Best Management Practices: How Economical is it in Southern Agricultural Systems?

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Abstract

Conventional drainage systems tend to aggravate runoff and nutrient leaching problems on farms especially during the off-season. This study uses a biophysical economic model to identify, evaluate and determine multifunctional benefits of implementing and establishing nitrogen rate fertilizer application and conservation tillage practices as best management practices (BMPs) in the lower Mississippi River Basin (MRB). Simulation results showed that agricultural producers generally preferred no tillage to conventional tillage in reducing nutrient runoffs from fields because of higher net revenue per acre. Finally, given nitrogen runoff restrictions, farmers reduced crop acreage and nitrogen fertilizer application rates to help minimize losses.

1. Introduction

Thirty one percent of Louisiana’s 66,294 river miles are impaired from elements such as phosphorus, ammonia, turbidity and sediments (LDEQ, 2006). Twenty percent of this impairment is directly attributable to irrigated and non-irrigated crop production. Lakes, wetlands and estuaries within the state are also not spared from these negative side effects of agricultural production.

Section 303(d) of the Clean Water Act (CWA) mandates that Louisiana should assign priority rankings and total maximum daily loads (TMDLs) for every water system that do not meet the state’s water quality standards. Additionally, for nonpoint source (NPS) pollution, the CWA section 319(b) asks states to prepare a nonpoint source management program which in part requires the identification of best management practices (BMPs) and methods which if adopted should help in the reduction of NPS pollution. Best management practices have therefore become the boon in the efforts to reduce NPS pollution especially in agriculture.

Riparian buffers such as trees, grasses, and shrubs serve as nutrient and sediment filters and therefore help in reducing nutrient erosion and sediment loss from croplands into streams and rivers. Though riparian buffers are listed as a BMP in Louisiana for agronomic crops (Agronomic Crops BMPs, 2000), its effectiveness in trapping agricultural pollutants is questionable. Open-ditch drainage systems, drained by bayous and streams, prevailing in almost every cropland in the state, circumvent planted or natural riparian buffers. This renders buffers virtually ineffective in trapping nutrient and sediments. Riparian buffers could still be effective within the state, but it will demand the planting of buffers between almost every stream and crop field border. This might be infeasible due to the huge stretches of streams located within croplands in Louisiana and the expense entailed in such a policy or project. Convincing farmers to adopt such a strategy is a herculean task. Alternatively, farmers could employ other BMPs such as cover crops, residue management, conservation tillage practices and nitrogen management plans to help lessen nutrient runoffs and sediment loss from fields. All these BMPs have been approved for Louisiana (Agronomic Crops BMPs, 2000).

This study therefore looks at the impact of tillage practices and nitrogen fertilizer application rates in reducing nutrient erosion and subsequent economic implications. Nitrogen reduction sensitivity analyses are also carried out to determine its effect on net returns. Specifically, the objective of this study is to assess the cost-effectiveness of different tillage practices and nitrogen fertilizer application rates in reducing nutrient runoffs and sediment loss.

2. Background

A lot of research has been conducted to ensure effective application of nitrogen fertilizer on croplands to help lessen nitrogen outflow into streams and rivers. An area which has generated much interest among researchers in terms of potential increased profits and reduced nutrient erosion is precision application of nitrogen fertilizer (Prato and Kang, 1998; Paz et al., 1999 and Koch et al., 2004). Results obtained from these studies are somewhat encouraging. Koch and others for example showed that variable rate nitrogen application which takes into cognizance field variability is more economically than a uniform strategy.

It is however unlikely that variable application of nitrogen on fields will become the norm in the short-run due to the following reasons. Foremost, agricultural producers will require demonstrated evidence of its effectiveness in terms of increased net returns within their locality. Secondly, a spatial mapping of most fields’ soil variability has to occur at some cost to farmers.

Last, but not the least, farmers will need access to investment capital to purchase precision technology and attend a workshop or be trained on how to use them effectively. Given these reasons, uniform application of nitrogen on fields would continue for the foreseeable future.

Given these obstacles, other studies have focused on simply reducing nitrogen fertilizer application rates on fields and assessing impact on net returns. For example, Ribaudo et al. (2001) compared the cost effectiveness of wetland restoration and reducing agricultural nitrogen loads deposited into the Mississippi Basin. In their analysis, profit maximizing landowners were paid to convert croplands into wetlands. They found out that the cost of adopting a nitrogen fertilizer reduction strategy was less than wetland restoration strategy given a nitrogen reduction goal of 1.2 million tons.

