total area of forest, % of landscape in forest, largest forest patch area as a percent of all forest, mean patch size, total core area, number of core areas and core area as a percent of all forest cover. Results are shown in Table 11. Core area was defined as the interior portion of a forest patch that was at least 5 cells (approx. 1640 ft or 500 m) away from a forest patch edge in any direction.

We saw modest increases in forest as a percent of the landscape under the scenario of 100% reforestation of EMF. The upper region increased from 20 to 28 % and the lower region from 36 to 42%. Natural land cover of at least 25-30% is thought to be a threshold for maintaining high quality natural habitat, and increased percentage of cover is thought to be the most important aspect of habitat restoration (Gustafson 1998). Clearly, these increases will bring many new portions of the Delta above that threshold, thereby improving habitat for a range of species.

We also saw an increase in total core area of about 25,000 acres in the upper scene and 17,000 acres in the lower scene. The number of core areas (patches with enough area to include more than edge habitat) increased by 400 in the upper scene and by about 175 in the lower scene. This is the equivalent to the creation of 575 new habitat "islands" in which interior plant, bird, and animal species can expand their range. The mean patch size jumped significantly in the northern scene from 44 to 64 acres, but remained the same (89 acres) in the more densely forested southern scene. These core area increases would tend to translate into both increased species abundance and species richness.

5.2.2. Aquatic Habitat Improvements

Farmland is known to leak nutrients into adjacent ecosystems, which can cause deterioration of aquatic environments (Matson et al. 1997). Excessive nutrients in surface waters, or eutrophication, can cause deterioration of aquatic systems through several processes. An overabundance of algal growth can influence fish survival by causing low oxygen conditions, particularly in bottom waters. Nutrients in the Mississippi River contribute to degraded water quality and to the formation of an hypoxic area that forms in the Gulf of Mexico, limiting aquatic habitat during those times.[13] Negative effects on fisheries include: decreases in stock levels, shifts in location of fishing grounds, increased congestion in unaffected fishing areas, and changes in the quality of harvested species (Doering et al. 1999). Eutrophication has been linked to the loss of underwater seagrass beds that serve as fish nurseries and habitat for many aquatic species. Also, eutrophication is thought to contribute to rapidly growing population of toxic algal species which create red or brown tides and can result in large fish kills, death of marine mammals and poisoning in humans who consume contaminated shellfish.

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[13] "On the Gulf of Mexico's Texas-Louisiana Shelf, an area of hypoxia (low dissolved oxygen levels) forms during the summer months covering 6,000 to 7,000 square miles, an area that has doubled in size since 1993. This condition is believed to be caused by a complicated interaction of excessive nutrients transported to the Gulf of Mexico by the Mississippi River; physical changes to the river, such as channelization and loss of natural wetlands and vegetation along the banks; and the interaction of freshwater from the river with the saltwater of the Gulf." (http://www.epa.gov/surf/surf98/Mississippi/backgrda.html)

In addition to the river, nitrogen on land also influences the atmosphere. Nitrous oxide, which is released from the breakdown of fertilizers, is a greenhouse gas that contributes to global climate change (Vitousek et al. 1997). Nitric oxide, another form of nitrogen, contributes to acid rain, which can damage aquatic systems and kill fish and other species.

Many farming practices also cause sediments and pesticides to move from farms to ecosystems. Sediment removal from cropland has a direct effect on water quality in terms of increasing turbidity. Indirect effects can result from sediment acting as a transport mechanism for nutrients and pesticides. And excessive sediment loads reaching estuaries can bury bottom-dwelling (benthic) communities such as shellfish and prevent or hinder their growth and reproduction. Pesticides applied to agricultural land typically move into adjacent ecosystems through leaching or aerial drift, where they can have unintended impacts on the diversity and abundance of species and result in changes to ecosystem structure and functions (Matson et al. 1997). These compounds can also pose serious health threats, either directly as humans come in contact with them or indirectly by altering biogeochemical processes.

This section provides estimates of a subset of potential benefits that result from the reforestation of EMF. Many of the same characteristics that cause farmland to be unproductive also result in the land causing problems to aquatic systems. Soil characteristics that lead to low yields when farmed, for example, also may result in excessive soil losses when farmed. We describe a subset of benefits that may be derived from reforestation and provide quantitative estimates when sufficient information is available. Many other benefits to aquatic ecosystems could potentially result from reforestation, for example improved habitat structure from improved stability along stream banks and inputs of coarse woody material. However accurate quantification of value for many of these benefits is not currently possible.

Benefits from Reduced Sediment Runoff

While cropping systems vary in terms of the sediment losses they cause, any agricultural system will tend to result in larger sediment loss than will a forested system. In most cases, erosion losses from forestland are 1-10% of the losses from agricultural land (Gianessi et al. 1986). In some cases (particularly young forest stands), forests act as a sediment sink, removing more suspended soil particles from floodwater and runoff than they contribute (Aust et al. 1991). As stands mature, the number of tree stems decreases due to self thinning and understory vegetation is reduced in density as light availability is reduced (Klimas 1988). For these reasons, sediment accumulation decreases as a forest ages or over the length of a rotation.

To estimate the potential amounts of soil that would be kept out of the river under reforestation, we multiplied the average sediment loss rate from soybean farms planted on soil typical of the Delta riparian areas by the area to be reforested. Actual sediment loss will be a function of soil type, rainfall, tillage practices, slope, forest age and other variables, but studies have shown an average of 4.9 tons/acre per year of sediment is lost from a Sharkey silty clay planted in soybeans (Murphree and McGregor 1991). So, assuming that forested wetlands retain at least 4.9 tons/acre/year of sediment, our general estimate of the increase in sediment retention from reforestation (Table 12) is 12.7 million tons of sediment per year.

This prevented erosion of 4.9 tons/acre/year is not the same as a direct measurement of sediment retention, but it does compare favorably to an estimate of sediment retention, based on field measurements in bottomland hardwood wetlands of 3.57 tons/acre/year (Kleiss 1996) and is similar to other measured values (Table 13). Even if we take the retention rate of 3.57 tons/acre/year and multiply it by our 2.6 million acres of reforestation, we still estimate as much as 9.3 million tons/year of sediment retained on land with the non-harvested reforestation scenario.

A study by Ribaudo (1998, as cited in Doering et al. 1999), estimated erosion damage costs at $3.44/ton in the Mississippi Delta. This value was based on damage to freshwater fishing, water storage, flooding, marine recreation, commercial fishing, navigation, roadside ditches, municipal water treatment, municipal and industrial water use, steam power cooling. Therefore, using the 2.6 million acres of wetlands that could be created from EMF and the estimate of 4.9 tons/acre/year we could expect total annual benefits to be about $43.8 million.

This value is only a rough estimate since sediment retention is affected by tree stand age, forest management techniques, and other physical and economic factors that have not been considered in our analysis. Also, we have limited information to calculate how sediment retention would differ under the frequent rotations for cottonwood, or how that might differ in scenarios that involve oak/cottonwood intermixing. Generally speaking, reforestation scenarios resulting in the largest number of woody and herbaceous stems will remove more sediment than stands with fewer stems and a sparse understory. Some erosion might be expected during and immediately following clear-cut harvesting, but management could be used to limit sediment runoff. Most importantly, once trees have regenerated following harvest, field evidence suggests that these young forested wetlands can retain twice as much sediment as mature forested wetlands (Aust et al. 1991) resulting in more sediment being retained with harvesting than without.

Reduced Pesticide Runoff

Much of the Delta is planted in crops using high pesticide inputs. Forestry-related activities have considerably less chemical input than most agricultural systems. Most forest cropping systems rely on herbicides for weed control only during the first growing season of the rotation. In contrast, row crop agriculture usually involves applications of several chemicals throughout the growing season every year. Soybeans in particular require insecticides and herbicides. Insecticide is applied to forest crops only rarely and only under the most intensive management scenarios. In the Delta, soybean farmers typically use 24.1 and 28.9 oz herbicide active ingredient per acre annually for conventional and stale seedbed methods, respectively (MAFES 1995, Ahrens 1994).

Cottonwood is the most chemical-intensive of the forest crops proposed here due to its sensitivity to weeds and short rotation length. If we assume that herbicide is applied once per rotation, at 19.2 oz of active ingredient per acre (MAFES 1995), then a cottonwood plantation harvested every 10 years (scenario 1) would reduce herbicide inputs by more than 3.9 billion oz over 70 years. Lower application rates are possible for oak and other hardwood species, but if we assume the same application rate, once per rotation, we end up with a reduction of more than 4.3 billion oz. of herbicide for the nutall oak scenario relative to soybean farms. Intensity of weed competition will dictate actual application rates, but these figures give some idea of the type of reduction possible.

Reduced Nutrient Runoff

With respect to the benefits from reduced nutrient runoff we can expect the reforestation of EMF in this region to have an effect disproportionate to acreage because these lands are in perennially flooded riparian regions where soil interacts directly with river water. Wetlands in such regions have a comparative advantage in trapping constituents of runoff and carry out denitrification, which reduces the nitrogen reaching the river waters. Also the clay soils, which dominate on these lands, have been shown to trap phosphorus more efficiently than coarse (silt and sand) soils (Mitsch and Gosselink 1993). Denitrification is carried out by microorganisms that thrive under conditions of high soil carbon and high nitrate availability. One of the consequences of forest growth is increased soil organic matter content due to leaf, twig and fine root accumulation, facilitating high nitrification rates throughout the life of the stand. Forest vegetation uses agricultural nutrients including nitrates and phosphorus (CENR, 1999). Riparian forests and streamside management zones have been shown to remove nutrients applied to adjacent agricultural lands, reducing their influx to rivers (Peterjohn and Correll 1984, Jordan et al. 1993). The reduction of nutrient levels by the wetlands that would replace the EMF would be expected to lessen the hypoxia problems in the Gulf of Mexico described earlier (CENR 1999, Council for Agricultural Sciences and Technology 1999, Mitsch 1999).

We used the following values to determine the change in nitrogen and phosphorus under the various scenarios. These values were calculated for the Yazoo River Basin, which lies in the Lower Mississippi subwatershed. The numbers were derived by modeling the entire Yazoo River basin and fitting the basin's land use proportions to the measured nutrient levels in river water. Therefore, these values take into account issues of soil type, slope, land configuration, typical rainfall intensity, and other factors.

Table 14. Pollutant loads from land uses as estimated for the Yazoo watershed (from Shabman and Zepp 2000)

	Total Nitrogen (lbs/acre/yr)	Total Phosphorus (lbs/acre/yr)
Forest	1.32	0.28
Wetland	0.66	0.17
Cropland Soybean	11.17	2.99

The values shown in the table for soybean farms represent nutrients moving from soybean farms into streams. These values are large compared to in-stream measurements of nutrients (Table 12). However, they are consistent with the high runoff values that would be expected from EMF given known farm characteristics.

If we assume the same nutrient loading for each acre of EMF being reforested, farmland converted to wetlands (with no harvesting) has the potential to prevent 27 million pounds of nitrogen and 7 million pounds of phosphorus from reaching the Mississippi each year. The harvested scenarios are likely to differ from the no-harvest scenario, although the net effects of harvesting are difficult to predict given the competing effects on nutrient cycles. Some amount of nitrogen and phosphorus may be released from the harvested sites shortly after harvesting although the dynamics of this are not well studied (Lockaby and Walbridge 1998). There is evidence that for forests with water tables at or near the surface, nitrogen dynamics may not be affected, but for non-inundated conditions nitrogen has been shown to move to streams in the year following harvest (Mader et al. 1989 as cited in Lockaby and Walbridge 1998). Since phosphorus tends to attach to soil particles, phosphorus dynamics are likely to be similar those for sediments (as described above). Immediately following harvest, sediment and phosphorus are typically released, but once vegetation begin to grow and fill in the site (within the first year), sediments and P are retained at higher rates than mature forests (Lockaby and Walbridge 1998). Another factor is that nitrogen is typically applied at least once to cottonwood trees, creating the potential for an initial release of nitrogen from the sites (Schweitzer et al. 1997). The differences between scenarios are difficult to quantify without modeling the important nutrient budget components and factoring in management activities.

In making our calculations of nutrient retention, we assumed that the nutrient export values calculated for farmland in the Yazoo River basin (Table 14), were a fair estimate for the entire Delta. One reason we made this assumption was that areas of the Lower Mississippi basin have been shown to produce similar levels of nitrate in river water for a given level of nitrogen applied to land (Coupe 1998, Fig. 6). This result indicates that nutrients tend to behave similarly within watersheds in the Delta, regardless of location. Although the Yazoo has shown a slightly lower nitrate level in river water compared to the Lower Mississippi basin, this difference is not likely to be important given the inexactness of the initial estimate. Our values are general estimates and without more sophisticated modeling, the Yazoo numbers provide the most reasonable estimate available.

Another analysis of nutrient release from Mississippi River basins provides estimates of the likely nutrient yields for the area we are examining (Goolsby et al. 1999). As with the Yazoo basin study, this study also examined all land uses and the nutrients measured within the river basin. The area being examined for reforestation is part of two basins analyzed in the Goolsby et al. study: the "Lower Mississippi" and the "Red and Ouachita". If we assume that the Lower Mississippi River Basin described in that study is representative of our entire region (since it includes about 2/3 of our study area), we can create another estimate of nutrient removal through reforestation for comparison. The 2.6 million acres that would be reforested under our scenario represent roughly 6% of the Lower Mississippi basin used in the Goolsby et al. study. If we assume that reforestation reduces the nutrient flux 6%, we still see 15 million pounds of nitrogen and 1.3 million lbs of phosphorus from reaching the river.[14] However, we have many reasons to suspect these numbers are underestimates of true nutrient sequestration since the basin includes a large proportion of upland areas and we know wetlands have a disproportionate effect on nitrogen. Also, we have reason to believe that phosphorus removal would also be enhanced in these sites (see beginning of this section).

[14] These numbers are based on assuming all reforested land came from the Lower Mississippi River Basin as described in Goolsby et al. This is meant only to be a rudimentary type of calculation for comparison with the Yazoo figures. Forested wetlands can and do release nitrogen and phosphorus, however, under conditions typical in the Delta; they have the potential to remove large quantities of these nutrients from runoff.

5.3. Dollar value of nutrient and sediment removal

While we do not have an exact method to place a dollar value on the worth of the nutrients that would be trapped or transformed by new wetlands, we can put a reasonable estimate on their worth by examining what nutrient credits would sell for, if nutrient credit trading was instituted in the Delta region. The likelihood of nutrient credit trading is increasing as governments increase their regulation of nutrient dischargers and dischargers look for low cost solutions to reducing nutrient flow. An efficient solution to nutrient reduction can theoretically be achieved by allowing businesses with different nutrient reduction costs to trade nutrient credits. Through such trading those who can achieve nutrient reductions at low cost, are paid to take on the burden of nutrient reductions by nutrient dischargers that would have to spend much more to reduce nutrients. Since the costs of nutrient reduction may vary greatly between treatment plants and as a result of changing land uses the opportunities to increase nutrient reduction at a lower costs can be significant with nutrient trading. Under such a trading system taking land out of crop production that results in nutrient discharges to nearby water bodies would be a valid way of generating marketable nutrient credits.

A recent study (Faeth 2000) evaluated the feasibility of phosphorus credit trading in the Upper Mississippi River Basin and developed a range of values that could be applied to regions with heterogeneity in phosphorus reduction costs. Faeth evaluated the costs of reducing a pound of phosphorus in three watersheds of the Upper Mississippi and found that the costs varied considerably, both between treatment plants and between farms and treatment plants. Using a scenario of a 1 ppm goal at all treatment plants, he found that costs averaged about \$10 - \$24/lb for treatment plants, but only \$6 - \$16/lb for farms. By allowing free trade under various regulatory scenarios, average costs were reduced to \$2-7/lb. with an average cost of \$4/lb. This cost estimate includes supplemental government money paid to farmers to implement nutrient management practices. Without government subsidies, the cost per pound would be higher. At this dollar value, the 2.6 million acres of EMF converted to wetlands could be worth \$27 million in phosphorus credits.

While the Faeth study estimated costs of phosphorus removal, a similar study examined the costs of nitrogen removal and the value of nitrogen credits (where available) from a variety of US locations (Doering et al. 1999). In the Mississippi Delta, the authors calculated weighted average point source treatment costs to be \$24/lb and the cost of a credit to achieve nutrient goals from trading between treatment plants and farms (or a marginal credit) was estimated to be \$41.92/lb. These estimates were based on a detailed analysis of costs of treatment, nitrogen discharge rates, and available farmland by region. They did not include government subsidies to farmers, which might lower the cost of a nitrogen credit.

If we assume each pound of nitrogen removed is worth \$24 on average, then 2.6 million acres of created wetland would be worth over \$650 million in nitrogen credits under no harvest and potentially half that or \$325 million under the cottonwood scenario.

Reduced Flood Damage

Reforestation in riparian zones may affect flood levels in several ways. First, the higher evapotranspiration rates of trees compared to soybeans would tend to dry the soil and remove water prior to flooding, allowing more floodwater to be retained. Also, forest floor litter and increased organic matter in the soil would be expected to increase the infiltration of water into the soil and slow its movement to the river (Dunne and Leopold 1978).

Increase in Carbon Sequestration

Evidence that the buildup of greenhouse gases is contributing to global warming is now overwhelming. One of the greatest environmental challenges facing policy makers everywhere is determining how to reduce the buildup of these gases, especially atmospheric carbon. Reducing carbon emissions will become expensive, but forests sequester significant amounts of carbon and reforesting farmland has been recognized as a potential way to offset the contribution of carbon emissions to the overall pool of atmospheric carbon. As a result of the 1998 Kyoto Protocol, or subsequent agreements, it is widely expected that markets will emerge for carbon credits, and that landowners that reforest their land will be able to earn income by selling carbon sequestration credits to carbon emitting industries.

Although these markets have not emerged yet, a recent deal in the Delta region involves an energy utility (Illanova) paying $11,000,000 to a private company (Environmental Synergy) to reforest 100,000 acres of publicly owned land in return for prospective carbon credits. This provides evidence of the potential for the reforestation of private land in the Delta region to provide carbon-related benefits and a new source of income for landowners.

The criteria that international carbon negotiators and national resource agencies are discussing for scoring carbon sequestration credits include not only expected increases in rates of carbon sequestration, but other ancillary environmental benefits and costs. Previous sections identify the habitat and water quality benefits associated with reforesting farmland in the Delta region. In this section, we summarize the potential for this reforestation to sequester carbon, and assess the potential for private landowners to earn income by selling carbon sequestration credits that result.

Methods

We developed models for carbon sequestration that were specific to the tree species identified in each reforestation scenario. We also tailored these models to the dominant soil types on the lands identified as EMF. Values for expected carbon stocks, the form of the tree growth equations for various tree species, and site qualities were derived from recent literature sources (Shabman and Zepp 2000, Amacher et al. 1997, Birdsey personal comm., Birdsey 1996, Row 1996, Mitsch and Gosselink 1993, STATSGO data base), previous models we have developed (King et al. 1999), and discussions with knowledgeable staff of federal agencies involved in carbon research.

We assumed a linear accumulation of carbon through time in soil, litter and debris, and in standing stock of cottonwood and nuttall oak biomass, up to a threshold value. The growth rate pattern for mixed species in bottomland hardwood (no harvest scenario) over time was modeled with a logistic (s-curve) model (King et al. 1999). With this model, accumulation of biomass is moderate in early years and increases rapidly until approximately 50% of eventual biomass is accumulated. At this mid-point, biomass growth is still rapid, but begins to slow until growth tapers off and only modest increments of biomass are being added. All models assumed some level of management and site preparation.

The linear and logistic equations of the carbon accumulation model were adapted to the particular scenarios by using parameters developed for each tree species and each harvesting scenario. Initial and maximum soil carbon values were calculated from data in the USDA STATSGO database (i.e. bulk density, %organic matter, soil depth). We used representative values based on the dominant soils in the Delta. The soils were assumed to be greatly depleted in organic matter, so that soils required many years to reach a steady state at which point increases in soil carbon sequestration stopped.

Cottonwood proved to be an unusual species in its ability to grow quickly, to resprout from cut trunks (known as coppicing), and to leave little debris behind at harvest (Amacher et al. 1997 and Russell, pers. comm.). As a result, we made novel assumptions about the carbon dynamics following harvest. Carbon typically leaks from harvested forest systems for many years, so we accounted for this "leakage" in the various scenarios. In the case of cottonwood, growth rates during the first 10 years were four times that of traditional pine species on similar sites (based on data provided by Birdsey, personal comm.). Therefore, we also assumed that carbon leaked from the system after harvest for only 1/4 as long as in a natural pine site (based on Birdsey 1996). Since site preparation after harvest is minimal, we assumed only a 3-year decline in soil carbon (5%/yr) and litter (20%/yr) after the initial litter increase at harvest. We further assumed tree carbon harvest rates increased a few percent each year until tree growth rates were 15% above initial values during the fifth rotation cycle, based on Amacher et al.'s (1997) reporting that observed tree production was 10-20% of forest inventory values on restored farmland.

For the nuttall oak harvest, we assumed a more traditional loss of 20% loss of soil carbon by age 10 (Birdsey 1996). Debris following harvest was assumed to increase a net of 1 MT/acre before losses began. Measures taken to reduce disruption at harvest could lead to less leakage of carbon from the soil. The growth model before harvest was drawn from Shabman and Zepp (2000).

Results[15]

Our analyses of carbon sequestration rates and accumulation levels demonstrated that both varied dramatically between reforestation scenarios. Carbon (C) sequestered in forests includes accumulations of C in aboveground material (tree biomass, leaf litter and debris) and belowground material (soil organic matter). At year 70 of each scenario accumulated C ranged from 34.7 MT/acre for the cottonwood scenario to 56.3 for the bottomland hardwood, no harvest scenario. Since our analysis would not have oak harvested by year 70, accumulated C was virtually the same in the harvest and no harvest scenarios. The cottonwood-oak interplant

[15] The numbers representing rates of carbon sequestration in this section are expressed in metric tons per acre (MT/acre). Each ton of carbon sequestered is equivalent to a reduction of 3.667 tons of atmospheric carbon dioxide. This is important if one is using these numbers to estimate the potential market value of carbon emission credits that landowners may earn from reforestation.

scenario achieved an intermediate level of accumulated C of 47.2 MT/acre by year 70 (Table 15).

We have calculated rates of carbon storage with and without harvest years (Tables 16 and 17). In the unharvested system, carbon sequestration rates peak in the 30-40th years of growth. In the oak with 80-year rotation harvests, carbon sequestration peaks shortly after the second thinning in year 55. Cottonwood carbon sequestration rates peaked during the 5th rotation and cottonwood – oak interplant during the 4th cottonwood rotation (after year 40).

We have not made any assumptions about the carbon retained in wood or paper products over the lifetime of the analysis, which would affect the net C sequestration dramatically. If we assume the cottonwood is being used to produce paper, only 55% of the original carbon is likely to be retained in the final product, and after 10 years, less than 10% of the harvested carbon is likely to be sequestered (Row and Phelps 1996). It may be more realistic, therefore, to examine only the carbon retained in soil and litter for the short rotation scenarios.

The carbon stocks for each scenario (Figures 14, 15, 16 and 17) show how the C stocks vary over the life of the scenario. Sharp declines in tree carbon stocks mark harvest times, but this drop in carbon in the standing stock of trees is partially offset by increases in litter carbon. While some speculative deals are being done, actual C credit markets are still years away. When they begin, the price of C sequestration credits will depend primarily on the supply and demand of C emission credits. Models that predict C credit trading are very imprecise, but the most reliable ones forecast prices in the range of $5 to $150 per ton of carbon. Most analysts are using a price of $15 per ton for assessing potential costs and revenues associated with C credit trading.

Figure 18 displays the stream of expected revenues from C credits earned by reforesting cropland in the Mississippi Delta based on the C sequestration rates described above and C credit prices of $10, $15, and $25 per ton of Carbon (tC). At a price of $15 per tC and annual sequestration rates of 1 to 2 tC per acre after ten years, the annual accrual of C credit values is around $15 to $30 per acre.

5.4. Benefit Summary

We considered many types of benefits that might result from 100% reforestation of the EMF we identified direct returns to the landowner and public goods in terms of improved condition of land and water resources. A summary of benefits from switching all 2.6 million acres of marginal soybean farms to forest is shown in Table 12. The benefits that we were able to quantify and distinguish to some degree between forest type scenarios included: financial returns from selling wood products, net reduction in sediment export from the land, net reduction in herbicides applications and herbicide quantity released to the environment, net reduction in nitrogen and phosphorus reaching the Mississippi, generalized habitat benefits, change in the core or interior area of forest which reflects an increase in rare habitat for terrestrial species, and the net increase in carbon sequestered by the system.

It is difficult to compare the advantages of reducing herbicide and nutrient flow to the Mississippi system. However, we have good reason to suspect that nitrogen is currently having a significant adverse impact on the Gulf of Mexico, its aquatic resources, and its commercial fisheries (Goolsby et al., 1999, CAST 1999) so there are demonstrated environmental and economic benefits from nitrogen reduction. The expected maximum reduction of 9.7-18 million pounds of nitrogen entering the Gulf would represent a noticeable 4-8% reduction in nutrient flux from the Lower Mississippi River Basin (as defined by Goolsby et al. 1999). Whether the environmental and economic payoffs from reducing nutrient loading to the Gulf by this amount are large or small depends on threshold effects that are not yet fully understood.

5.4.1. Scenario Comparison

Although we did not always have adequate information to distinguish likely effects between tree planting scenarios, in the cases where we did more detailed modeling, we found interesting differences in scenarios. Financial returns varied considerably. Under the 4% discount rate, the cottonwood scenario scored only $1.71/acre/year in annual equivalent value as opposed to the highest return of $6.55/acre/year for seeded nuttall oak. The relative financial gains of the different scenarios varied under the 7% discount rate. Seeded nuttall oak achieved the lowest losses (best financial return), but the all cottonwood scenario ranked as the next best solution (Table 9). The seeded nuttall oak shows greater returns than the nuttall oak due to lower establishment costs.

For carbon sequestration, the highest sequestration levels were found in the bottomland hardwood no-harvest scenario. However, the nuttall oak scenario produced similar levels of accumulated carbon sequestration by year 70, just before the first harvest. The cottonwood/oak interplant scenario achieved a carbon sequestration level of roughly 80% of the bottomland hardwood no-harvest scenario. And finally, we found that the all cottonwood scenario resulted in accumulated C sequestration that was 40% of the bottomland hardwood no-harvest scenario (Figures 14, 15, 16 and 17).

In terms of sediment and nitrogen reduction, we assumed that the nuttall oak and natural reforestation scenarios would be largely equivalent over a 70-year period given the long rotation times of the nuttall oak. Based on soil carbon comparisons, we created a rough estimate of how nutrient and sediment sequestration might differ with the frequent harvesting of the cottonwood. Since soil carbon accumulation in the all-cottonwood scenario was roughly half that of the bottomland hardwood no-harvest scenario, we assumed sediment and nitrogen retention were also half of the no-harvest scenario for lack of better information. Sediment and nitrogen differ from carbon in their mobility; thus, this is only a crude estimate.

6. Conclusions

6.1. Quantity of EMF

We estimate that roughly 2.6 million acres of EMF is available for reforestation in the Mississippi Delta, which are about 7% of the 3-state Delta land area. Maps of deforestation between the 1950s and the 1970s were used to determine the probable location and extent of EMF. Other estimates based on STATSGO data provided lower estimates and are likely to be underestimates of EMF due to data accuracy issues.

All of the EMF acreage estimates provided by our analysis required assumptions that put our results in the category of first-approximations. The best available data were not ideal for this analysis, which required us to evaluate and compare results from analyzing three different sets of information. The two data sets yielding lower estimates of EMF had greater sources of error than the data used in the deforestation calculation, so we feel the higher number based on the later is the most accurate. For our estimate of EMF from the deforestation data, we used only the portion of deforested area that was mapped in the 1990s as soybean farms and was not deforested area shown in any other land use. Since some of the EMF is abandoned or may not have been farmed in any given year when images were taken, our choice will tend to lead to a conservative estimate of EMF.

6.2. Benefits from Reforestation

We found that significant benefits would be derived from reforesting EMF in the Delta, although many of our calculations are rough estimates of the specific changes that may occur. We considered financial and environmental benefits from 4 scenarios of reforestation plans that are shown in Table 12. Our benefit calculations assume that the entire 2.6 million acre area of EMF would be reforested.

The financial benefits from switching to tree plantations from soybeans are small. If the returns from reforestation and soybean production are both discounted at the same rate, then the most favorable conditions exists where soybean returns (assuming a 25/bu/ac flood free yield) are replaced with returns from the seeded nuttall oak plantation. At a 4% discount rate, this results in an average net financial return of $3.54/acre/year ($6.55 – $3.01 from Tables 10 and 4) from the sale of wood products alone. Other income sources, such as the sale of hunting licenses, are not included in this figure. Under the 7% discount rate, switching from soybean production to tree plantations resulted in negative financial returns in all cases. The least negative value also occurs with the replacement of soybeans (assuming a 25 bu/ac flood –free yield) with a seeded nuttall oak plantation, resulting in an average net financial loss of -$3.48/acre/year. However, none of these figures considered potential losses incurred under soybean farming as a result of changes in federal farm subsidy programs or long-term forecasts of international markets.

While the direct financial benefits of reforestation to private landowners were modest (or negative), the off-site public benefits associated with water quality, human health and terrestrial and aquatic habitats are significant. These stem from increases in the quality and diversity of terrestrial ecosystems and the prevention of nitrogen, sediment, herbicides, and other contaminants from reaching the River and Gulf. Further, the carbon that would be sequestered in restored wetlands would help offset the effects of deforestation and fossil fuel use on the buildup of greenhouse gases and global warming. The special characteristics of the soil and plants in bottomland hardwood forests give them the capacity to sequester relatively large amounts of nutrients, sediments, toxins and carbon. Their position adjacent to streams gives them a valuable advantage in protecting aquatic resources since they can prevent runoff constituents from entering the streams and reaching other water bodies. Denitrification commonly occurs in these types of wetlands where large amounts of nitrogen, phosphorus and sediments are typically trapped. Plant productivity is also high because plants are rarely water limited, allowing large amounts of carbon to be trapped in plant matter.

One of the most significant effects of the reforestation is that it would increase the proportion of forested land (based on reforestation of land in soybean only) to 28% in the upper Delta region, and 42 % in the lower Delta region (Section 5.2.1). A natural land cover of 25% is thought to be an important threshold for maintaining certain wildlife species and water quality. Increasing the forested area in these areas by EMF to forests would bring more sub-basins within both regions above this threshold value. This would increase habitat range for species, leading to potential increases in species survival rates and population levels. It would also improve water quality in small streams that should be expected to support more diverse aquatic ecosystems (Allan et al. 1997, Boward and Hurd 1996, Richards et al. 1996, Richards and Minshall 1992, Roth et al. 1996).

It is important to note that there would be a lag period between the time of reforestation and some of the environmental benefits described above. The response in the nitrogen content of the surface or ground water, for example, would depend on the pool of nitrogen already present in the basin (Goolsby et al. 1999). These lag effects highlight the fact that programs and policies aimed at improving problems related to habitat loss, species survival, excess nutrients, and climate change need to be put in place well in advance of critical conditions. Based on our analysis it seems that reforesting EMF is a relatively low cost strategy for addressing many environmental problems that will be more difficult and more costly to address in any other way.

Our ability to assign dollar-based measures of value to the many ecosystem services that would result from large-scale reforestation of EMF in the Delta area is limited. However, we believe our research provides evidence that such a switch from soybeans to forests would put this land into its highest and best economic use. Two trends strengthen our confidence in this conclusion, despite weak empirical evidence regarding the dollar value of some forest ecosystem services. First, new markets are emerging for environmental services and they are become more scarce and valuable. This suggests that landowners will have new and expanding opportunities to earn income from reforesting marginal farmland. Second, world soybean markets are becoming oversupplied and risky, and forecasts of already depressed international grain prices indicate further long-term declines. This suggests that farmland left in soybean production will provide landowners with declining revenues and little or no profits. Our research provides evidence that forests, not soybeans, is the highest and best economic use of this land under current market conditions. Evidence of growing opportunities to earn income from forest products and services, and declining opportunities to earn income from soybeans supports this conclusion.

Summary of Reforestation Benefits

In summary, reforesting EMF in the Delta will result in a mix of commercial, recreational, and environmental benefits as follows:

Commercial Benefits
- Timber Production
- Bioenergy Production

Recreational Benefits
- Hunting Rights
- Fishing Rights
- Other Recreational (e.g. birding)

Environmental Benefits

Increased carbon sequestration
Reduced nutrient deliveries
Reduced sediment deliveries
Reduced contaminant deliveries
Improved terrestrial and aquatic habitat values
Improved biodiversity support

The dollar value of some of these benefits are reflected in markets, and can be captured by the landowner as income (e.g., timber and hunting rights). Other benefits accrue to the general public, are not reflected in any market transactions, and result in landowner income only by way of government programs that provide "green payments" (e.g., CRP) or allow environmental credit trading (e.g., carbon and nutrient credit trading systems). Reforestation strategies that favor one category of benefits typically result in fewer benefits in other categories (e.g., habitat values vs. timber values).

Previous sections present dollar estimates of some types of benefits, and describe what is known about assigning dollar-based measures of value to others. Markets for hunting rights, for example, peg their value at roughly $10 to $30 per acre. There are no "official" carbon credit trading systems in place to establish the economic value of carbon sequestration. However, there have been some unofficial carbon trades in the Delta region, and most forecasting models are predicting that when carbon trading commences the likely market price will be around $15 per ton of Carbon. Similarly, there are no nutrient credit trading systems in place in the Delta, but there are several nutrient trading systems operating elsewhere in the Mississippi River watershed which estimate the market value of phosphorus and nitrogen reductions $4-$24 per pound on average. We view these as useful leading indicators of the economic value of some environmental services that will result from reforestation, and as possible leading indicators of the income landowners may earn in the future as a result of reforesting.

Table 18 provides a summary of the potential economic benefits from reforesting 25%, 50%, 75% and 100% of the 2.6 million acres of EMF in the Delta area. Some of the dollar benefits provided are based on actual market observations (e.g., market value of hunting rights). Others are based on leading indicators of the potential market value of environmental "credits, if and when programs evolve that allow environmental credit trading. Table 19 provides a simple framework (an Excel spreadsheet) for further developing and refining estimates of public benefits and potential landowner revenues from reforestation as environmental markets evolve and establish actual market values.

Attachment A describes the approach we used to determine the potential market value of increased carbon sequestration that would result from EMF in the Delta. Similar approaches could be used to establish: a) the net increase in other environmental services that would result from reforestation, b) their overall (social) economic value; and c) their potential financial value to landowners.