Moreover, most research has gradually shifted towards the watershed level because US EPA has adopted the watershed as the area of focus for policy and possible future regulations. Rejesus and Hornbaker (1999) examined economic and environmental effects of different nitrogen timing and rate application practices, as well as a site-specific management (SSM) precision technology impact on profits and water quality in Lake Decatur watershed, Illinois. Ignoring fixed costs of investments, results showed that SSM technology greatly stabilizes corn yield returns and reduced total nitrogen pollution in the watershed compared to other practices.

Prato and Kang (1998) also analyzed the impact of variable and uniform application of nitrogen on water quality and net returns in Goodwater Creek watershed, north central Missouri. The study was conducted under a framework that combined GIS, an EPIC model and an economic optimization model. Results showed that for both uniform and variable application rates, profitability and water quality effects varied with crop rotation. Variable and uniform application rates also had different impacts on nitrogen application rates, surface and ground water quality, as well as crop yield, with no application method necessarily superior to another.

Wu et al. (1995) also conducted a study on the policy alternatives for reducing agricultural water pollution in the US southern high plains. The effectiveness of a given policy was determined on the basis of impact on farm income and social welfare. Results showed farmers preferred restrictions on per acre nitrogen use to either taxes on nitrogen use or irrigation water use.

The current analysis however presents various nitrogen fertilizer application rates and obtainable crop yields for different tillage practices. Farmers are given the alternative to choose among these combinations to maximize net returns. An additional watershed nitrogen runoff restriction was assessed and impact on net returns ascertained. Results are compared to the baseline unconstrained watershed scenario.

3. Cabin-Teele Sub-Watershed

For nonpoint source pollution reduction, the state of Louisiana and US-EPA has adopted the watershed level as the unit of focus to help improve water quality (LDEQ, 2006). The study was undertaken in the Cabin-Teele sub-watershed (figure 1), located in Madison Parish, northeastern Louisiana. Figure 1 shows some of the streams flowing through this sub-watershed. The sub-watershed has impaired waters due to excess amounts of nitrate, phosphorus and sediment deposition (Appelboom and Fouss, 2006).

Agriculturally, the watershed has more than 700 farms, with sizes ranging from one to over 1000 acres (Appelboom and Fouss, 2005). Eleven soil maps and four different soil series are found in Cabin-Teele. The soil series are Bruin, Commerce, Sharkey and Tunica. These soils are generally low in nitrogen and organic matter content, with pH ranging from highly acidic to mildly alkaline. Moreover, the similar soils, slopes and crops found in the area lend to relatively easy replication of best management practices.

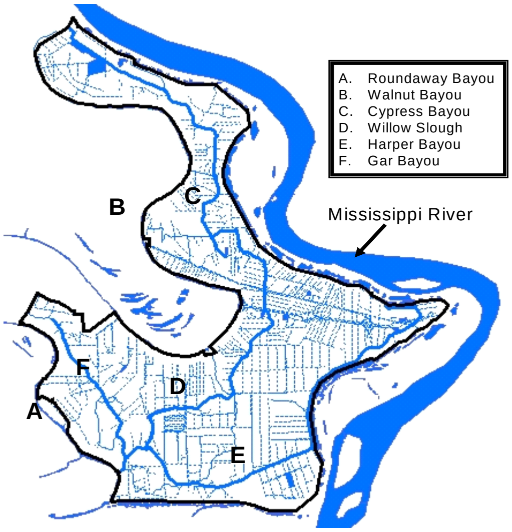

Figure 1: Site Map of Cabin-Teele Sub-watershed.

4. Modeling and Data Sources

4.1 AnnAGNPS Modeling and Data Sources

Annualized Agricultural Nonpoint Source (AnnAGNPS) pollutant loading model was used to collate sediment, nutrient and phosphorus runoffs from nitrogen fertilizer application rates and tillage management practices. Annualized AGNPS[1] is a watershed scale model which enables continuous simulation of surface water, nutrients, pesticides and sediments runoff quantities and their movement through the watershed. Sediment and nutrient runoffs calculations are conducted using the Revised Universal Soil Loss Equation and runoff curve numbers respectively. Before simulations are carried out, the watershed is divided into homogeneous soil types, land use and land management. The model has various components which enable evaluation of the environmental impact of BMPs. Output of modeling can be given on an event basis over the simulation period.

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[1] Internet site: www.broel.nrw.de/links/Fact_Sheet_AnnAGNPS.pdf (Accessed on August 29, 2008).

Model inputs essential for AnnAGNPS simulations include: field, schedule and operation management data, fertilizer application data, reach data, impoundment data, crop data, non-crop land use data and soil data. This information was acquired from the extensive work done by Appelboom and Fouss (2006) in Cabin-Teele sub-watershed. Climatic data is also of absolute importance in the modeling process. Daily climatic data were obtained from Dr. Kevin Robbins of the Southern Regional Climate Center, Louisiana State University. In the modeling, two initialization years (1996-1997) and seven historical years (1998-2004) rainfall data were used. The average annual rainfall for the latter was 1226.15mm. The actual simulation used only cropping data for the year 2002 (the most detailed yearly cropping data available) which is then averaged over the historical weather data to obtain a more reliable output.