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Table 1. Counties Completely Within Delta

Sum of Failed 1000 acres	Yield (bu/acre)	Acres Planted not Harvest (1000 acres)			Average of Proportion Planted
	Average	Max Year	Min Year	Total	Average
County	1989-1990	1989	1994	1989-1998	1989-1998
BOLIVAR	30	16	1.5	57.7	2.7%
CHICOT	28	11	3	40	3.7%
CLAY	29	0	1	29	2.2%
COAHOMA	29	10	1	42.1	3.4%
CONCORDIA	23	6	7	67	5.6%
CRAIGHEAD	29	0	1	11	1.0%
CRITTENDEN	28	8	1	37	1.9%
CROSS	31	5	3	22	1.2%
DESHA	26	7.5	1	22	2.2%
EAST CARROLL	29	4	2	21	2.4%
FRANKLIN	22	4	1	23.8	6.0%
GREENE	27	0	1	11	1.3%
HUMPHREYS	25	6.1	0.9	20.7	3.8%
IBERVILLE	37	0.8	0.1	9.8	8.2%
ISSAQUENA	25	2.6	0.2	13.7	2.1%
LEE	29	8	5	28.5	1.6%
LEFLORE	26	6.8	1.9	25.8	2.7%
MADISON	26	2	3	27	2.5%
MISSISSIPPI	30	1	2	36	1.6%
PHILLIPS	27	5	1	21	1.1%
POINSETT	30	0	1	14.5	1.0%
POINTE COUPEE	36	10	1	30.5	4.7%
QUITMAN	24	6	0.5	20.1	2.3%
RICHLAND	22	2.5	1	14.7	5.6%
SAINT FRANCIS	27	2	2	17	1.1%
SAINT JAMES	34	1.3		1.6	0.0%
SHARKEY	26	12.5	0.4	25.6	3.0%
ST CHARLES		0	0	0	0.0%
ST JOHN THE BAPTIST		0	0	0	0.0%
SUNFLOWER	26	9	1	36.2	2.9%
TENSAS	25	3	1	19.5	3.4%
TUNICA	27	10	1	34.1	2.8%
WASHINGTON	29	18	1	41.3	3.4%
WEST BATON ROUGE	32	1.9	0.4	8.4	6.6%
WEST CARROLL	25	6.5	1	15.5	6.9%
WOODRUFF	28	2	1	18	1.2%
Grand Total	28	188.5	49.9	863.1	3.1%

Table 7. Current land use of area deforested between 1950s and 1992

	Area (ha)	Area (1000 Acres)	Area (%)
Aquaculture	33400	82	2.3
Urban High Density	1050	3	0.1
Urban Low Density	25100	61	1.7
Dirt Roads	11800	29	0.8
Clouds	2950	7	0.2
Rice	220000	540	15.0
Soybean	696000	1720	47.5
Cotton	290000	710	19.8
Milo	41000	100	2.8
Sugarcane	26300	65	1.8
Corn	57100	140	3.9
Winter Wheat	6300	15	0.4
Other Crops	54200	130	3.7
Total	**1470000**	**3600**	**100**

(Values shown do not sum to total because of rounding error)

Table 8. Acreage enrolled in Wetland Reserve and Conservation Reserve Programs

STATE	COUNTY	WRP ACREAGE (1999 for LA 2000 for AK and MS)	CRP ACREAGE New Trees (2000)	TOTAL ACREAGE	Counties completely within DELTA
AR	ARKANSAS	241	127	368	
AR	ASHLEY	3674	431	4105	
AR	CHICOT	4979	2	4981	4981
AR	CLAY	436	5	441	441
AR	CRAIGHEAD	222	277	499	499
AR	CRITTENDEN	166	0	166	166
AR	CROSS	411	258	669	669
AR	DESHA	5029	65	5094	5094
AR	DREW	1614		1614	
AR	GREENE	498	27	525	525
AR	INDEPENDENCE	149	0	149	
AR	JACKSON	933	199	1132	
AR	JEFFERSON A	229	647	876	
AR	LAWRENCE		315	315	
AR	LEE	6168	0	6168	6168
AR	LINCOLN	154	502	656	
AR	LONOKE	825	144	969	
AR	MISSISSIPPI	1065	0	1065	1065
AR	MONROE	6034	55	6089	
AR	PHILLIPS	2584	149	2733	2733
AR	POINSETT	2016	17	2033	2033
AR	PRAIRIE	2934	2	2936	
AR	PULASKI	1983	17	2000	
AR	RANDOLPH	505	0	505	
AR	SAINT FRANCIS	3146	32	3178	3178
AR	WHITE	4698	302	5000	
AR	WOODRUFF	3464	731	4195	4195
AR Total		**54157**	**4303**	**28460**	**31747**
LA	ASCENSION			0	
LA	ASSUMPTION			0	
LA	AVOYELLES	523	2	525	
LA	CALDWELL	3349	164	3513	
LA	CATAHOULA		2	2	
LA	CONCORDIA	850	5	855	855
LA	EAST BATON ROUGE			0	
LA	EAST CARROLL	1000	2	1002	1002
LA	EVANGELINE		229	229	
LA	FRANKLIN	468	3	471	471
LA	IBERIA			0	
LA	IBERVILLE			0	0
LA	JEFFERSON DAVIS		0	0	
LA	LA SALLE			0	

LA	LAFAYETTE			0	
LA	LAFOURCHE			0	
LA	LIVINGSTON			0	
LA	MADISON		2	2	2
LA	MOREHOUSE		415	415	
LA	ORLEANS			0	
LA	OUACHITA		0	0	
LA	PLAQUEMINES			0	
LA	POINTE COUPEE			0	0
LA	RAPIDES		0	0	
LA	RICHLAND	341	304	345	345
LA	SAINT JAMES			0	0
LA	SAINT LANDRY		0	0	
LA	SAINT MARTIN			0	
LA	SAINT MARY			0	
LA	SAINT TAMMANY			0	
LA	ST BERNARD			0	
LA	ST CHARLES			0	0
LA	ST JOHN THE BAPTIST			0x	
LA	TANGIPAHOA		423	423	
LA	TENSAS	3344	3	3347	3347
LA	TERREBONNE			0	
LA	UNION			0	
LA	VERMILION			0	
LA	WEST BATON ROUGE			0x	
LA	WEST CARROLL	75	3	78	78
LA	WEST FELICIANA			0	
LA Total		**9951**	**1980**	**11931**	**6099**
MS	ADAMS	3389	253	3642	
MS	BOLIVAR	2774	0	2774	2774
MS	CARROLL		903	903	
MS	CLAIBORNE	1831		1831	
MS	COAHOMA	7897	1	7898	7898
MS	DESOTO		106	106	
MS	GRENADA	1020	652	1672	
MS	HOLMES	2844	3	2847	
MS	HUMPHREYS	3097	185	3282	3282
MS	ISSAQUENA	8598	0	8598	8598
MS	JEFFERSON M	4883	499	5382	
MS	LEFLORE	4097	2	4099	4099
MS	PANOLA		2	2	
MS	QUITMAN	3313	2	3315	3315
MS	SHARKEY	14858	633	15491	15491
MS	SUNFLOWER	6293	393	6686	6686
MS	TALLAHATCHIE	210	2	212	
MS	TATE		871	871	
MS	TUNICA		0	0	0
MS	WARREN	2048	684	6732	
MS	WASHINGTON	566	198	764	764

MS	WILKINSON	1510	72	1582	
MS	YAZOO	2025	3	2028	
MS Total		**75251**	**5464**	**80715**	**52907**
Grand Total		**139359**	**11747**	**151106**	**90753**

Source: WRP Information from USDA NRCS website at http://www.wl.fb-net.org/.
CRPInformation from USDA FSA website at http://www.fsa.usda.gov/dafp/cepd/20th/main.htm

Table 11. Comparison of Fragmentation Indices generated by FRAGSTATS for Current Forest and 100% reforestation scenario for upper and lower Delta (3-state area)

Land Use Scenario	% of Landscape in Forest	Total Area of Forest (1000 acres)	Largest Patch Index (%)	Mean Patch Size (acres)	Total Core Area (1000 acres)	Number of Core Areas	Total Core Area Index (%)
			Largest patch as % of forest				Core area as % of forest
Upper Scene							
Current Forest	20	2,757	12	44	330	1,160	12
100% reforested	28	3,790	17	64	354	1,567	9
Lower Scene							
Current Forest	36	4,087	17	89	738	2,374	18
100% reforested	42	4,720	16	89	755	2,556	16

Table 12. Benefits Summary for 100% Reforestation Scenarios

Reforestation Scenario		Net present value for 130 yr period		Benefits over 70 year period								
	Area Reforested	Financial Returns from Sale of Wood Products		Sediment Reduction		Herbicide Reduction		Nitrogen Reduction	Phosphorus Reduction	Habitat Benefits		Carbon Sequestered
	(1000 acres)	Annual equivalent value with 4% discount rate (year 1998 dollars/yr)	Annual equivalent value with 7% discount rate (year 1998 dollars/yr)	Based on sediment export from land (Murphree & McGregor, 1991) (1000 tons/yr)	$ value (millions, 1998 dollars)	Reduction in applications (assumes 1 application per rotation for trees) (# / 70 yrs)	Reduction in quantity of active ingredient released (billions oz/ 70 yrs)	Based on Shabman and Zepp (1000 lbs/yr)	Based on Shabman and Zepp (1000 lbs/yr)	See Appendix A	Core Area Increase from 1.7 million acres reforestation (rare habitat) (acres)	Million metric tons
1. all cottonwood on 10-year rotations for pulp	2600	4446	-6396	~6370	$22	62	3.9	~13600		Moderate	40500	90
2. cottonwood/nutall oak interplant with cottonwood on 10-year rotation	2600	12792	-13416	12740	$44	66	4.1			High	40500	123
3. nutall oak for sawlog production on 70-80 year rotations (nutall – seeded nutall)	2600	12974 – 17030	(-15496) – (-3354)	12740	$44	69	4.3	27300		High	40500	144
4. bottomland hardwood with no harvest	2600			12740	$44	70	4.4	27300	7300	High	40500	146

~ indicates cottonwood values are extremely rough estimates calculated as 1/2 bottomland hardwood scenario estimates based on comparison of soil carbon values for cottonwood and bottomland hardwood

Table 13. Literature Values for Nutrient Export, Application Rates and In-Stream Measurements

			Nutrient Export (Edge-of-Field)			Application Rates			Pollutant Loads (In-Stream)	
References	Land Use	location	Total Nitrogen Export (lb/ac/yr)	Total Phosphorus Export (lb/ac/yr)	Soil Erosion Rates (lb/ac/yr)	Fertilizer Application lb/ac/yr N	P	K	Total Nitrogen lb/acre/yr	Total Phosphorus lb/acre/yr
Reckhow, 1980	Soybeans; two crops/yr; conventional tillage (.01 ha)	Holy Springs, MS	0.041	0.016	na	0	0.005	0.05	0.041	0.016
Reckhow, 1980	Soybeans; two crops/yr; no till (.0 ha)	Holly Springs, MS	0.005	0.002	na	0	0.005	0.05	0.004	0.003
Reckhow, 1980	Soybeans-corn two crops/yr no till(.01 ha)	Northern MS	0.02	0.006	na	0	0.005	0.05	0.03	0.006
Reckhow, 1980	corn-soybeans; two crops/yr no till (.01 ha)	Northern MS	0.017	0.003	na	136	0.02	0.03	0.02	0.004
USGS Water Resources Investigations Report 98-4219	single cropped watershed per year	Northern MS	41.4 lbs/ac	15.2 lbs/ac	na					
USGS Water Resources Investigations Report 98-4219	single cropped watershed per year	Yazoo River Basin	38.5 lbs/ac	18.9 lbs/ac	na					
Hohenstein 1994	Cropping system: corn	typical impacts			0.000000019	0.12	0.05	0.07		
Hohenstein 1994	Cropping system: soybeans	typical impacts			0.000000036	0.02	0.04	0.06		
Kleiss, 1996	mixed	Yazoo Basin			7100					
McElroy et al. (1976)*	Cropland	Connecticut	.0007-.009	.001-.014						
USEPA (1982)*	Cropland	Connecticut	.008-.018	.002-.005						
Ott et al. (1990)*	63% Agric.	Connecticut	.024-.038	.0016-.002						
Donigian et al. (1990)*	Cropland conserv.	Connecticut	.005-.02	.0003-.002						
Donigian et al. (1990)*	Cropland conserv.	Connecticut	.005-.069	.0005-.005						
Clesceri et al. (1986)*	Forest	Connecticut	.003-.0034	.0000008-.00002						
Ott et al. (1990)*	100% Forest	Connecticut	.018-.003	.00003-.00004						
Donigian et al. (1990)*	Forest	Connecticut	.0002-.005	.00005-.0003						
Shabman & Zepp (2000)	Forest	Yazoo watershed							1.32	0.28
Shabman & Zepp (2000)	Wetland	Yazoo watershed							0.66	0.17
Shabman & Zepp (2000)	Cropland-soybean	Yazoo watershed							11.17	2.99

Table 15. Cumulative Carbon Storage for Reforestation Scenarios (MT/acre)

Stand Age	Bottomland Hardwood No Harvest	Nutall Oak 80-year Rotation with 2 Thinnings	Cottonwood 10-year Rotations	Cottonwood-Oak Interplant
0	7	7	7	7
5	9	11	16	17
10	12	16	26	27
15	15	21	18	22
20	19	26	28	34
25	23	30	18	29
30	28	35	31	42
35	32	34	20	37
40	37	39	30	50
45	41	43	23	45
50	45	48	34	58
55	49	53	24	51
60	52	46	34	63
65	54	51	24	35
70	56	55	35	47
75	58	59	24	38
80	60	64	35	50
85	61	27	25	43
90	63	28	36	55
95	64	32	26	49
100	65	37	37	61

Table 16. Average Annual Carbon Storage (Trees, Soil, Litter & Debris) for Reforestation Scenarios (MT/acre/yr)

Stand Age	Bottomland Hardwood No Harvest	Nutall Oak 80-year Rotation with 2 Thinnings	Cottonwood 10-year Rotations	Cottonwood-Oak Interplant
0-15	0.58	0.95	0.73	1.00
16-50	0.86	0.76	-0.09	0.48
51-70	0.55	0.33	0.03	0.25
51-100	0.39	-0.22	0.41	0.37
0-100	0.59	0.59	0.28	0.50

Table 17. Average Annual Carbon Storage (Trees, Soil, Litter & Debris) for Reforestation Scenarios Excluding Harvest Years (MT/acre/yr)

Stand Age	Bottomland Hardwood No Harvest	Nutall Oak 80-year Rotation with 2 Thinnings	Cottonwood 10-year Rotations	Cottonwood-Oak Interplant
0-15	0.58	0.95	1.89	2.14
16-50	0.86	0.68	2.02	2.48
51-70	0.55	0.68	1.96	2.11
51-100	0.39	0.76	1.98	2.25
0-100	0.59	0.85	1.98	2.31

N.B. Depending on assumptions, the Tree C sequestration that contributes to these values would be reduced by the amount of C not remaining in wood products.

TABLE18.
REFORESTATION BENEFIT SUMMARY - ANNUAL VALUES

Illustrative Economic Value of Reforesting Economically Marginal Farmland (EMF)
in the Mississippi River Delta
Scenario #1: Nutall oak on 80 year rotations with 2 thinnings

I. Background

Region: 36 counties in the Delta region of Arkansas, Louisiana, and Mississippi
Extent of Area: 2.6 million acres of economically marginal farmland
Source of Benefits: Reduced nutrient/contaminant runoff, increased carbon sequestration flood damage avoided, biodiversity support, hunting/fishing opportunities
Source of Landowner Earnings:
Current: Hunting rights, timber rights unofficial carbon sequestration credits
Pending: Official carbon sequestration credits, nutrient/sediment reduction credits biodiversity credits, bioenergy crops

II. Summary

Benefit Category	Annual Per Acre (Dollars)	Total Annual Benefits (Millions of Dollars) Percent reforestation of 2.6 million acres of EMF 25% (.65m acres)	50% (1.3m acres)	75% (1.95m acres)	100% (2.6m acres)
Commercial					
Timber Production[a]	4.99	3.244	6.487	9.731	12.974
Recreational					
Hunting Rights[b]	10.00	6.500	13.000	19.500	26.000
Wildlife Viewing	????	????	????	????	????
Environmental					
Carbon Credits[c]	7.50	4.875	9.750	14.625	19.500
Nutrient Credits[d]	11.20	7.280	14.560	21.840	29.120
Total	$33.69	21.899	43.797	65.696	87.594

a) Annual Values presented for Timber Production are based on Table 10
b) Annual Values for Hunting are based on the low end of the range of prevailing prices in the Delta area (roughly $10 to $30 per acre per year as described in Section 5.1).
c) Annual Values for Carbon credits are speculative and are based on: 1) the emergence of Carbon credit markets, 2) potential Carbon sequestration credit earnings of .5 tons of Carbon (tC) per acre per year, and 3) a market value of $15 per tC (See Section 5.3)
d) Annual Values for Nutrient credits are speculative and are based on: 1) the emergence of Nutrient credit markets, 2) potential nutrient reduction credit earnings of 2.8 pounds per acre per year and 3) a potential market value of $4 per pound. (See Table 12 and Section 5.3) Nitrogen reductions were considered too unreliable to use at this time so the nutrient credit values are based only on Phosphorus.

NOTES

These annual values are based on existing commercial markets for timber and hunting and potential environmental markets for carbon and nutrient credits. The values presented for potential environmental markets are speculative. They are annualized values assumed to exist throughout the period of analysis. They are not adjusted to reflect either changes in demand conditions that may limit the ability of landowners to sell increased production at prevailing prices (i.e., demand elasticity); nor are they adjusted to reflect changes in supply conditions that will result from the emergence of these markets and will change prevailing prices (i.e., supply elasticity).

In the case of nutrients the values shown are based on a actual credit trades in a few small markets outside the Delta region. (See Section 5.3) In the case of carbon the values are based on the best available econometric forecasts of expected national and/or international credit prices. (See Section 5.3). In the absence of any "official" carbon credit scoring criteria annual carbon credits earned in this scenerio are assumed to be 50% of average annual carbon sequestration rates based on the "no harvest" scenerio.

TABLE19.

REFORESTATION BENEFIT SUMMARY - NET PRESENT VALUES

Illustrative Economic Value of Reforesting Economically Marginal Farmland (EMF)
in the Mississippi River Delta
Scenario #1: Nutall oak on 80 year rotations with 2 thinnings

I. Background

Region: 36 counties in the Delta region of Arkansas, Louisiana, and Mississippi

Extent of Area: 2.6 million acres of economically marginal farmland

Source of Benefits: Reduced nutrient/contaminant runoff, increased carbon sequestration flood damage avoided, biodiversity support, hunting/fishing opportunities

Source of Landowner Earnings:

Current: Hunting rights, timber rights unofficial carbon sequestration credits

Pending: Official carbon sequestration credits, nutrient/sediment reduction credits biodiversity credits, bioenergy crops

II. Summary

Benefit Category	Per Acre[a] (Dollars)	Net Present Value (Millions of Dollars) Percent reforestation of 2.6 million acres of EMC 25% (.65m acres)	50% (1.3m acres)	75% (1.95m acres)	100% (2.6m acres)
Commercial					
Timber Production	119.34	77.571	155.142	232.713	310.284
Recreational					
Hunting Rights	239.15	155.448	310.895	466.343	621.790
Wildlife Viewing	????	????	????	????	????
Environmental					
Carbon Credits	179.37	116.591	233.181	349.772	466.362
Nutrient Credits	267.85	174.103	348.205	522.308	696.410
Total	$805.71	523.712	1047.423	1571.135	2094.846

a) These are based on the annualized values presented in Table 18 accruing during each year over an 80 year period and discounted to present value at 4%.

NOTES

These net present values are based on existing commercial markets for timber and hunting and potential environmental markets for carbon and nutrient credits. The values presented for potential environmental markets are speculative. They are annualized values assumed to exist throughout the period of analysis. They are not adjusted to reflect either changes in demand conditions that may limit the ability of landowners to sell increased production at prevailing prices (i.e., demand elasticity); nor are they adjusted to reflect changes in supply conditions that will result from the emergence of these markets and will change prevailing prices (i.e., supply elasticity).

In the case of nutrients the values shown are based on a actual credit trades in a few small markets outside the Delta region. (See Section 5.3) In the case of carbon the values are based on the best available econometric forecasts of expected national and/or international credit prices. (See Section 5.3). In the absence of any "official" carbon credit scoring criteria annual carbon credits earned in this scenerio are assumed to be 50% of average annual carbon sequestration rates based on the "no harvest" scenerio.

Location of Mississippi Delta

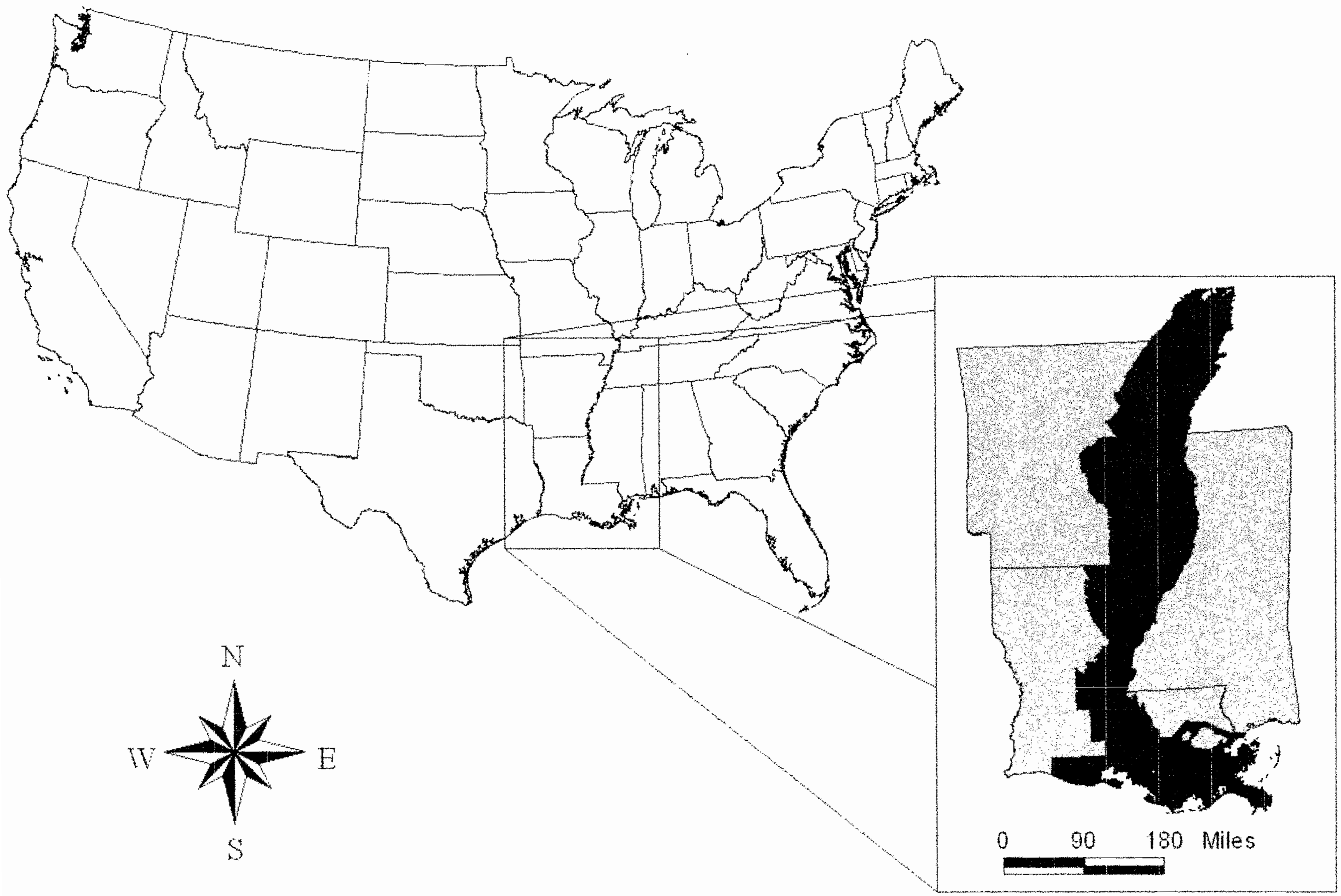


Figure 1

Counties used in Analysis of Delta

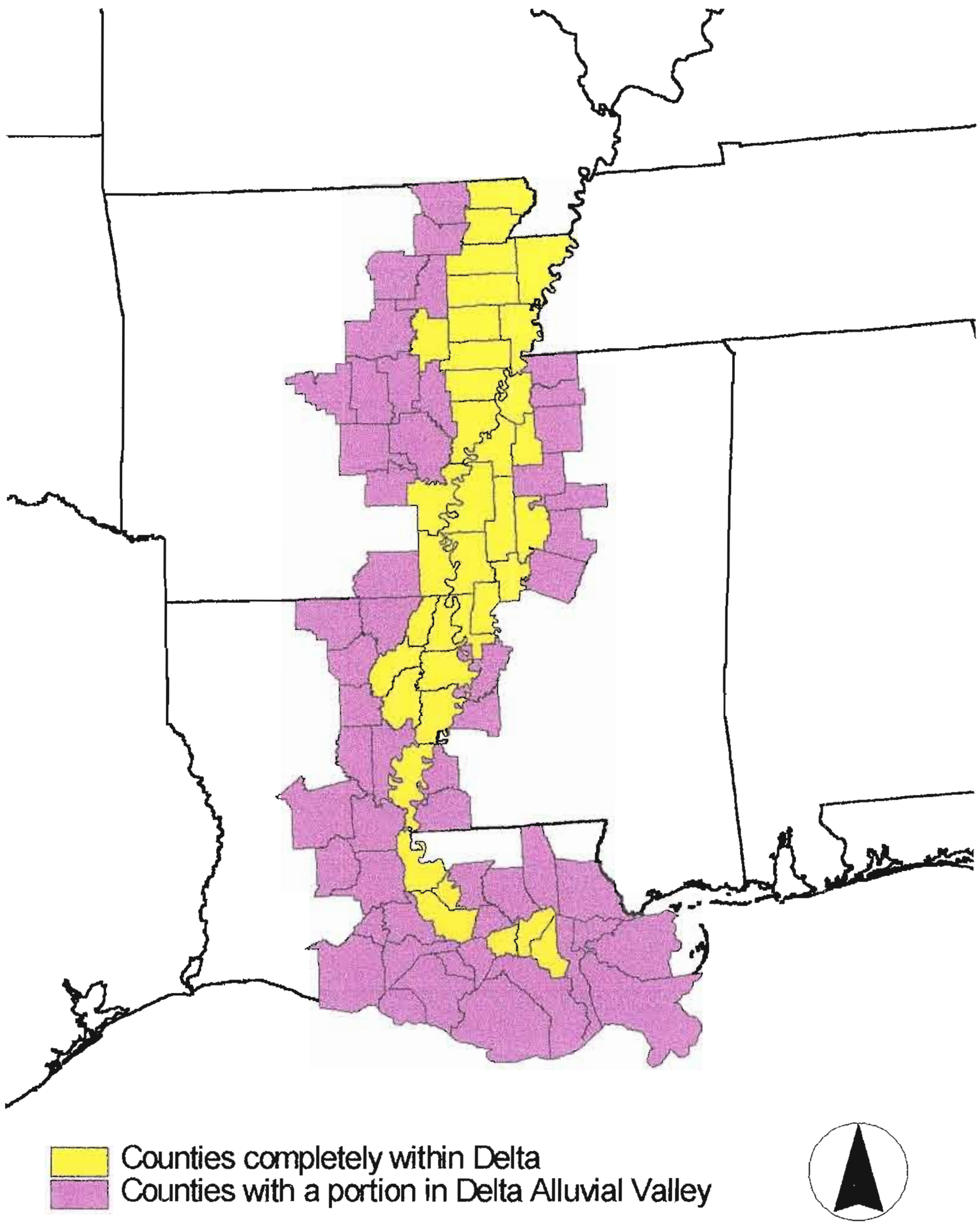


Figure 2

Geology of the Mississippi Alluvial Valley and Deltaic Plain

Data Source: LMV / GIS Steering Committee 1996
Original Source: Saucier 1994, US Army COE

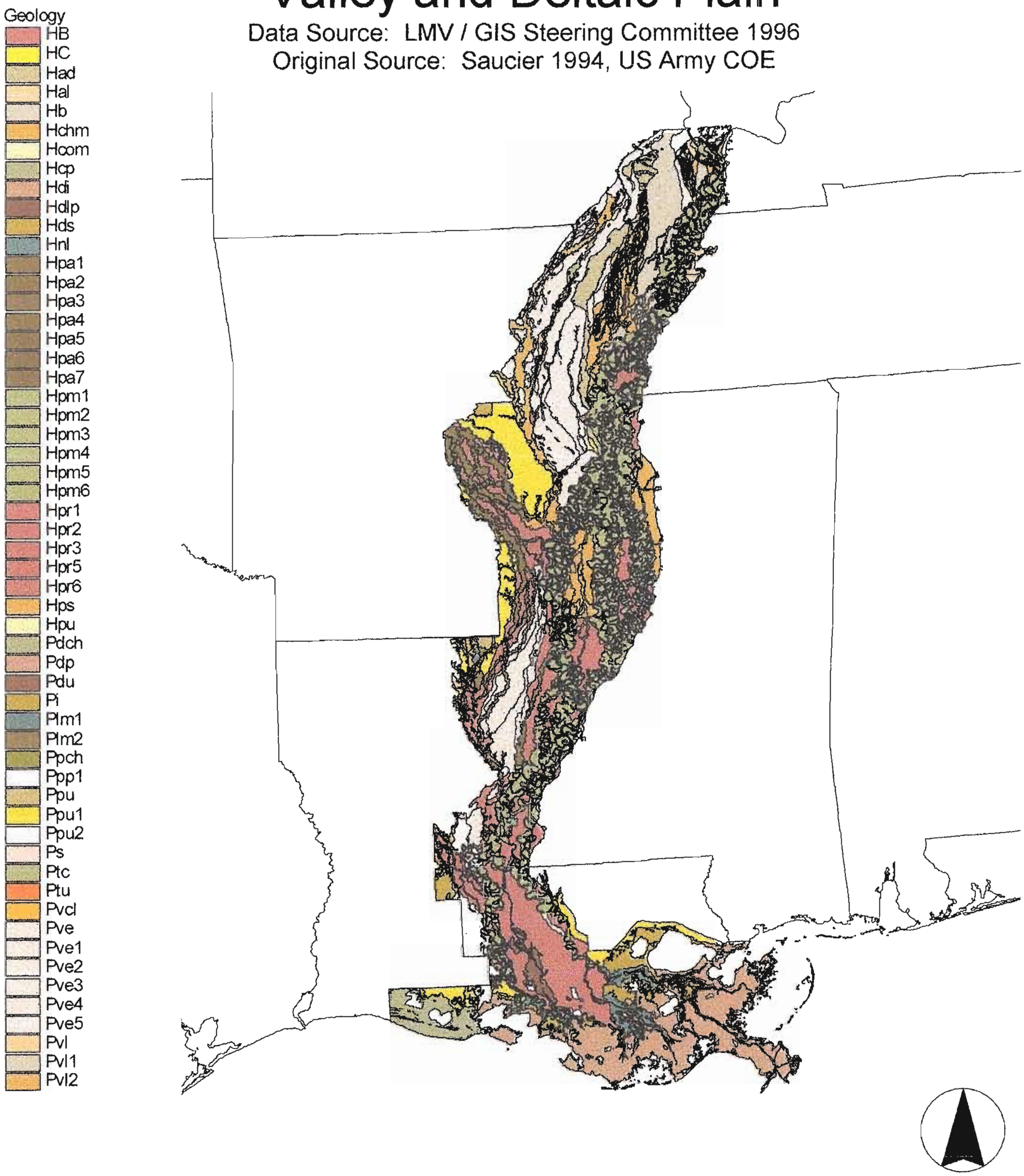
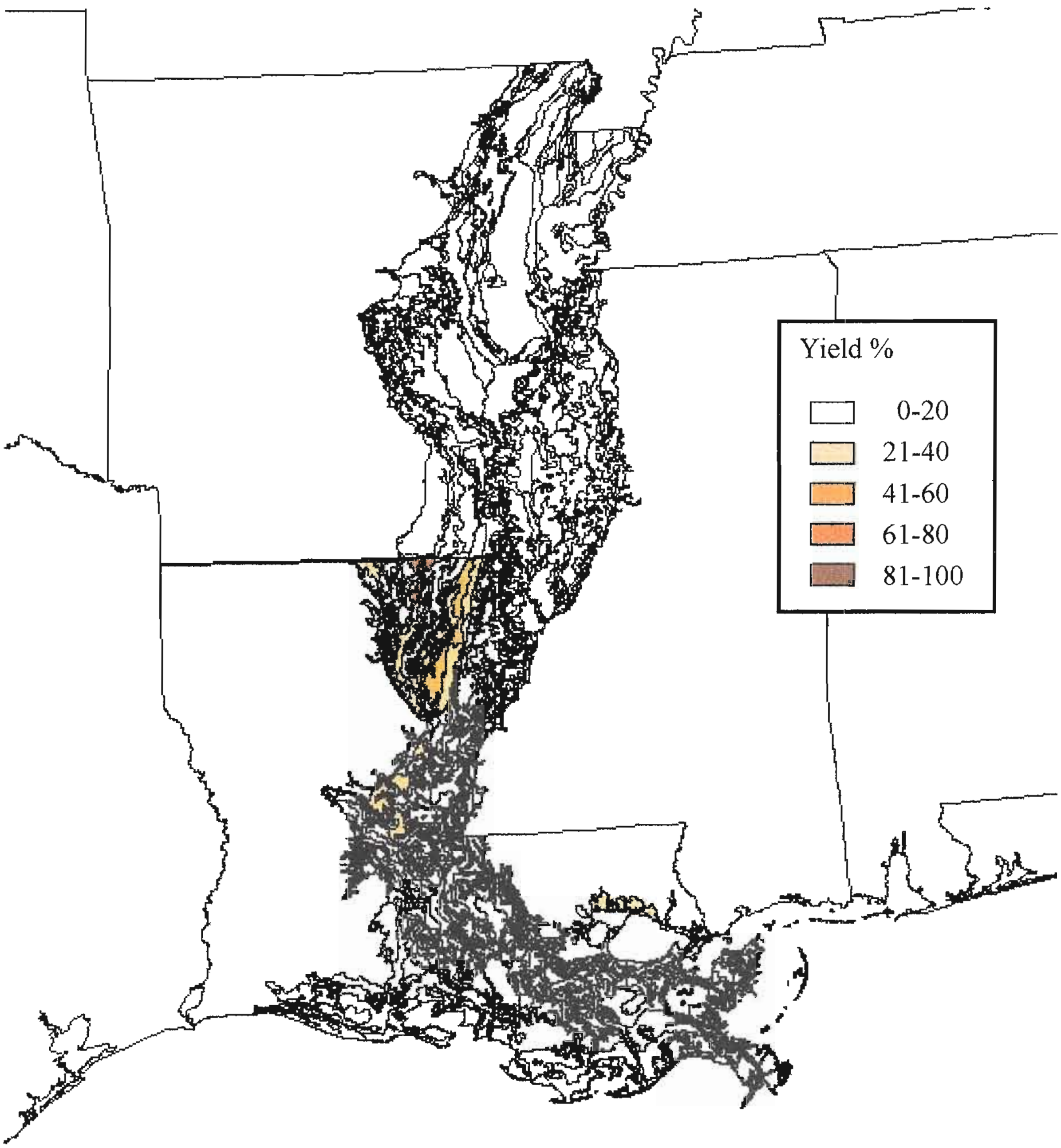