A vital element in biophysical simulations is model calibration, which is important for validation and applicability (Taylor and others, 1992). The model was not calibrated but the results fell within the range of the measured data that was collected in the watershed. Weather conditions were also similar to the average of the simulated years.

The main limitations of AnnAGNPS include: (1) does not cater for differential rainfall quantities within a region; (2) simulation are done on a daily basis by essentially channeling every nutrient and sediment runoffs to the watershed outlet; (3) discharges from point sources have constant loading rates throughout the simulation period; and (4) does not provide for the daily determination of the amount of nutrients attached to sediments deposited into streams.

4.2 Estimation of Yield Data

Actual yield data for various nitrogen fertilizer application rates were unavailable for the Cabin-Teele region. To resolve this problem, experimental crop yield data for different levels of nitrogen fertilizer application rates were obtained from agronomists from the LSU AgCenter

Northeast Research Station. For rice and grain sorghum, the data were obtained respectively from LSU AgCenter 2007 Rice Research Station Annual Report and Reginelli et al., 1990.

Data obtained from these sources did not correspond exactly to current farmer’s nitrogen application rates on crops. Therefore, a quadratic equation was fitted between nitrogen application rates and crop yield to derive values which correspond to present farming practices in the watershed. A quadratic function is used because it was assumed that diminishing marginal returns of yields will occur with increasing amounts of nitrogen fertilizer application rates. For the case of convenience, it was assumed that the effects of climate and soil conditions on crop yields are minor and following the example of Giraldez and Fox (p.397, 1995), the equation employed for each crop was:

$$cyd(nit)_i = nit_i + nit_i^2 \qquad (1a)$$

In equation (1a), *i*, refers to different rates of nitrogen fertilizer application rates. The variables cyd and nit refers to crop yield and amount of nitrogen fertilizer applied in pounds. Estimates obtained employing this equation corresponded well with crop yield values obtained from agronomists. Moreover, these values corresponded well with LSU Agcenter extension and research values. No data was available for reduced tillage. Various agronomists contacted were non-committal on possible yield values. Therefore, for the purposes of this research, it was assumed that reduced tillage values will lie within the continuum of conventional and no tillage. In that regard, the average value between conventional and no tillage values were assumed to be a representative of reduced tillage. Table 1 summarizes this information.

Moreover, to obtain crop yield by soil type, the following method was employed. The soil series map of Madison Parish (Soil Survey Map of Madison Parish) gives estimated dryland average yield per acre of soils for commercial farmers under the following assumptions: “rainfall is effectively used and conserved; surface drainage systems are installed; crop residue is managed to maintain soil tilth; minimum but timely tillage is used; insect, disease and weed control measures are consistently used; fertilizer is applied according to soil test and crop needs; and suitable crop varieties are used at recommended seeding rates".

Table 2 section (a) gives a summary of this information. The soil survey gave no yield data for grain sorghum. For the purposes of this analysis, it was assumed that corn and grain sorghum will have similar soil type yield patterns. Generally, the soil survey attributed missing crop yield information pertaining to soil type to the fact that the soils were unsuitable for those crops.

Table 1: Applied Nitrogen Fertilizer Rates and Yield.

Experimental Data			**Applied and Estimated Data**			
N[1] lb/acre	**Conv[3]**	**No-till**	**N lb/acre**	**Conv**	**No-till**	**Red-till[4]**
BGII/Flex Cotton (lb/acre)						
135	913	1082	100[2]	905.68	1116.46	1011.07
90	888	1109	90	887.55	1109.15	998.35
45	716	982	80	862.19	1094.21	978.20
0	399	700	70	829.59	1071.65	950.62
Round Up Ready Corn (bushels/acre)						
200	174	178	200	174.05	178.05	176.05
150	158	162	180	169.43	173.43	171.43
100	126	130	160	162.33	166.33	164.33
50	79	83	140	152.75	156.75	154.75
Cheniere Rice [Drill Planted] (cwt/acre)						
180	64.93	73.19	150	67.44	70.69	69.06
150	67.25	69.43	135	67.43	69.54	68.48
120	67.21	69.58	120	67.02	68.32	67.67
90	66.37	65.27	105	66.21	67.04	66.63
Grain Sorghum (bushels/acre)						
200.00	74.93	77.83	100	78.79	82.67	80.73
120.00	80.54	80.22	90	78.04	82.14	80.09
80.00	76.48	82.75	80	77.09	81.41	79.25
40.00	70.89	78.88	70	75.94	80.49	78.21
0.00	62.49	66.94				

[1] N refers to nitrogen amount applied.
[2] First element for each sub-heading here shows actual amount of nitrogen fertilizer currently applied.
[3] Conv refers to conventional tillage.
[4] Red refers to reduced tillage.