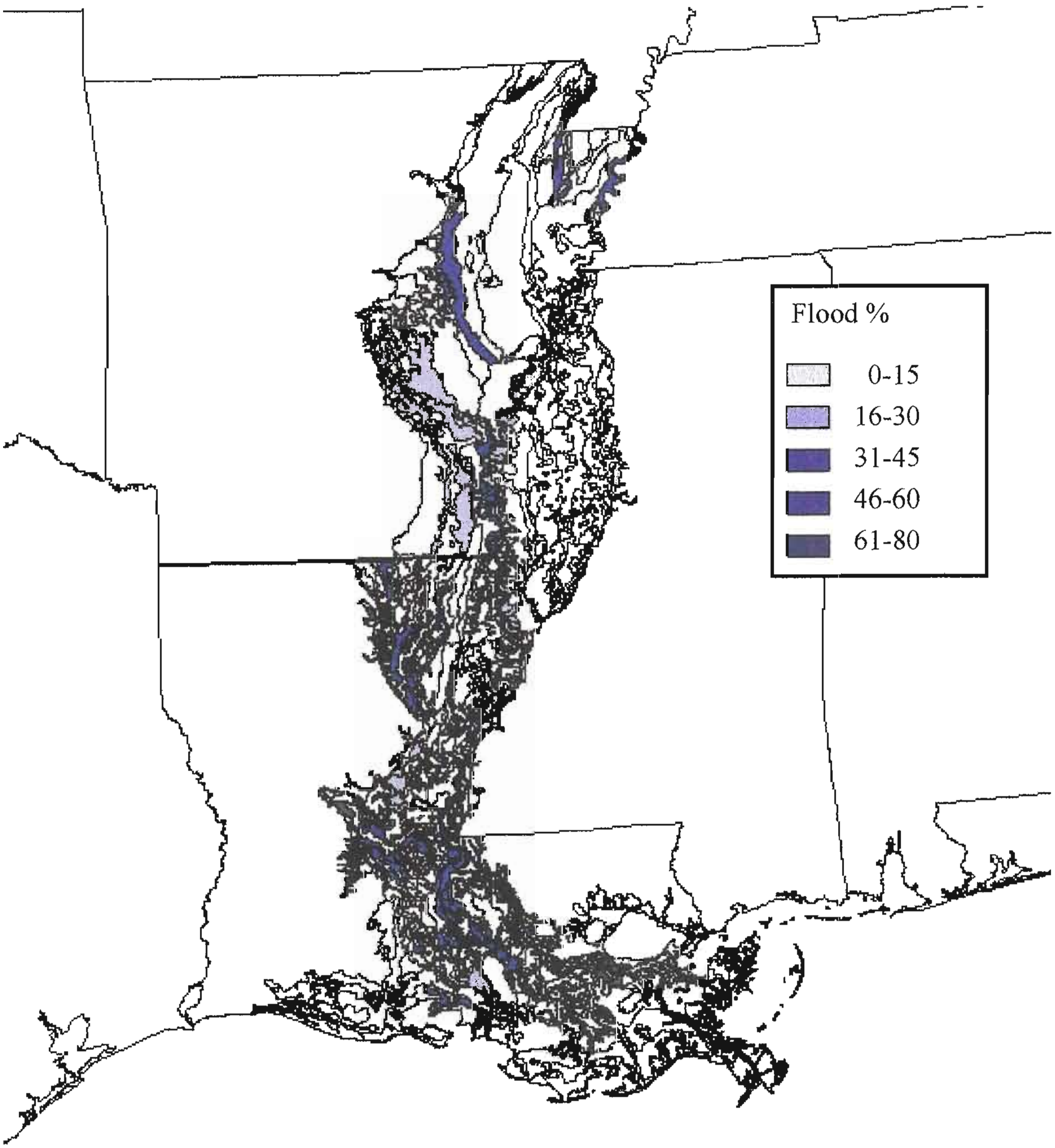
Figure 3

Percentages of Soy Yields 10-25 bu/acre by Map Unit



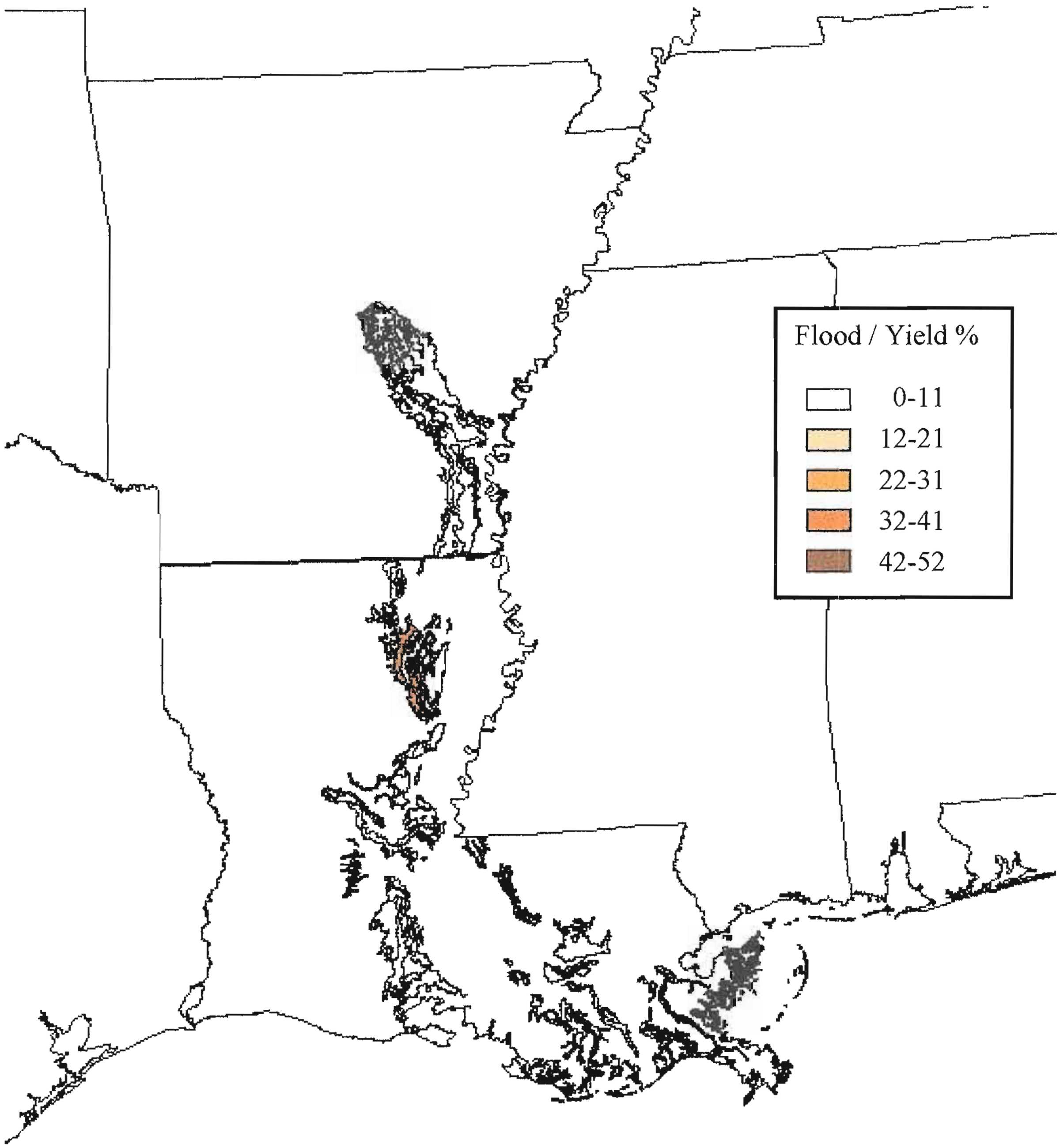
(Source of base data: USDA, NRCS STATSGO database)
Figure 4

Percentages of Annual Average Flood End Date of May or June by Map Unit



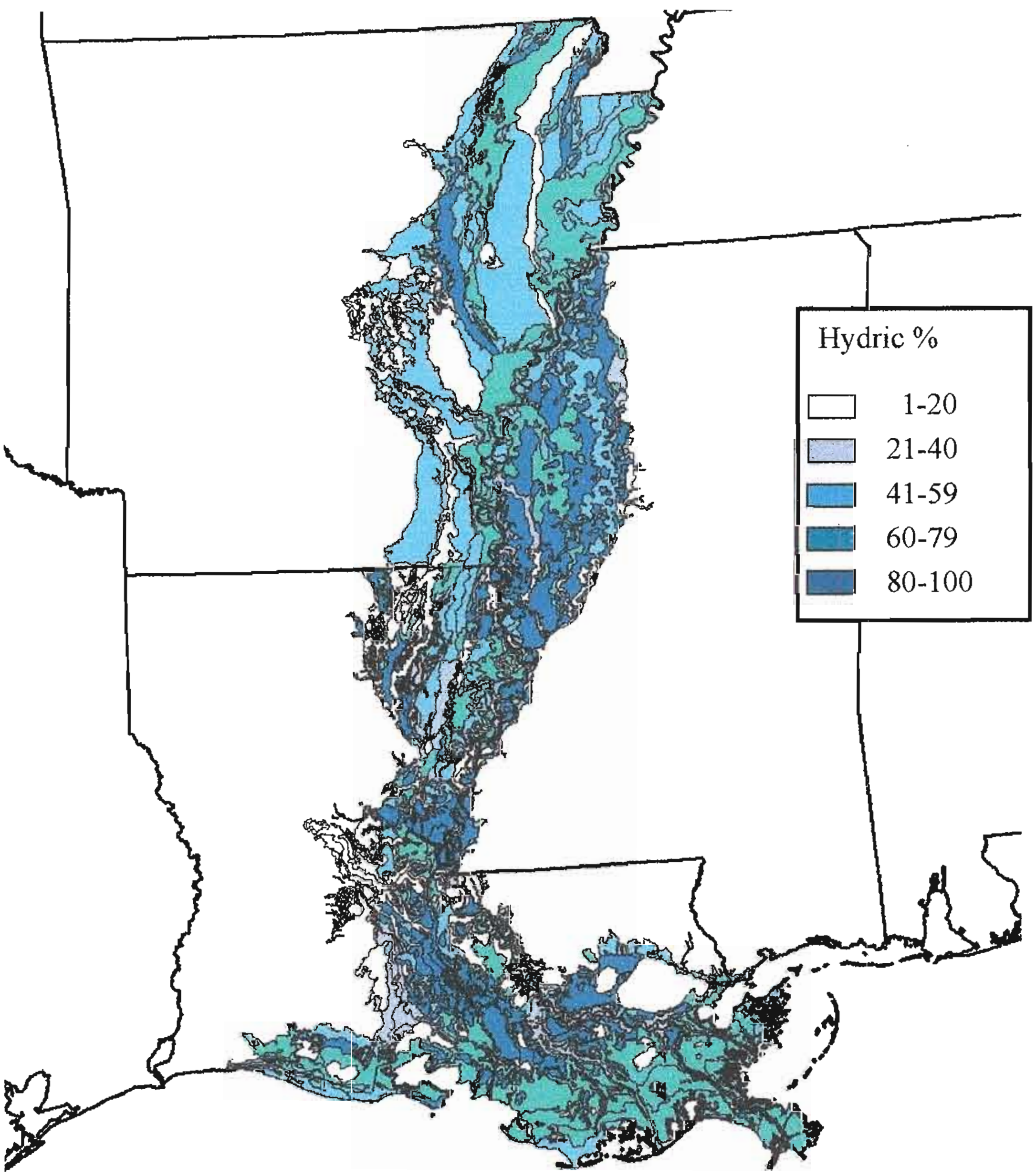
(Source of base data: USDA, NRCS STATSGO database)
Figure 5

Percentages of Marginal Farm Yields and Annual Flood End Dates of June by Map Unit



(Source of base data: USDA, NRCS STATSGO database)
Figure 6

Percentages of Hydric Soils by Map Unit



(Source of base data: USDA, NRCS STATSGO database)
Figure 7

Land Cover in the Delta

Data Source: LMV / GIS 1996,
Original Source: USFWS and NBS

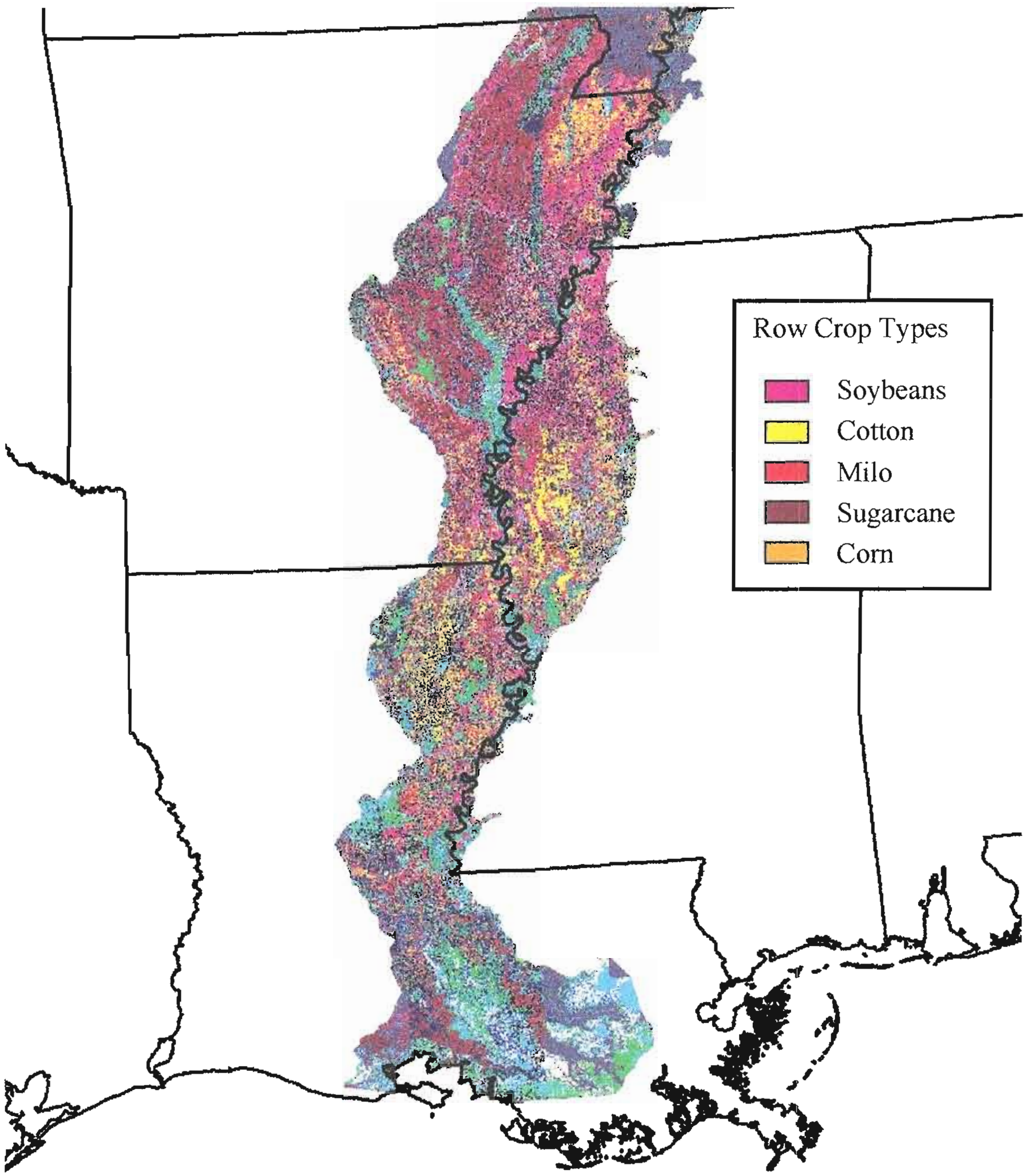


Figure 8

Forest Lost to All Development Types Between 1950s and 1992

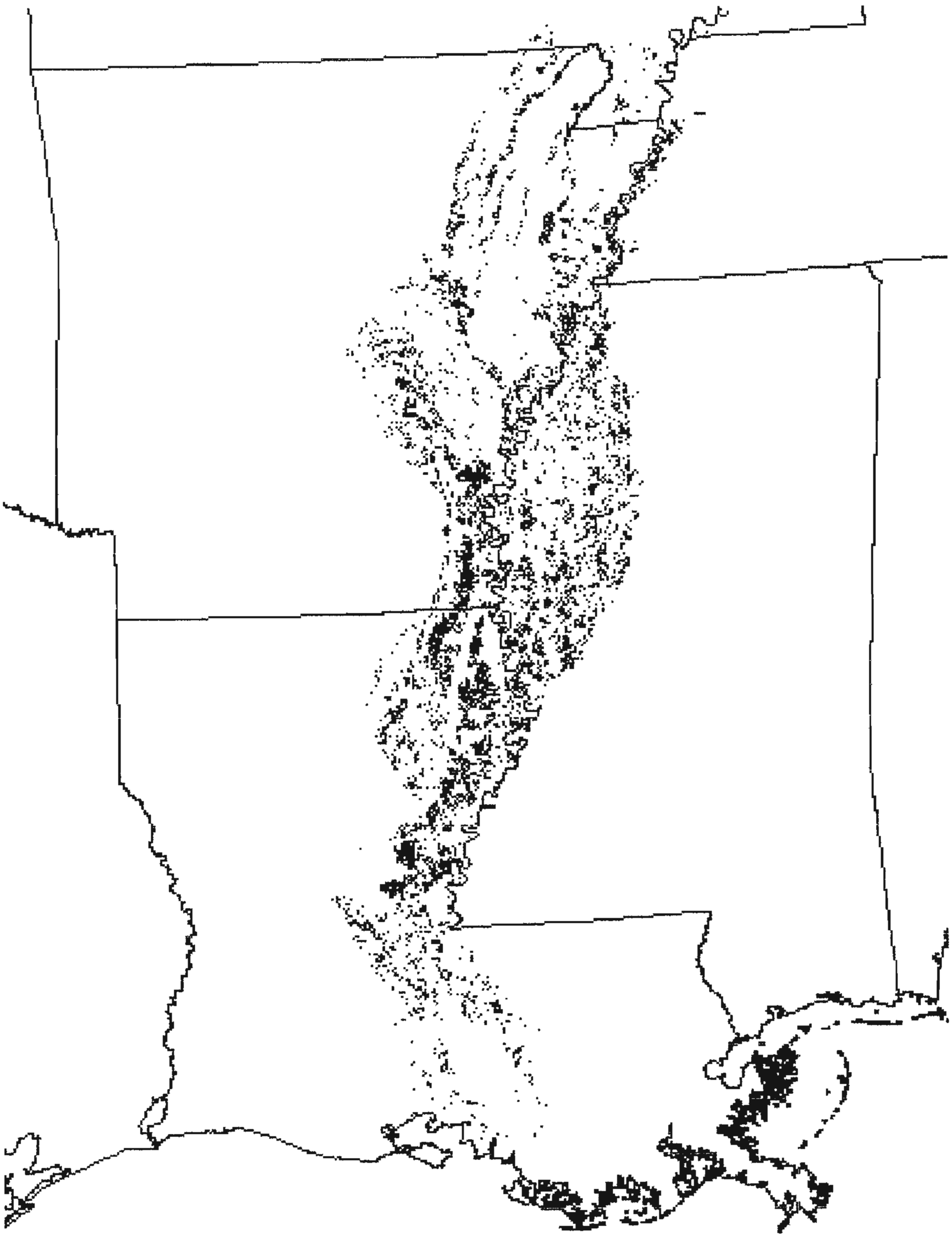


Figure 9

Forest Lost to Soybean Agriculture Between 1950s and 1992

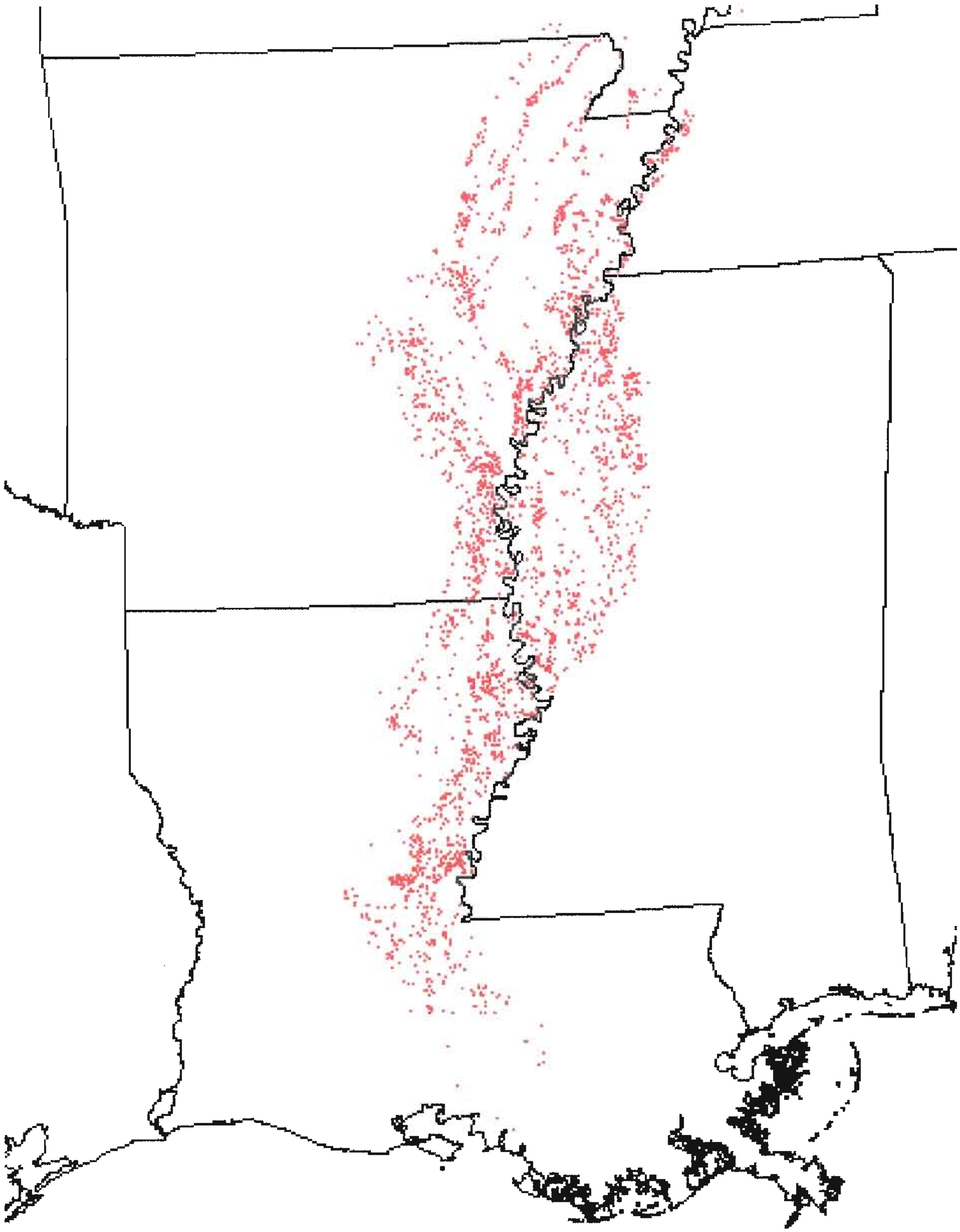


Figure 10

MRLC Land Use in Delta

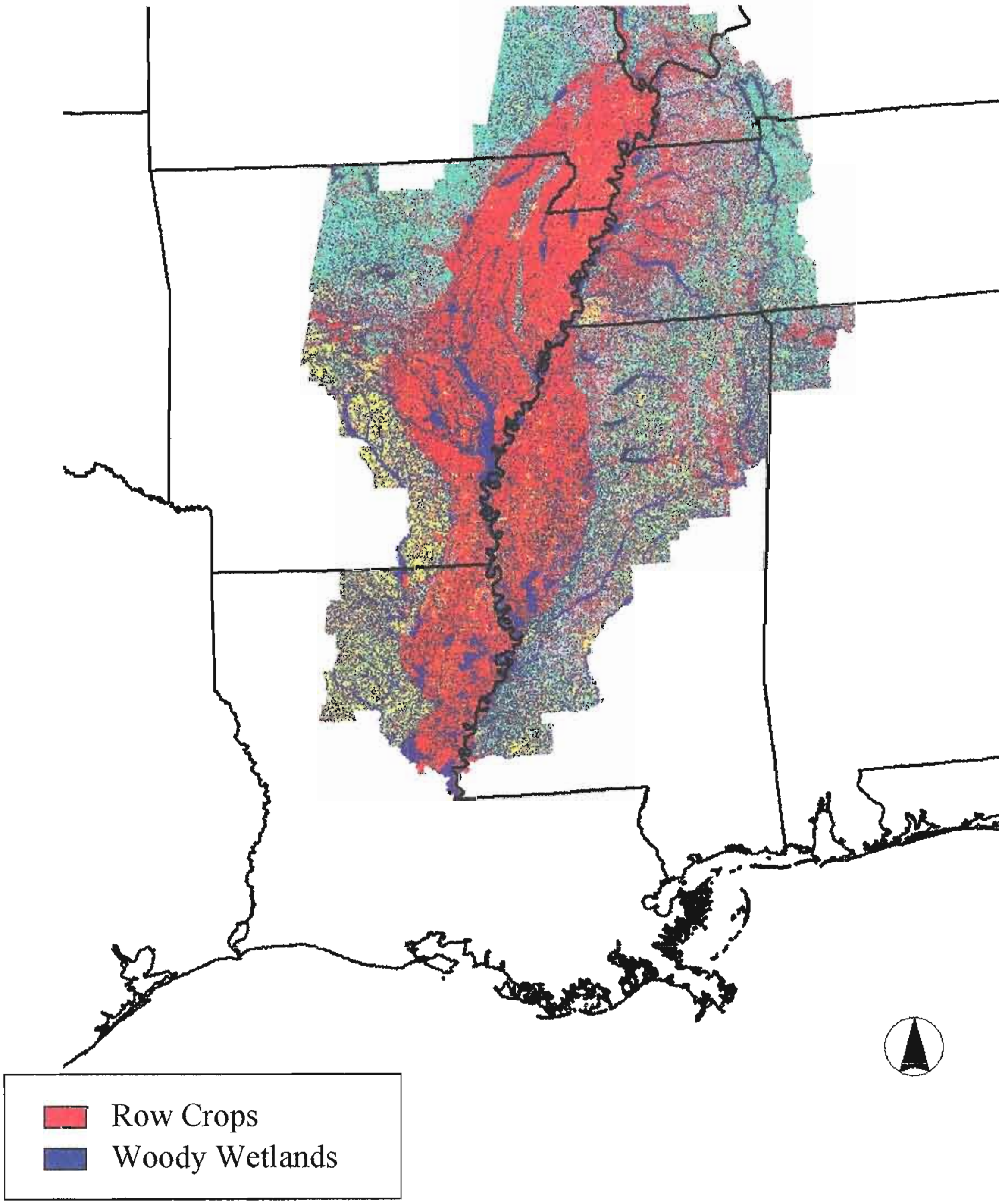


Figure 11

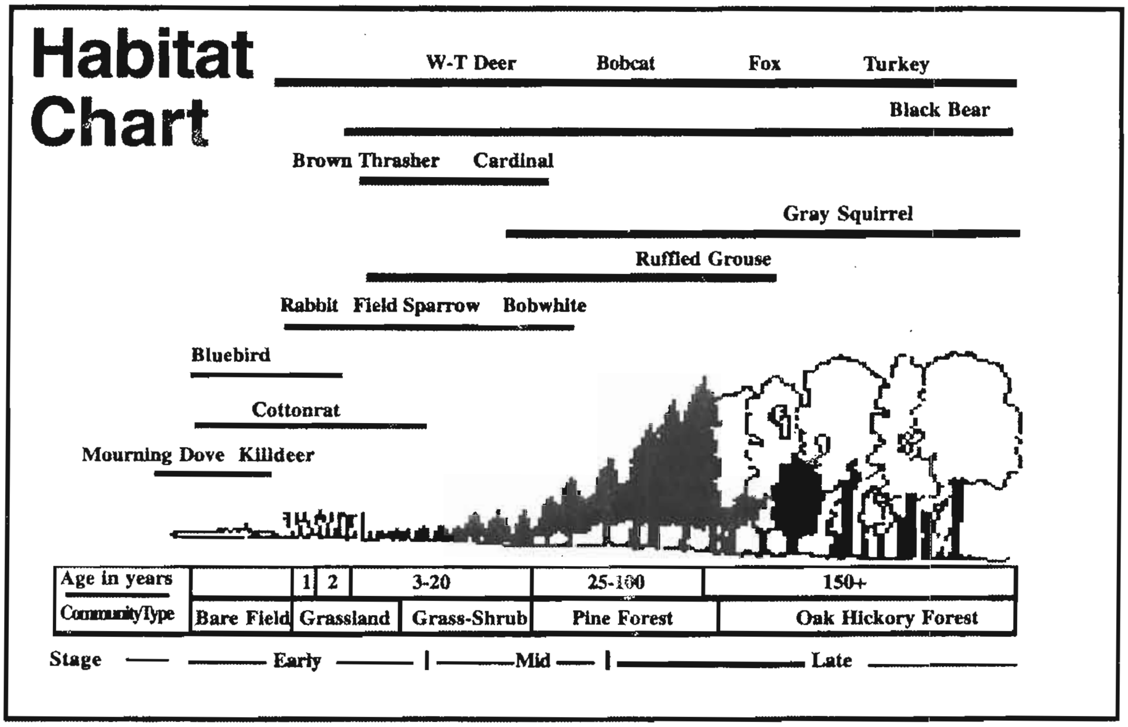


Figure 12

Source: Hamilton, R.A. Forest*A*Syst: A self-assessment guide for managing your forest for timber production, wildlife, recreation and aesthetics, and water quality. Dept of Forestry, North Carolina State University. Farmasys@uwex.edu

100% Reforestation Scenario Showing Current Forest (green) and Marginal Soybean Farms with Potential for Restoration (red)