Table 2: Estimated Average Yield per Acre For Principal Crops in Madison Parish.

Soil Type	**Symbol**	**Cotton**	**Corn**	**Soybeans**	**Rice**	**Sorghum**
(a)						
Bruin Silt Loam	Ba	950	100	42		
Commerce Silt Loam	Cm	900	95	40		
Commerce Silty Clam Loam	Cn	850	85	40		
Commerce Silty Clam Loam Gently	Co	800	85	35		
Sharkey Silty Clay Loam	Sb	700	75	40	130	
Sharkey Clay	Sc	675		40	130	
Sharkey Clay Undulating	Sd	600		35		
Sharkey Clay Frequently Flooded	Sf	600		35		
Sharkey-Tunica Complex Gently	St	600		35		
Tunica Clay	Tu	650		40	130	
(b)						
Bruin Silt Loam	Ba	950	100	42	137	100
Commerce Silt Loam	Cm	900	95	40	130	95
Commerce Silty Clam Loam	Cn	850	85	40	130	85
Commerce Silty Clam Loam Gently	Co	800	85	35	120	85
Sharkey Silty Clay Loam	Sb	700	75	40	130	75
Sharkey Clay	Sc	675	72	40	130	72
Sharkey Clay Undulating	Sd	600	64	35	120	64
Sharkey Clay Frequently Flooded	Sf	600	64	35	120	64
Sharkey-Tunica Complex Gently	St	600	64	35	120	64
Tunica Clay	Tu	650	69	40	130	69
(c)						
Bruin Silt Loam	Ba	1.41	1.39	1.05	1.05	1.00
Commerce Silt Loam	Cm	1.33	1.32	1.00	1.00	0.95
Commerce Silty Clam Loam	Cn	1.26	1.18	1.00	1.00	0.85
Commerce Silty Clam Loam Gently	Co	1.19	1.18	0.88	0.92	0.85
Sharkey Silty Clay Loam	Sb	1.04	1.04	1.00	1.00	0.75
Sharkey Clay	Sc	1.00	1.00	1.00	1.00	0.72
Sharkey Clay Undulating	Sd	0.89	0.89	0.88	0.92	0.64
Sharkey Clay Frequently Flooded	Sf	0.89	0.89	0.88	0.92	0.64
Sharkey-Tunica Complex Gently	St	0.89	0.89	0.88	0.92	0.64
Tunica Clay	Tu	0.96	0.96	1.00	1.00	0.69

However, intensive cultivation at the margins has brought almost every soil type under cultivation. To estimate crop yield values for all the soil types, a simple proportional relationship was assumed between different soil types. For example from table 2 section (a), if Sharkey silty clay loam soils (Sb) produces 700 lbs of cotton and 75 bushels of corn, then Sharkey clay soils (Sc) with 675 lbs of cotton will produce how much bushels of corn? Table 2 section (b) summarizes the estimates obtained using this simple relationship.

A soil yield index was also created to enable estimation of potential crop yield for tillage practices given different amounts of nitrogen fertilizer application rates. Corn, rice, cotton, and soybeans were grown on Sharkey clay, while grain sorghum on Bruin Silt loam[2]. The soil index values as presented in table 2 section (c) are simply quotients of the values in section (b) by the soil type value from which the actual yield data was obtained. For example, the yield data for corn obtained from agronomists was produced on Sharkey clay. In table 2 section (c) the index value for Sc is therefore 1 (675/675) and that for Sb is 1.04 (700/675).

4.3 Economic Data and Methods

Crop machinery and input requirements for tillage practices were acquired[3]. Data for physical inputs, machinery complements for example, were gathered from producers and prices from historic sources such as USDA-National Agricultural Statistics Service and Outlook for Louisiana's Agriculture. Historical prices on direct payment rates and counter-cyclical payment rates were obtained from USDA-Farm Service Agency and Natural Resources Conservation Service. Production costs and returns estimates as well as those for farm income (returns to management and land) for each owner operations on a per-acre basis, for conventional, conservation and no-till tillage practices were customized to farming practices in the sub-

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[2] Information obtained from agronomists publications. In the case of rice and grain sorghum, actual soil type differed from the ones found in Madison Parish. However, soil types were matched with the ones in Madison Parish based on soil properties, specifically, permeability and fertility rate.

[3] Roider, C.A., L.J. Kameray, and P.A. Bollich. Personal Communication. Ben-Hur Research Station, Baton Rouge, April 28, 2008.

watershed with the help of Dr. Kenneth Paxton[4]. Input and equipment costs for the period 2007/2008 were used in preparing the budgets. Costs accounted for the current rise in input prices[5].