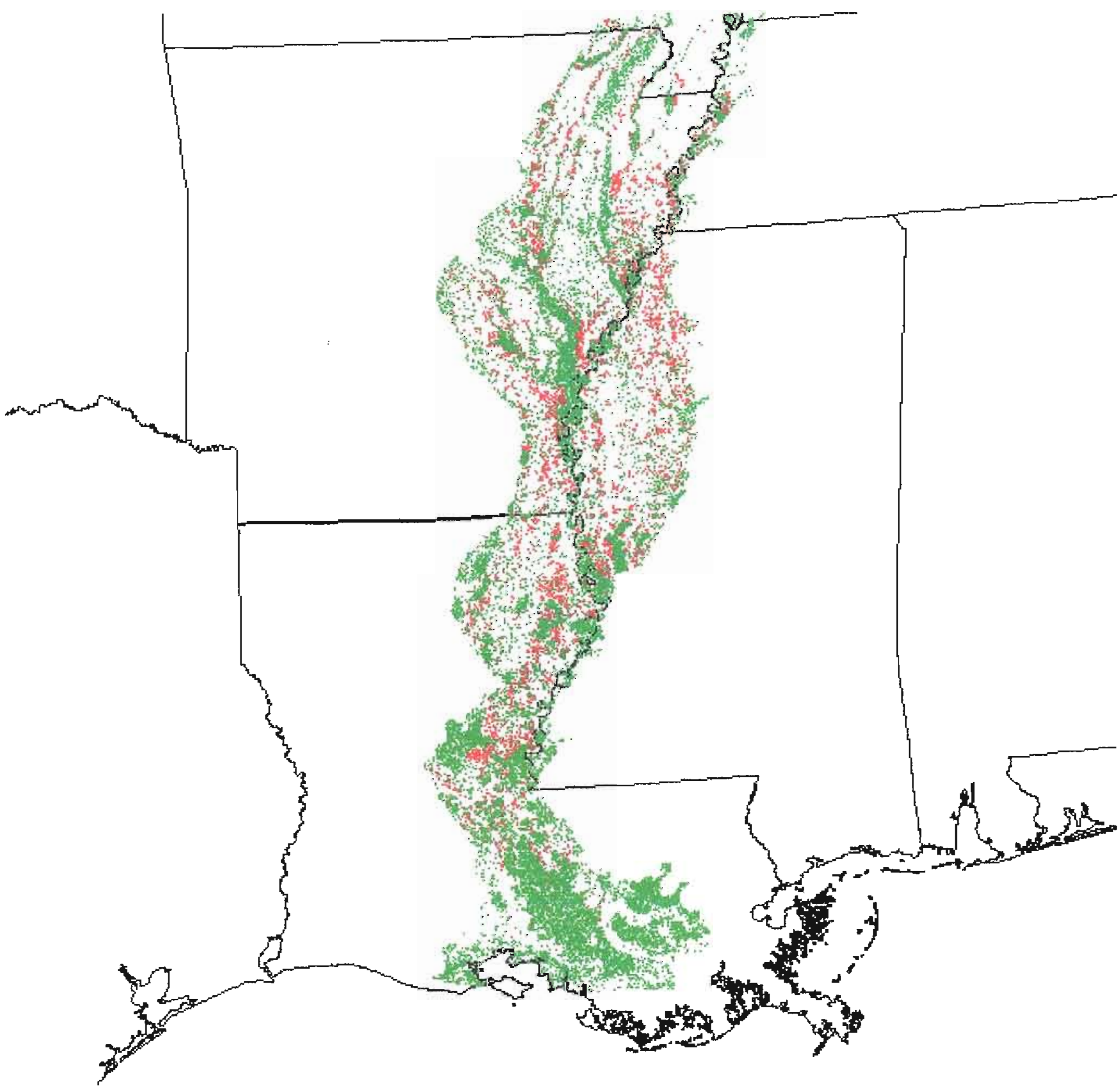


Figure 13

Figure 14

Cottonwood on 10-year rotation

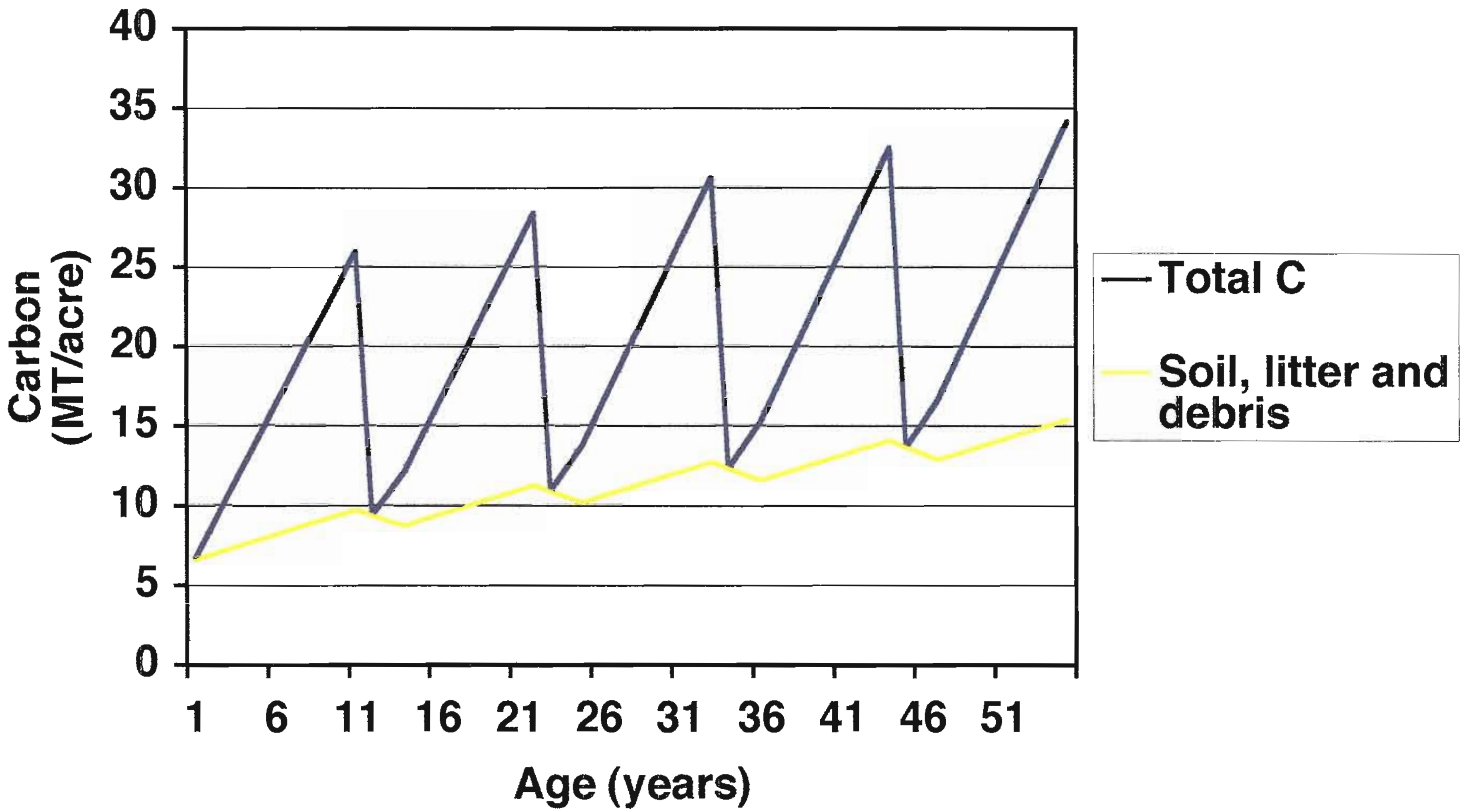


Figure 15
Cottonwood - Oak Interplant

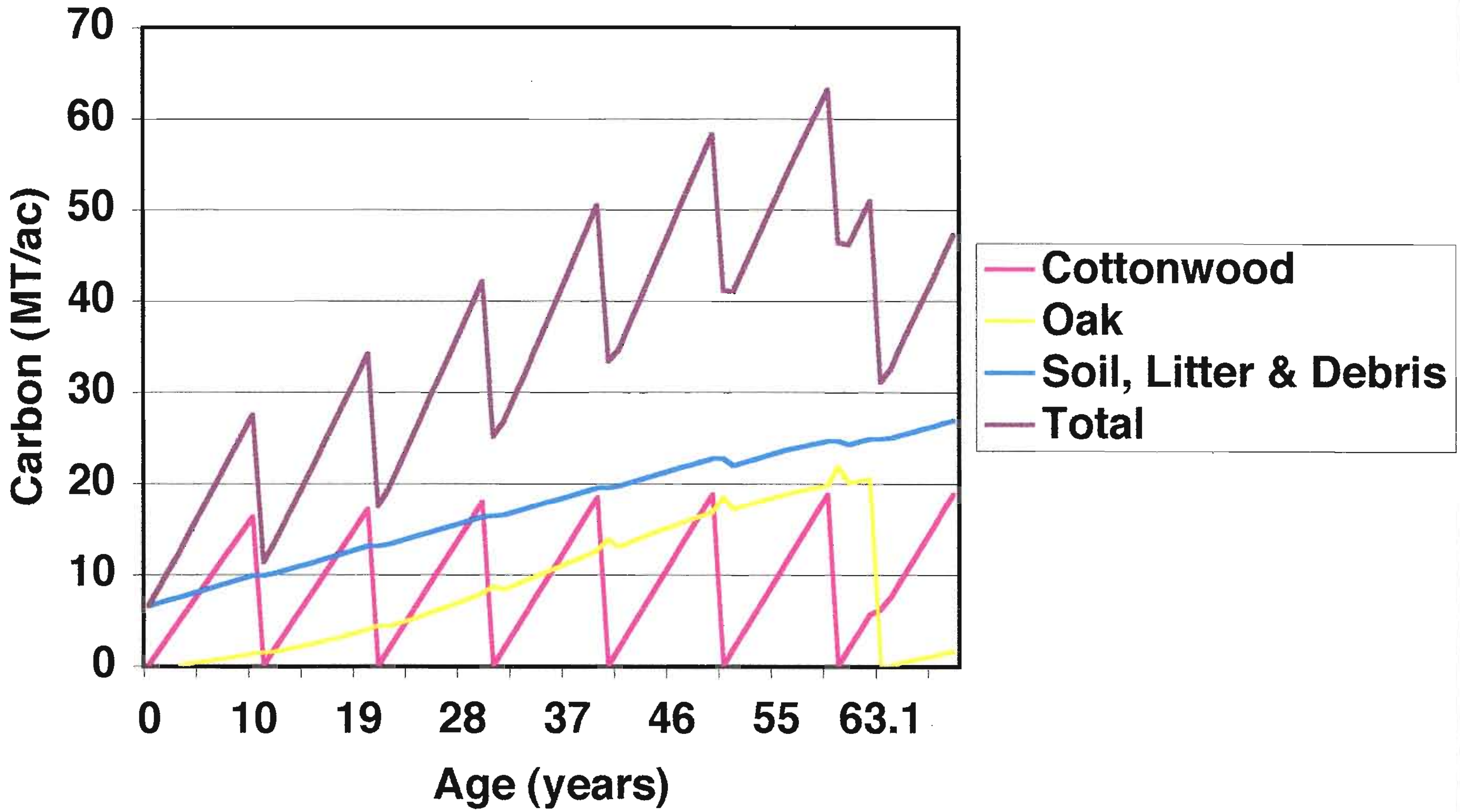


Figure 16

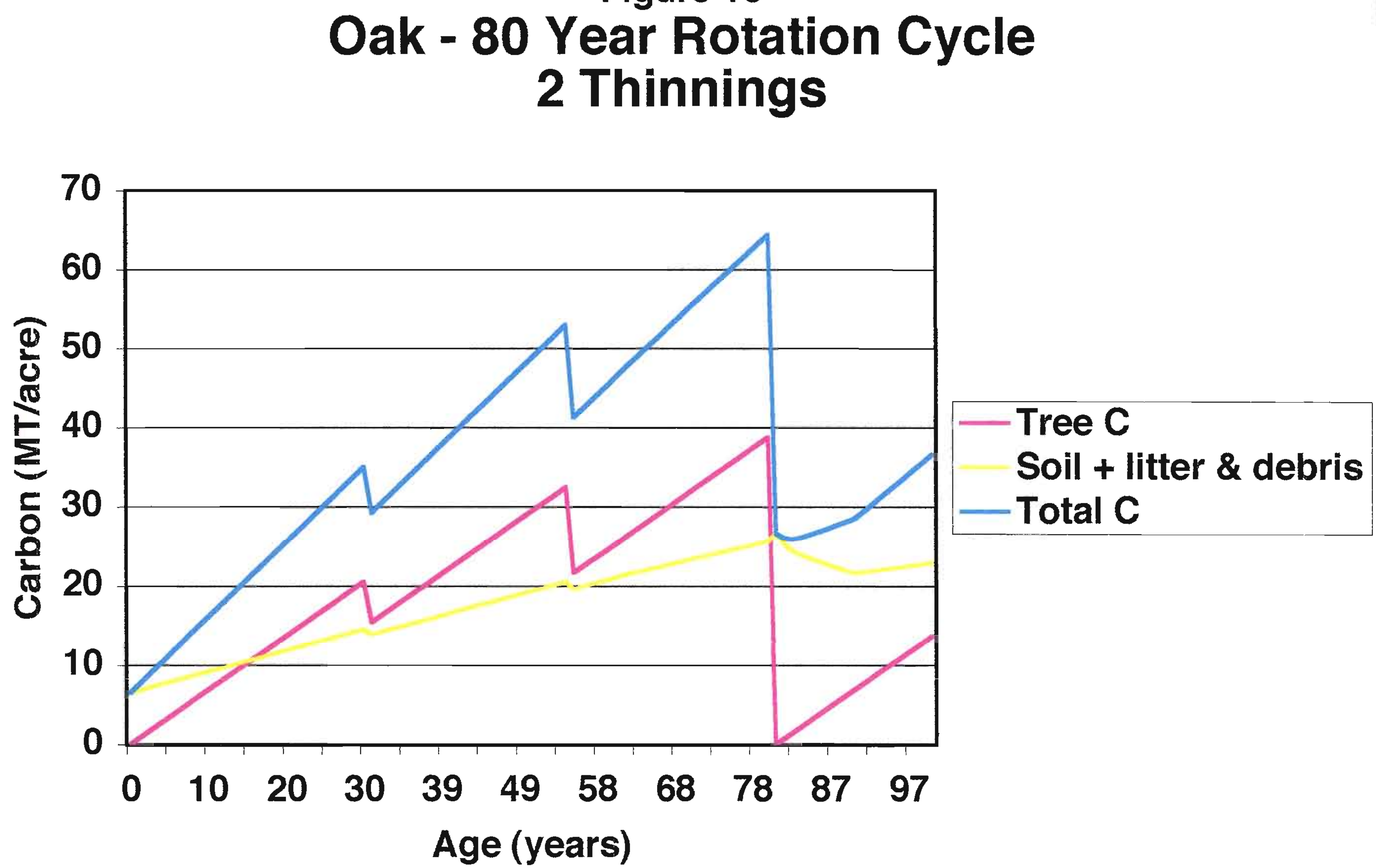

Oak - 80 Year Rotation Cycle
2 Thinnings
Carbon (MT/acre)
70
60
50
40
30
20
10
0
0
10
20
30
39
49
58
68
78
87
97
Age (years)
Tree C
Soil + litter & debris
Total C

Figure 17

Bottomland Hardwood - No Harvest

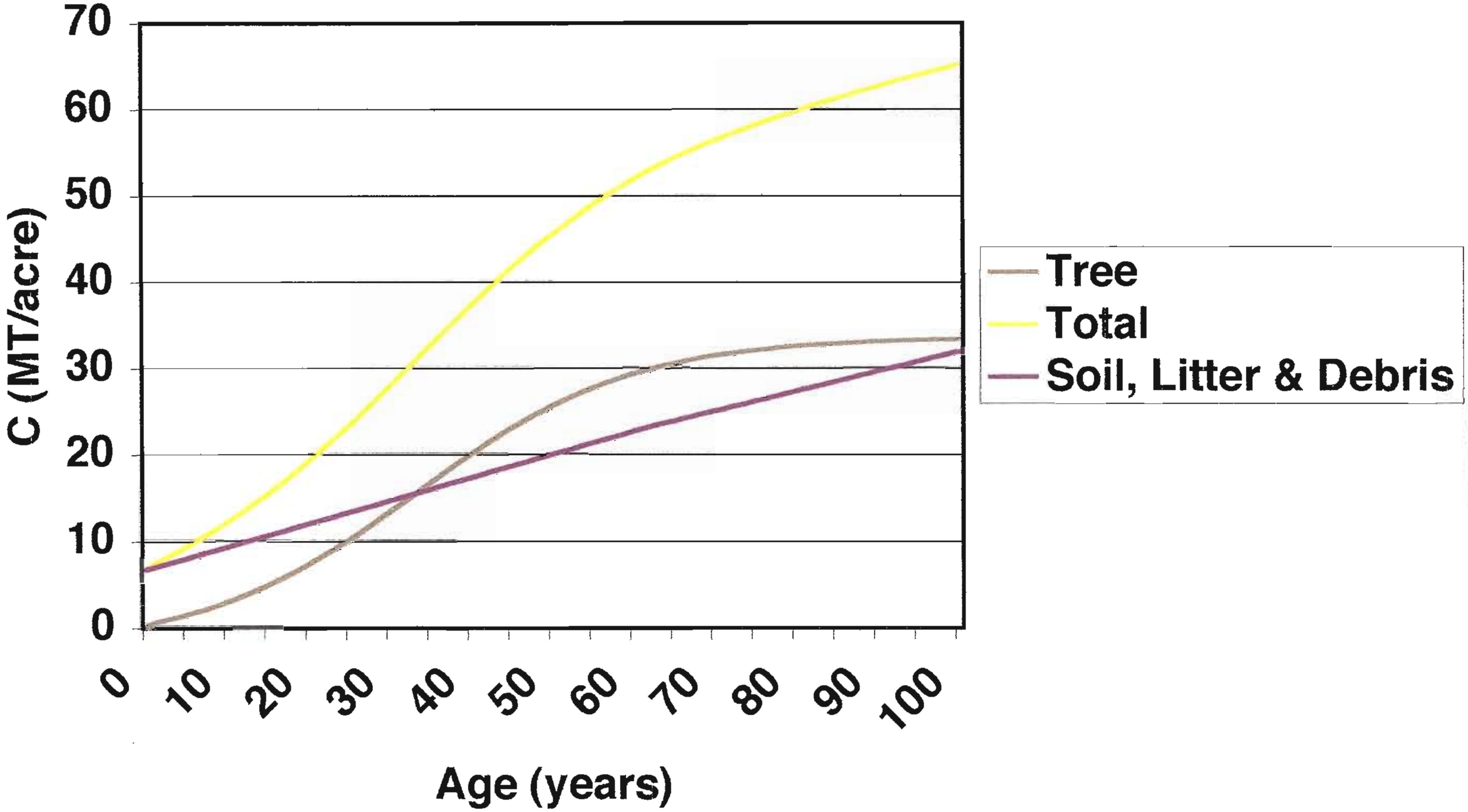
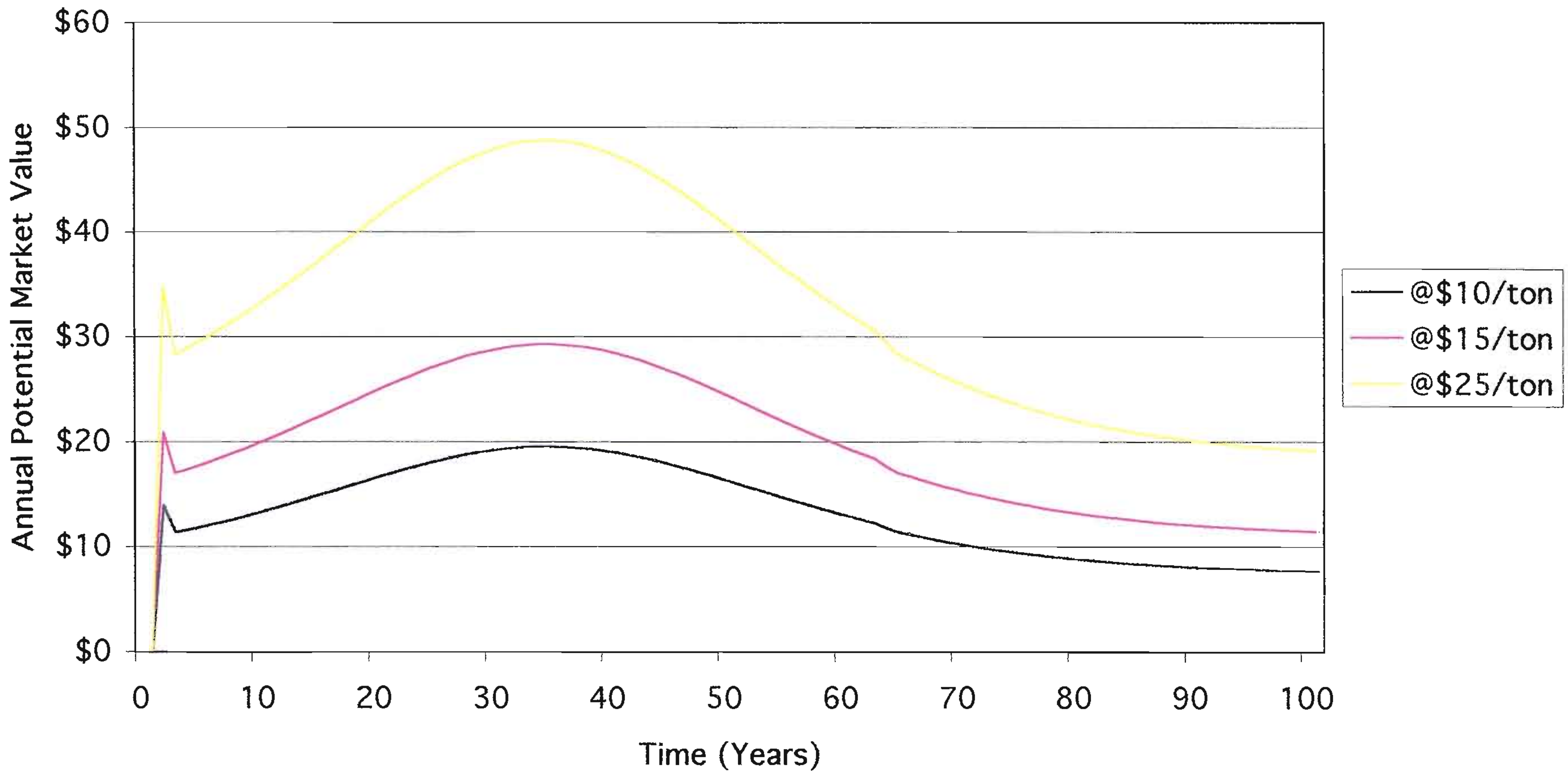


Figure 18
Reforesting Cropland in the Mississippi Delta
Expected Annual Value of Earned Carbon Credits



Appendix A Characteristics of selected tree and shrub species suitable for reforestation of bottomland hardwood forests in the southeastern United States: suitability for direct seeding, wildlife food/habitat, and wood products.
Key to Suitability: H = high, M = medium, L = low, I = insufficient data to determine suitability or unsuitability. (Reproduced from: Allen et al. *in press*)

	Suitability for				
Species Name	Direct seeding	Water fowl food	Deer/ turkey food	Neo-tropical migrant	Wood products
Ash, Green Fraxinus pennsylvanica	I	L	L	I	M
Ash, Pumpkin Fraxinus profunda	I	L	L	I	M
Ash, White Fraxinus americana	I	L	L	I	H
Bay, loblolly Gordonia lasianthus	I	L	L	I	I
Bay, red Persea borbonia	I	L	L	I	L
Bay, swamp Persea palustris	I	I	I	I	L
Bay, sweet Magnolia virginiana	I	L	L	I	L
Beech, American Fagus grandifolia	I	L	M	I	L-M
Birch, River Betula nigra	I	L	L	I	L
Blackgum Nyssa sylvatica	I	M	M	I	L
Boxelder Acer negundo	I	L	H	I	L
Buttonbush Cephalanthus occidentalis	I	M	L	I	L
Cherry, Black Prunus serotina	I	L	M	I	H
Cottonwood, Eastern Populus deltoides	I	L	M	I	H
Cottonwood, Swamp Populus heterophylla	I	L	M	I	L
Cypress, Bald Taxodium distichum	I	L	L	I	H

Cypress, Pond Taxodium distichum var. nutans	I	L	L	I	M
Dogwood, flowering Cornus florida	I	L	H	H	L
Dogwood, Rough-leafed Cornus drummondii	I	L	H	H	L
Elm, American Ulmus americana	I	M	M	M	L-M
Elm, cedar Ulmus crassifolia	I	M	M	M	L
Elm, slippery Ulmus rubra	I	M	M	M	L
Elm, winged Ulmus alata	I	M	M	M	L
Elm, water Planera aquatica	I	M	L	M	L
Hackberry Celtis occidentalis	I	L	L-M	H	M
Hawthorn Crataegus spp.	I	L	M-H	M-H	I
Hickory, water Carya aquatica	L	L-M	L	I	L
Hickory, shellbark Carya laciniosa	I	L	M	I	L
Hickory, shagbark Carya ovata	L	I	M	I	L
Holly, American Ilex opaca	I	L	L	I	L
Honeylocust Gleditsia triacanthos	I	L	L	H	L
Hophornbeam, eastern Ostrya virginiana	I	L	L	I	L
Hornbeam, American Carpinus caroliniana	I	L	L	I	L
Magnolia, southern Magnolia grandiflora	I	L	L	M-H	L-M
Maple, Florida Acer barbatum	I	L	I	I	L
Maple, red Acer rubrum	I	L	M	I	L
Maple, silver Acer saccharinum	I	L	H	I	M

Mulberry, red Morus rubra	I	L	M-H	H	M
Oak, bur Quercus macrocarpa	I	L	H	I	H
Oak, cherrybark Quercus pagoda	H	H	H	I	H
Oak, Delta post Quercus stellata var. Mississippiensis	I	I	H	I	H
Oak, laurel Quercus laurifolia	I	H	H	I	L
Oak, live Quercus virginiana	M	H	H	I	L
Oak, Nuttall Quercus nuttallii	H	H	H	I	M
Oak, overcup Quercus lyrata	M	M	H	I	L
Oak, pin Quercus palustris	H	H	H	I	L
Oak, Shumard Quercus shumardii	H	M-H	H	I	H
Oak, swamp chestnut Quercus michauxii	M	M	H	I	H
Oak, water Quercus nigra	H	H	H	I	M
Oak, white Quercus alba	M	H	H	I	H
Oak, swamp white Quercus bicolor	I	I	M	I	M
Oak, willow Quercus phellos	H	H	H	I	M
Pawpaw Asimina triloba	I	L	I	I	L
Pecan Carya illinoensis	M	H	H	I	H
Persimmon, Common Diospyros virginiana	I	L	H	I	M
Poplar, yellow Liriodendron tulipifera	I	L	L	I	H
Possumhaw Ilex decidua	I	L	L	H	L
Sassafras Sassafras albidum	I	L	L	M-H	L
Sugarberry Celtis laevigata	I	L	L-M	H	M

Swampprivet Forestiera accuminata	I	L	L	I	L
Sweetgum Liquidambar styraciflua	I	M	L	H	M
Sycamore Platanus occidentalis	I	L	L	I	M
Tupelo, Ogeechee Nyssa ogeche	I	M	M	I	L
Tupelo, swamp Nyssa sylvatica var. biflora	I	L-M	L-M	I	L-M
Tupelo, water Nyssa aquatica	I	L-M	L	I	L-M
Walnut, black Juglans nigra	I	L	L	I	H
Waterlocust Gleditsia aquatica	I	L	M	I	L
Willow, black Salix nigra	I	L	H	M-H	M
Willow, sandbar Salix exigua	I	L	H	I	L

Appendix B

POTENTIAL CARBON CREDITS FROM LAND USE/LAND COVER CHANGE

by
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Activity: Reforest economically marginal farmland (EMF)
Location: Mississippi Delta (Mississippi, Louisiana, Arkansas)
Potential: 1 to 2 tons of Carbon (tC)per acre annually on up to 2.6 million acres

1 SOURCES OF CARBON CREDITS

Reforesting EMF reduces contributions to atmospheric greenhouse gases (GHG) in three ways:

(1) **Increases above-ground C Sequestration** (tree trunks, limbs, leaves, and leaf litter)
The accumulation of C in aboveground biomass generally follows an S-shaped (logistic) curve (See Figure B1). Annual accumulation rates peak about midway through the tree growth cycle (e.g., 40 years) and decline to zero as the tree stand matures and carbon reaches a steady-state where biomass growth = biomass decay (e.g., 50 to 80 years depending on species).

(2) **Increases below-ground C Sequestration** (soils)
The accumulation of C below ground is relatively constant (linear) from year to year until soil carbon reaches a steady-state (about 25 to 50 years) where accumulation is flat and there are no additional annual increases in C sequestration. (See Figure B2).

(3) **Reduces Emission Reduction** (less energy, fertilizer use)
C emission reduction benefits from reduced energy /fertilizer use in farming depend on expected agricultural practices if the land was not reforested (baseline emissions). These accumulate in a relatively constant (linear) pattern over time (See Figure B3)

2 ACCUMULATION OF CARBON CREDITS

The total accumulation of carbon credits over time from reforesting cropland is the sum of the three sources listed above, as depicted in Figure B4 (left-hand legend). The annual amount of carbon sequestered, the potential accrual of carbon "credits", is also depicted in Figure 2 (right-hand legend.)