Enterprise cotton budgets included ginning revenue and cost. This was to offset the negative projected costs and returns per acre for 2007 cotton for northeastern Louisiana. Inclusion of ginning in the budget is justified on the grounds that cotton farmers obtain additional revenue from ginning which is not included in the traditional enterprise cotton budgets. Mitchell et al. (2007) find that seed per lint ratio in Texas has been declining since the 1970's. The lint to seed ratio for the 2000's has been 1.57 (Mitchell et al.). For Louisiana, in consultation with Dr. Paxton on current lint to seed ratio obtained by ginners for new cotton varieties, an estimate of 1.33 was used in this analysis.

Crop prices were averaged over 6 years (2002-2007). The bio-economic modeling which follows looked at the impact on farming net returns in the sub-watershed when a policy is implemented that seeks to reduce nutrient levels in the watershed.

4.4 Economic Modeling with Environmental Constraints

The model employed in the analysis incorporates crop yield , input prices, government subsidies, tillage practices, nitrogen fertilizer management plans, soil types, and cropland effluents of nitrogen (attached and dissolved), phosphorus (attached and dissolved) and sediments (clay, silt, and sand) in maximizing net returns. Only continuous cropping was considered in the analysis.

Maximization of expected net returns is the primal factor driving crop production. Net farm income is maximized in the following equations by subtracting total cost from total returns

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[4] Farm Management Research & Extension Personnel, Department of Agricultural Economics & Agribusiness, Louisiana State University (responsible for preparing Crop Planning Budgets for Louisiana).

[5] Internet site: http://www.nass.usda.gov/Newsroom/2008/08_07_2008.asp (Accessed on 09/06/2008).

across various combinations of crop type, tillage practices, soil type and fertilizer nitrogen application rates. The objective function, equation (1), is maximized subject to these constraints:

$$\text{Max } NB = \left(\sum_{i,k,b,t} \left[(p_i + cp_i + dp_i) y_{i,k,b,t} - VC_{i,k,b,t} - FC_{i,k,b,t} \right] \right) x_{i,k,b,t} + CP \quad (1)$$

$$\sum_{i,k,b,t} x_{i,k,b,t} \leq \overline{A} \quad (2)$$

$$\sum_{i,k} x_{i,k,b,t} \leq \overline{\overline{A}}_{i,k} \quad (3)$$

$$x_{i,k,b,t} \geq 0 \quad \forall i,k,b,t \quad (4)$$

In the above equations, *i*, *k*, *t* and *b* respectively represent crop type (corn; cotton; rice; sorghum; soybean; and grass), soil type (Bruin silt loam; Commerce Silt loam; Commerce silty clay loam; Commerce silty clay loam, gently undulating; Sharkey silty clay loam; Sharkey clay; Sharkey clay, undulating; Sharkey clay, frequently flooded; Sharkey-Tunica complex, gently undulating; and Tunica clay), tillage practices (conventional; reduced tillage; and no till) and fertilizer nitrogen application rates (hund, ninety, eighty and seventy percent levels). Hund represents current nitrogen application rate levels in the sub-watershed. Ninety, eighty and seventy show a 10 percent, 20 percent and 30 percent reduction in nitrogen fertilizer application rate levels from the baseline levels accordingly. Additionally, *x* refers to cropping acres; p_i, cp_i, and dp_i are respectively vectors of the average of Louisiana crop prices, average of counter-cyclical payment rates, average direct payment rates received over the years 2002-07; *y*, refers to crop yields; *VC*, is variable cost of inputs; *FC* is fixed cost; *CP* refers to revenue obtained from both Wetlands Reserve Programs (WRP) and Conservation Reserve Program (CRP); $\overline{\overline{A}}$ refers to soil type-land acreage allocated to a specific crop and $\overline{A}$ is total available acreage in the sub-watershed for crop production.

Equation (2) constrains the total acreage used in actual production to total available acreage. Equation (3) constrains total acreage in the watershed by soil and crop acreage combinations. It ensures that less productive soils are not wholly ignored in the mathematical simulation process. Equation (4) is a non-negativity constraint of the variables *i*, *k*, *t* and *b*. On estimation of net farm income, the environmental aspect of the modeling was added by the incorporation of these equations:

$$\sum_{i,k,b,t} s_{i,k,b,t} x_{i,k,b,t} \leq \overline{S} \tag{5}$$

$$\sum_{i,k,b,t} n_{i,k,b,t} x_{i,k,b,t} \leq \overline{N} \tag{6}$$

$$\sum_{i,k,b,t} ph_{i,k,b,t} x_{i,k,b,t} \leq \overline{ph} \tag{7}$$

For the environmental factors, *n* is nitrate runoff at the outlet per acre; *ph* is phosphorus runoff at the outlet per acre and *s* is sediment erosion at the outlet per acre; $\overline{S}$ refers to the total amount of sediments loss at the outlet; $\overline{N}$ total amount of nitrogen runoffs at the outlet and $\overline{ph}$ total amount of phosphorus runoffs at the outlet. In the equations, $s_{i,k,b,t}$, $n_{i,k,b,t}$ and $ph_{i,k,b,t}$ respectively show the tons/acre sediment erosion, lbs/acre nitrogen runoffs, and lbs/acre phosphorus runoffs. The environmental equations show the limits on overall quantity of sediments, nitrogen and phosphorus loss across crops, tillage, soils and nitrogen fertilizer rate application in the watershed. The equations are solved using the General Algebraic Modeling Systems (GAMS).

5. Biophysical Economic Simulation Results

Outputs from the biophysical modeling were used as technical coefficients for each acre under production in the integrated biophysical-economic model. Model's efficiency is examined prior to the simulation of various policy scenarios. Simulated cropping acres using the biophysical economic model was the same as actual acreage levels for the year 2002 (table 3). This showed that the model's performance is good. Examining crop acreage across crops, one observes that corn is the dominant crop grown within this watershed.

Table 3: Baseline Acreage Estimates.

	cotton	corn	soybean	sorghum	rice	**SUM**
BA	108	215	132			454
CM	2,525	1,701	229			4,456
CN	763	1,714	85	68		2,629
CO	270	39				309
SB	253	672	583	146		1,653
SC	2,652	3,576	5,850	1,687	276	14,040
SD		29				29
ST	1,372	1,921	843			4,136
TU	341	238	129			708
SUM	8,284	10,104	7,850	1,900	276	28,414

Table 4: Crop per Acre Net Revenue.

	Cotton	corn	soybean	sorghum	rice
BA	238.62	379.83	215.12		
CM	192.03	342.27	194.90		
CN	151.27	272.67	190.60	36.87	
CO	110.50	268.37			
SB	23.15	193.86	177.09	2.79	
SC	-0.14	172.75	174.63	-5.84	221.29
SD		60.01			
ST	-64.2	114.69	131.14		
TU	-23.44	151.63	172.17		

This is followed closely by cotton, soybean, then, sorghum and rice. Table 4 presents estimated crop per acre net revenue by soil type. The simulated results showed that net revenue per acre was negative for cotton and sorghum for some soil types. Especially for sorghum, there is a possibility that the earlier assumption on soil yield pattern imitating that of corn could be invalid. Moreover, cotton and sorghum contract specifications with crop procurers might explain why farmers will continue producing these crops even with negative net returns per acre. For cotton, farmers also derive additional revenue as shareholders of cotton ginneries (not incorporated in the analysis). Last but not the least, multiple cropping, high yielding seed varieties, and field soil spatial variability are other factors that might influence net revenue unaccounted for in this analysis.

Table 5: Baseline Crop Net Revenue and Environmental Output.

	Corn	Cotton	rice	sorghum	soybean	Net Returns
Conventional Tillage						
BA	81,800	25,678			28,295	135,773
CM	582,242	484,964			44,693	1,111,899
CN	467,280	115,349		2,496	16,121	601,247
CO	10,386	29,860				40,246
SB	130,260	5,859		406	103,203	239,728
SC	617,675	-371	61,014	-9,853	1,021,592	1,690,057
SD	1,753					1,753
ST	220,282	-88,108			110,502	242,676
TU	36,026	-7,995			22,246	50,276
Net Returns (US $)	2,147,704	565,236	61,014	-6,950	1,346,652	4,113,655
Environmental Impacts						
Nitrogen (lbs)	239,351	33,838	4,209	26,171	341	303,910
Phosphorus (lbs)	602	424	16	113	455	1,609
Sediments (tons)	849	864	13	160	681	2,567

Table 5 shows that corn accounted for about 52 percent of the total watershed net revenue of about 4.1million. Corn also contributed 78 percent of nitrogen runoff at the outlet (239,351 lbs), cotton 11 percent and sorghum 8 percent. Overall, simulated net revenue ranged between $2.1 million for corn and -$6,950 for grain sorghum. For the watershed, additional revenue of $400,018 is also acquired from WRP and CRP.

Compared to the baseline scenario, the all systems-unconstrained scenario shows a scenario where farmers have the option to choose between conventional, reduced and no tillage practices and nitrogen fertilizer application rates to maximize net revenue.

TABLE 6: Nitrogen Reduction Scenarios.

	Corn	Cotton	Rice	Sorghum	Soybean	Sum
			All Systems- Unconstrained			
Reduced Tillage (acres)						
Ninety			276			276
No Tillage (acres)						
Hund	10,104	3,666			7,850	21,620
Ninety		4,618				4,618
Seventy				1,900		1,900
Sum	10,104	8,284	276	1,900	7,850	28,414
Net Returns (US $)						
Hund	2,550,343	1,283,425			1,584,277	5,418,045
Ninety		490,585	70,479			561,064
Seventy				63,014		63,014
Sum	2,550,343	1,774,010	70,479	63,014	1,584,277	6,042,123
Percent change from baseline	18.75	213.85	15.51	1006.63	17.65	46.88
			10% Nitrogen Reduction			
Reduced Tillage (acres)						
Eighty			276			276
No Tillage (acres)						
Hund	4,806	3,666			7,850	16,322
Ninety	5,298	4,618				9,916
Seventy				1,060		1,060
Sum	10,104	8,284	276	1,060	7,850	27,573
Net Returns (US $)						
Hund	1,560,670	1,283,425			1,584,277	4,428,372
Ninety	981,574	490,585				1,472,159
Eighty			70,172			70,172
Seventy				37,111		37,111
Sum	2,542,244	1,774,010	70,172	37,111	1,584,277	6,007,813
Percent change from baseline	18.37	213.85	15.01	633.93	17.65	46.05
Environmental Impacts (Cabin-Teele Sub-Watershed)						
Nitrogen (lbs)	273,519					
Percent change from Baseline	-10.00					
Phosphorus (lbs)	1,609					
Percent change from Baseline	0					
Sediment (tons)	1,969					
Sediment (tons)	-23.31					
Shadow Prices of Nitrogen ($/lbs)	0.73					

TABLE 6: Nitrogen Reduction Scenarios (cont'd.).

	Corn	Cotton	Rice	Sorghum	Soybean	Sum
			20% Nitrogen Reduction			
Reduced Tillage (acres)						
Eighty			276			276
No Tillage (acres)						
Hund	1,916	2,633			7,850	12,400
Ninety	2,711	5,651				8,362
Eighty	5,477					5,477
Seventy				213		213
Sum	10,104	8,284	276	213	7,850	26,727
Net Returns (US $)						
Hund	752,522	970,620			1,584,277	3,307,419
Ninety	755,202	802,942				1,558,144
Eighty	977,773		70,172			1,047,944
Seventy				11,039		11,039
Sum	2,485,496	1,773,562	70,172	11,039	1,584,277	5,924,545
Percent change from baseline	15.73	213.77	15.01	258.82	17.65	44.02
Environmental Impacts (Cabin-Teele Sub-Watershed)						
Nitrogen (lbs)	243,128					
Percent change from Baseline	-20.00					
Phosphorus (lbs)	1,558					
Percent change from Baseline	-3.14					
Sediment (tons)	1,907					
Percent change from Baseline	-25.71					
Shadow Prices of Nitrogen ($/lbs)	3.09					
			30% Nitrogen Reduction			
Reduced Tillage (acres)						
Eighty			276			276
No Tillage (acres)						
Hund		108			7,850	7,958
Ninety	4,341	4,152				8,493
Eighty		4,024				4,024
Seventy	5,440			213		5,653
Sum	9,781	8,284	276	213	7,850	26,404

TABLE 6: Nitrogen Reduction Scenarios (cont'd.).

	Corn	**Cotton**	**Rice**	**Sorghum**	**Soybean**	**Sum**
Net Returns (US $)						
Hund		45,597			1,584,277	1,629,874
Ninety	1,441,074	1,310,017				2,751,091
Eighty		400,334	70,172			470,506
Seventy	901,814			11,039		912,853
Sum	2,342,888	1,755,948	70,172	11,039	1,584,277	5,764,323
Percent change from baseline	9.09	210.66	15.01	258.82	17.65	40.13
Environmental Impacts (Cabin-Teele Sub-Watershed)						
Nitrogen (lbs)	212,737					
Percent change from Baseline	-30.00					
Phosphorus (lbs)	1,538					
Percent change from Baseline	-4.38					
Sediment (tons)	1,893					
Percent change from Baseline	-26.27					
Shadow Prices of Nitrogen ($/lbs)	6.30					

It is assumed that farmers have perfect information on the options available. Table 6 shows that reduced and no tillage are optimal under perfect information. Given these options, different nitrogen fertilizer application rates are employed by farmers to increase their baseline revenues.