The rates of C sequestration presented in Figures B1 through B3 do not reflect: a) risks of project failure, or b) risks that carbon sequestered through successful projects will later be released into the atmosphere as a result of fire, storms, floods, droughts, invasive species, political, legal, or market shifts, and so on. In an actual trading system credits earned in any year t might be associated with the amount of carbon sequestered in year t that is expected to remain sequestered until at least year t+25. The carbon sequestered during year t in a forest area with a 99.5% annual survival rate, for example, would have only an 88% chance of remaining sequestered until year t+25. In this overview we are ignoring how time and risk will be factored into the eventual scoring of C sequestration credits.

3 PRELIMINARY C SEQUESTRATION NUMBERS

Table B1 presents estimates of the expected annual increases in carbon sequestration and reductions in carbon emissions that would result from reforesting EMF in the Mississippi Delta region.

Accrual of annual carbon emission credits from sequestration plus emission reduction are expected to increase from nearly 1 ton per acre-year to nearly 2 tons per acre-year by year 25; they then decline back to around 1 ton per acre-year by year 60. The accumulated total C benefits as a result of this land use change is 19.5 tC over 10 years, 43.6 tC over 25 years, 90 tC over 50 years, and 140 tC over 100 years.

4 TYPICAL C SEQUESTRATION CREDIT VALUES

Actual carbon credit markets are still years away. When they develop C sequestration credit prices will be driven primarily by C emission reduction costs and C emission reduction credit prices. Most market forecasting models are predicting carbon credit prices in the range of $5 per tC to $150 per tC. Most industry analysts have been using a price of $15 per tC for purposes of speculating on credit selling opportunities.

Based on the accumulation of C credits shown in Table B1 the expected dollar value of credits earned over time based on prices of $10, $15, and $25 per tC are those shown in Table B2.

5 CONCLUSIONS

<u>Carbon Sequestration</u>

The amount of carbon sequestered, as a result of reforesting EMF in the Mississippi Delta will depend on factors in five categories:

1) Initial site conditions,
2) Matching species to site conditions,
2) Site preparation, planting and management techniques
4) Landscape factors that affect site productivity (e.g., hydrological variability)
5) Risks due to natural events such as floods, droughts, and fire.

6 CAVEATS ABOUT C CREDIT EARNINGS

The amount of carbon credits earned by reforesting will depend on the above five factors and, importantly, on how trade regulators account for time and risk in the scoring of C credits "Certified" C credits will most certainly be associated with expected long-term outcomes, not early carbon gains, and should be expected to account for both time and risk. In advance of any official basis for scoring C sequestration potential economic returns from C sequestration should be based on either discounting potential C sequestration credit revenues to account for time and risk, or factoring in the cost of providing C trade regulators with insurance.

TABLE B1

Potential Accumulation of Carbon (C) Credits From Reforesting Economically Marginal Farmland in the Mississippi Delta (Scenario #4: Bottomland hardwood, no harvest)

Time	Above Ground (MT/acre)	Below Ground (MT/acre)	Emission Reduction	C Reduction Total Cumulative	C Reduction Annual
0	0	6.5	0.5	7.0	N/A
1	0.7	6.7	1.0	8.4	1.4
2	1.1	7.0	1.5	9.5	1.1
3	1.5	7.2	2.0	10.7	1.2
4	1.9	7.4	2.5	11.9	1.2
5	2.4	7.7	3.0	13.1	1.2
6	2.9	7.9	3.5	14.3	1.2
7	3.4	8.1	4.0	15.5	1.3
8	4.0	8.3	4.5	16.8	1.3
9	4.6	8.6	5.0	18.2	1.3
10	5.2	8.8	5.5	19.5	1.3
11	5.8	9.0	6.0	20.9	1.4
12	6.5	9.3	6.5	22.3	1.4
13	7.2	9.5	7.0	23.7	1.4
14	8.0	9.7	7.5	25.2	1.5
15	8.8	10.0	8.0	26.7	1.5
16	9.6	10.2	8.5	28.3	1.5
17	10.4	10.4	9.0	29.8	1.6
18	11.3	10.6	9.5	31.5	1.6
19	12.2	10.9	10.0	33.1	1.6
20	13.2	11.1	10.5	34.8	1.7
21	14.2	11.3	11.0	36.5	1.7
22	15.2	11.6	11.5	38.2	1.7
23	16.2	11.8	12.0	40.0	1.8
24	17.3	12.0	12.5	41.8	1.8
25	18.4	12.3	13.0	43.6	1.8
26	19.5	12.5	13.5	45.5	1.9
27	20.7	12.7	14.0	47.4	1.9
28	21.8	12.9	14.5	49.3	1.9
29	23.0	13.2	15.0	51.2	1.9
30	24.2	13.4	15.5	53.1	1.9
31	25.4	13.6	16.0	55.0	1.9
32	26.6	13.9	16.5	57.0	1.9
33	27.8	14.1	17.0	58.9	1.9
34	29.1	14.3	17.5	60.9	1.9
35	30.3	14.6	18.0	62.8	1.9
36	31.5	14.8	18.5	64.8	1.9
37	32.7	15.0	19.0	66.7	1.9
38	33.9	15.2	19.5	68.6	1.9
39	35.0	15.5	20.0	70.5	1.9
40	36.2	15.7	20.5	72.4	1.9
41	37.3	15.9	21.0	74.3	1.9
42	38.5	16.2	21.5	76.1	1.8
43	39.5	16.4	22.0	77.9	1.8
44	40.6	16.6	22.5	79.7	1.8
45	41.6	16.9	23.0	81.5	1.8

46	42.6	17.1	23.5	83.2	1.7
47	43.6	17.3	24.0	84.9	1.7
48	44.6	17.5	24.5	86.6	1.7
49	45.5	17.8	25.0	88.2	1.6
50	46.3	18.0	25.5	89.8	1.6
51	47.2	18.2	26.0	91.4	1.6
52	48.0	18.5	26.5	92.9	1.5
53	48.7	18.7	27.0	94.4	1.5
54	49.5	18.9	27.5	95.9	1.5
55	50.2	19.2	28.0	97.3	1.4
56	50.9	19.4	28.5	98.7	1.4
57	51.5	19.6	29.0	100.1	1.4
58	52.1	19.8	29.5	101.4	1.3
59	52.7	20.1	30.0	102.7	1.3
60	53.2	20.3	30.5	104.0	1.3
61	53.7	20.5	31.0	105.3	1.2
62	54.2	20.8	31.5	106.5	1.2
63	54.7	21.0	32.0	107.7	1.2
64	55.1	21.2	32.5	108.8	1.1
65	55.5	21.5	33.0	109.9	1.1
66	55.8	21.7	33.5	111.0	1.1
67	56.2	21.9	34.0	112.1	1.1
68	56.5	22.1	34.5	113.1	1.0
69	56.8	22.4	35.0	114.1	1.0
70	57.0	22.6	35.5	115.1	1.0
71	57.3	22.8	36.0	116.1	1.0
72	57.5	23.1	36.5	117.1	1.0
73	57.8	23.3	37.0	118.1	1.0
74	58.0	23.5	37.5	119.0	0.9
75	58.2	23.8	38.0	119.9	0.9
76	58.4	24.0	38.5	120.8	0.9
77	58.5	24.2	39.0	121.7	0.9
78	58.7	24.4	39.5	122.6	0.9
79	58.8	24.7	40.0	123.5	0.9
80	59.0	24.9	40.5	124.4	0.9
81	59.1	25.1	41.0	125.2	0.9
82	59.2	25.4	41.5	126.1	0.9
83	59.3	25.6	42.0	126.9	0.8
84	59.4	25.8	42.5	127.8	0.8
85	59.5	26.1	43.0	128.6	0.8
86	59.6	26.3	43.5	129.4	0.8
87	59.7	26.5	44.0	130.2	0.8
88	59.8	26.7	44.5	131.0	0.8
89	59.9	27.0	45.0	131.8	0.8
90	59.9	27.2	45.5	132.6	0.8
91	60.0	27.4	46.0	133.4	0.8
92	60.1	27.7	46.5	134.2	0.8
93	60.1	27.9	47.0	135.0	0.8
94	60.2	28.1	47.5	135.8	0.8
95	60.2	28.4	48.0	136.6	0.8
96	60.3	28.6	48.5	137.3	0.8
97	60.3	28.8	49.0	138.1	0.8
98	60.3	29.0	49.5	138.9	0.8
99	60.4	29.3	50.0	139.6	0.8
100	60.4	29.5	50.5	140.4	0.8

Table B2

Potential Value of Accumulated Carbon (C) Credits From Reforesting Economically Marginal Farmland in the Mississippi Delta (Scenario #4: Bottomland hardwood, no harvest)

Year	Carbon Total C Reduction Cumulative	Carbon Total C Reduction Annual	@ $10/ton Cumulative	@ $10/ton Annual	@ $15/ton Cumulative	@ $15/ton Annual	@ $25/ton Cumulative	@ $25/ton Annual
0	7.0	N/A	$70	N/A	$105	N/A	$175	N/A
1	8.4	1.4	$84	$14	$126	$21	$210	$35
2	9.5	1.1	$95	$11	$143	$17	$238	$28
3	10.7	1.2	$107	$12	$160	$17	$267	$29
4	11.9	1.2	$119	$12	$178	$18	$296	$29
5	13.1	1.2	$131	$12	$196	$18	$326	$30
6	14.3	1.2	$143	$12	$214	$18	$357	$31
7	15.5	1.3	$155	$13	$233	$19	$389	$31
8	16.8	1.3	$168	$13	$253	$19	$421	$32
9	18.2	1.3	$182	$13	$272	$20	$454	$33
10	19.5	1.3	$195	$13	$292	$20	$487	$34
11	20.9	1.4	$209	$14	$313	$21	$522	$34
12	22.3	1.4	$223	$14	$334	$21	$557	$35
13	23.7	1.4	$237	$14	$356	$22	$593	$36
14	25.2	1.5	$252	$15	$378	$22	$630	$37
15	26.7	1.5	$267	$15	$401	$23	$668	$38
16	28.3	1.5	$283	$15	$424	$23	$707	$39
17	29.8	1.6	$298	$16	$448	$24	$746	$39
18	31.5	1.6	$315	$16	$472	$24	$787	$40
19	33.1	1.6	$331	$16	$497	$25	$828	$41
20	34.8	1.7	$348	$17	$522	$25	$870	$42
21	36.5	1.7	$365	$17	$547	$26	$912	$43
22	38.2	1.7	$382	$17	$574	$26	$956	$44
23	40.0	1.8	$400	$18	$600	$27	$1,000	$44
24	41.8	1.8	$418	$18	$627	$27	$1,045	$45
25	43.6	1.8	$436	$18	$655	$27	$1,091	$46
26	45.5	1.9	$455	$19	$682	$28	$1,137	$46
27	47.4	1.9	$474	$19	$711	$28	$1,184	$47
28	49.3	1.9	$493	$19	$739	$28	$1,232	$47
29	51.2	1.9	$512	$19	$768	$29	$1,279	$48
30	53.1	1.9	$531	$19	$796	$29	$1,327	$48
31	55.0	1.9	$550	$19	$826	$29	$1,376	$48
32	57.0	1.9	$570	$19	$855	$29	$1,424	$49
33	58.9	1.9	$589	$19	$884	$29	$1,473	$49
34	60.9	1.9	$609	$19	$913	$29	$1,522	$49
35	62.8	1.9	$628	$19	$942	$29	$1,570	$49
36	64.8	1.9	$648	$19	$971	$29	$1,619	$49
37	66.7	1.9	$667	$19	$1,000	$29	$1,667	$48
38	68.6	1.9	$686	$19	$1,029	$29	$1,715	$48
39	70.5	1.9	$705	$19	$1,058	$29	$1,763	$48
40	72.4	1.9	$724	$19	$1,086	$28	$1,810	$47
41	74.3	1.9	$743	$19	$1,114	$28	$1,857	$47
42	76.1	1.8	$761	$18	$1,142	$28	$1,903	$46
43	77.9	1.8	$779	$18	$1,169	$27	$1,948	$45
44	79.7	1.8	$797	$18	$1,196	$27	$1,993	$45
45	81.5	1.8	$815	$18	$1,222	$26	$2,037	$44
46	83.2	1.7	$832	$17	$1,248	$26	$2,081	$43
47	84.9	1.7	$849	$17	$1,274	$26	$2,123	$43
48	86.6	1.7	$866	$17	$1,299	$25	$2,165	$42

49	88.2	1.6	$882	$16	$1,323	$25	$2,206	$41
50	89.8	1.6	$898	$16	$1,347	$24	$2,246	$40
51	91.4	1.6	$914	$16	$1,371	$24	$2,285	$39
52	92.9	1.5	$929	$15	$1,394	$23	$2,323	$38
53	94.4	1.5	$944	$15	$1,416	$23	$2,361	$38
54	95.9	1.5	$959	$15	$1,438	$22	$2,397	$37
55	97.3	1.4	$973	$14	$1,460	$21	$2,433	$36
56	98.7	1.4	$987	$14	$1,481	$21	$2,468	$35
57	100.1	1.4	$1,001	$14	$1,502	$21	$2,503	$34
58	101.4	1.3	$1,014	$13	$1,522	$20	$2,536	$33
59	102.7	1.3	$1,027	$13	$1,541	$20	$2,569	$33
60	104.0	1.3	$1,040	$13	$1,560	$19	$2,601	$32
61	105.3	1.2	$1,053	$12	$1,579	$19	$2,632	$31
62	106.5	1.2	$1,065	$12	$1,597	$18	$2,662	$31
63	107.7	1.2	$1,077	$12	$1,615	$18	$2,692	$29
64	108.8	1.1	$1,088	$11	$1,632	$17	$2,720	$28
65	109.9	1.1	$1,099	$11	$1,649	$17	$2,748	$28
66	111.0	1.1	$1,110	$11	$1,665	$16	$2,775	$27
67	112.1	1.1	$1,121	$11	$1,681	$16	$2,802	$27
68	113.1	1.0	$1,131	$10	$1,697	$16	$2,828	$26
69	114.1	1.0	$1,141	$10	$1,712	$15	$2,853	$26
70	115.1	1.0	$1,151	$10	$1,727	$15	$2,878	$25
71	116.1	1.0	$1,161	$10	$1,742	$15	$2,903	$25
72	117.1	1.0	$1,171	$10	$1,756	$15	$2,927	$24
73	118.1	1.0	$1,181	$10	$1,771	$14	$2,951	$24
74	119.0	0.9	$1,190	$9	$1,785	$14	$2,975	$24
75	119.9	0.9	$1,199	$9	$1,799	$14	$2,998	$23
76	120.8	0.9	$1,208	$9	$1,812	$14	$3,021	$23
77	121.7	0.9	$1,217	$9	$1,826	$14	$3,043	$23
78	122.6	0.9	$1,226	$9	$1,839	$13	$3,066	$22
79	123.5	0.9	$1,235	$9	$1,853	$13	$3,088	$22
80	124.4	0.9	$1,244	$9	$1,866	$13	$3,109	$22
81	125.2	0.9	$1,252	$9	$1,878	$13	$3,131	$21
82	126.1	0.9	$1,261	$9	$1,891	$13	$3,152	$21
83	126.9	0.8	$1,269	$8	$1,904	$13	$3,173	$21
84	127.8	0.8	$1,278	$8	$1,916	$13	$3,194	$21
85	128.6	0.8	$1,286	$8	$1,929	$12	$3,215	$21
86	129.4	0.8	$1,294	$8	$1,941	$12	$3,235	$21
87	130.2	0.8	$1,302	$8	$1,953	$12	$3,256	$20
88	131.0	0.8	$1,310	$8	$1,965	$12	$3,276	$20
89	131.8	0.8	$1,318	$8	$1,978	$12	$3,296	$20
90	132.6	0.8	$1,326	$8	$1,990	$12	$3,316	$20
91	133.4	0.8	$1,334	$8	$2,001	$12	$3,336	$20
92	134.2	0.8	$1,342	$8	$2,013	$12	$3,355	$20
93	135.0	0.8	$1,350	$8	$2,025	$12	$3,375	$20
94	135.8	0.8	$1,358	$8	$2,037	$12	$3,395	$20
95	136.6	0.8	$1,366	$8	$2,048	$12	$3,414	$19
96	137.3	0.8	$1,373	$8	$2,060	$12	$3,433	$19
97	138.1	0.8	$1,381	$8	$2,072	$12	$3,453	$19
98	138.9	0.8	$1,389	$8	$2,083	$12	$3,472	$19
99	139.6	0.8	$1,396	$8	$2,095	$11	$3,491	$19
100	140.4	0.8	$1,404	$8	$2,106	$11	$3,510	$19

Figure B1 through Figure B3
Patterns of C Sequestration and Emission Reduction

Figure B1
Increase in
Above-ground C
(Trees)

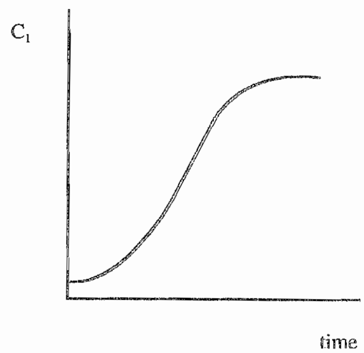


Figure B2
Increase in
Below-ground C
(Soil)

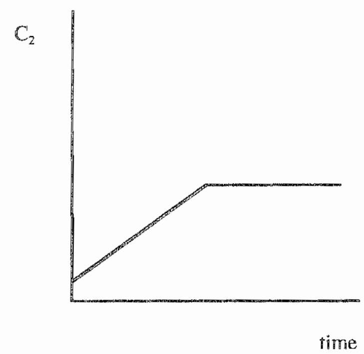
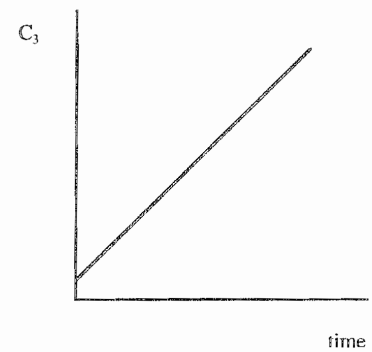


Figure B3
Decrease in
C Emissions
(Land retirement)



C_1=metric tons of Carbon (tC) above-ground in tree trunks, limbs, leaves, and leaf litter

C_2= metric tons of Carbon (tC) below-ground in forest soils

C_3 = metric tons of Carbon (tC) emission reductions from reducing energy and fertilizer use

C_T = Total Reduction in Atmospheric carbon
$= C_1 + C_2 + C_3$

Note: a metric ton of Carbon (C) is equivalent to 3.67 metric tons of atmospheric carbon dioxide (tCO2)

Figure B4

Cumulative C Sequestration and Emission Reduction (left-hand legend) and Annual C Sequestration (right-hand legend) From Reforesting Economically Marginal Farmland in the Mississippi River Delta (Scenario #4: Bottomland hardwood, no harvesting)