Under the all systems-unconstrained scenario, revenue increased for every crop compared to the baseline unconstrained scenario (conventional tillage). Percentage increase in revenue ranged from 1006 percent for grain sorghum, to 15.51 percent for rice. The drastic increase in grain sorghum revenue might seem odd. However, because producers are rational, they reduced nitrogen fertilizer application rates on grain sorghum by 30 percent (compared to baseline levels) and opted for no tillage (had higher net revenue per acre). Hence, though the overall acreage allocations for each crop remained unchanged, farmers moved from conventional tillage to the other two tillage practices. They also reduced nitrogen fertilizer application rates to increase net revenue. Importantly, net revenue increase is attained while maintaining baseline nutrient runoffs and sediment loads.

An assumed state-EPA environmental policy initiative to reduce nitrogen runoffs at the outlet by 10 percent, 20 percent and 30 percent in this watershed resulted in increases of 46.05 percent, 44.02 percent and 40.05 percent in simulated net revenue respectively, compared to the baseline unconstrained scenario. This increased revenue was attained by reducing nitrogen fertilizer application rates as well as adopting reduced and no-tillage practices as against conventional tillage (table 6). Moreover, farmers reduced total crop acreage to meet nitrogen runoff restrictions. Table 6 shows that compared to the baseline and all systems unconstrained scenarios, total watershed crop acreage decreased from 28,414 to 27,573, 26,727 and 26,404 for nitrogen runoff restrictions of 10, 20 and 30 percent respectively.

Acreage allocated and the amounts of nitrogen fertilizer applied on crops have an influence on nutrient runoffs at the outlet. Implementation of nitrogen runoff restrictions will affect net returns of farmers and improve the state's water bodies. Knowing the marginal costs of reducing nitrate runoffs would help policy makers adopt better policies and initiatives. Shadow prices, an estimate of forgone marginal benefits helps derive these estimates. In reducing nitrogen runoff rates, shadow costs here show the forgone marginal net returns in attaining unit lb reductions in nitrogen runoffs in the watershed.

Table 6 indicates that the shadow prices for a 10 percent, 20 percent and 30 percent reduction in nitrogen runoffs at the outlet as respectively \$0.73, \$3.09 and \$6.30. The shadow price of \$0.73 for a 10 percent reduction for example implies that the cost to farmers in reducing nitrogen runoffs in Cabin-Teele sub-watershed by 10 percent is \$0.73 per lb. Additionally, under the above respective restriction scenarios, simulation results showed that phosphorus reductions were 0 percent, 3.14 percent and 4.38 percent, while sediment reductions were 23.31 percent, 25.71 percent, 26.27 percent respectively. These reductions could also be attributed to the reduction in acreage levels. Moreover, reductions in phosphorus levels are minimal because farmers in Cabin-Teele sub-watershed do not apply phosphorus fertilizers on crops. This is due to the naturally high phosphorus content of soils.

Farmers in northeast Louisiana respectively account for 83 percent, 81 percent, 20 percent, 36 percent, and 60 percent of cotton, corn, rice, grain sorghum and soybean total farm produce in Louisiana (LSU AgCenter, 2008[6]). It is therefore safe to deduce that they account for a substantial portion of agricultural pollutant loads into water systems through conventional drainage systems. This research therefore shows the options available to farmers and policy makers in reducing agricultural pollutant loads and net revenue implications.

6. Conclusion

This research adds to current literature by examining farmers' choices given the opportunity to combine different tillage practices and nitrogen fertilizer application rates in reducing nitrogen runoffs. Assuming perfect information on enterprise crop budgets, soil productivity and favorable climatic conditions, agricultural producers generally preferred no tillage system to conventional tillage system in the Cabin-Teele sub-watershed. No tillage is preferred due to higher crop per acre net revenue and lower nitrogen runoff output at the outlet. However for rice production, reduced tillage is preferred for almost the same reasons.

Scenario analysis was also conducted on further nitrogen runoff restrictions to possibly meet any future TMDLs stipulations for impaired water bodies within this region. Simulation results showed that for crops with higher net returns and nitrogen runoffs, farmers lowered nitrogen fertilizer application rates to attain restriction levels. In addition, total crop acreage levels were

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[6] Northeast Research Station: Louisiana agriculture depends on it. Internet site: http://www.lsuagcenter.com/en/our_offices/research_stations/northeast/news/northeast+research+station+louisiana+agriculture+depends+on+it.htm (Accessed on January 4, 2009).

reduced to further achieve nitrogen runoff restrictions at the watershed outlet. This enabled agricultural producers to reduce losses. Shadow prices indicated that marginal costs increased with higher nitrogen reduction levels. Moreover, increased restrictions on nitrogen resulted in lower sediment yield at the outlet.

This research provides policymakers and agricultural producers with the needed information on an alternative method for addressing the negative side effects entailed in current agricultural practices in northeast Louisiana and the lower Mississippi River Basin in general. It suggests that a shift from conventional to conservation tillage as well as the adoption of nitrogen management plans might be one of the solutions to reducing nitrogen runoffs in the lower Mississippi River Basin.

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