



British Journal of Environment & Climate Change
2(2): 113-136, 2012

SCIENCEDOMAIN international
www.sciencedomain.org



Using GIS to Assess the Contribution of Farming Activities towards Climate Change in the State of Mississippi

Edmund C. Merem^{1*}, Chandra Richardson¹, Corney Romarno¹,
Joan Wesley¹ and Yaw Tuwmasi²

¹Department of Urban and Regional Planning, Jackson State University, 3825 Ridgewood,
Jackson MS, 39211, USA.

²Department of Agriculture and Advanced Technologies, Alcorn State University, MS, USA.

Authors' contributions

This work was carried out in collaboration between all authors. ECM designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. CRichardson and CRomarno managed the analyses of the study. 'JW and YT managed the literature searches. All authors read and approved the final manuscript.

Research Article

Received 26th March 2012
Accepted 25th May 2012
Online Ready 3^d June 2012

ABSTRACT

The study uses primary data, descriptive statistics, Geographic Information Systems (GIS) and correlation analysis to analyze the contributions of farming activities to climate change in Mississippi between 1992 through 2002. This involved the assessment of methane emissions from rice cultivation in the state of Mississippi as well as the relationship between the levels of methane gas concentration and other variables associated with rice production. In highlighting the extent to which rice production activities fuel climate change, the results of the study not only showed greenhouse gas emission related rice production activities to be on the rise, but there is a relationship between methane emissions and rice farming. The GIS analysis also points to a visible concentration of rice production activities associated with methane emissions in the major counties of Bolivar, Sunflower and Washington along the Northwest portion of the state. While this raises the threats of climate change predictors in the area. To remedy the problems, the paper suggests five future lines of actions from the need for education to the promotion of emission trading.

*Corresponding author: edmund.c.merem@jsums.edu;

Keywords: GIS; rice farming activities; climate change; agriculture; rice production; descriptive statistics; assess.

DEFINITIONS

Environmentalism¹ for the Merriam Webster dictionary (2012); "is a theory that views environment rather than heredity as the important factor in the development and especially the cultural and intellectual development of an individual or group".

ACRONYMS

IPCC: Intergovernmental Panel on Climate Change; MFA: Mississippi Forestry Association; UN: United Nations; USEPA: United States Environmental Protection Agency; U.S: United States; MMTCE: Million Metric Tons of Carbon Equivalent.

1. INTRODUCTION

1.1 The Threats of Climate Change

The state of Mississippi compared to its size and land area has enormous tracts of agricultural land dedicated to rice farming and other activities with whole range of ecological and economic benefits for society and other life forms (Merem and Twumasi, 2005; Hite, 2003). While the agricultural land areas provide habitats for different species of animals, they also act as a carbon sink for greenhouse gas (Duxbury, 1997). During the last several years, analyzing the linkages between agricultural management practices and climate change trends continue to assume great importance in both academic and policy arena (Wightman, 1997; IPCC, 2007; UN Report, 2007). With the rise of environmentalism¹ in the 1960s and the growing awareness of the impacts of externalities from agricultural operations, popular ideas concerning proper management and use of agricultural land have changed. In the process, practices such as burning of cultivated rice land areas by producers and others are becoming controversial (US EPA, 1998; Justus, 1996). Not only has society become highly interested in the condition of its cultivated agricultural land along with animal husbandry, land and nutrient management practices, but the reports of the linkages of global warming to these practices, has put enormous pressure on today's resource managers to report on the status and condition of the farming activities under their charge (National Center For Atmospheric Research, 2004). Fortunately, this intense interest coincides with the growing acceptance of Geographic Information Systems (GIS) and hosts of other analytical approaches as valuable spatial monitoring tools for management (Munn and Cleaves, 1998). In the literature, Merem and Twumasi have used GIS in different occasions in the analysis of environmental and ecological change. For a complete review of the literature and the previous use of GIS, see their work in various years (Merem and Twumasi, 2005a, 2005b; 2006a, 2006b; 2007a, 2007b; 2008a, 2008b).

At the same time, the chemical composition of the atmosphere through the buildup of greenhouse gases, primarily carbon dioxide, methane and nitrous oxide continue to intensify at an alarming proportion within various countries including the United States and its

agricultural producing states (Wightman, 1997; United States Administration, 1999; IPCC, 1990; IPCC, 2007; UN Report, 2007; Justus, 1996). With the ensuing impacts, public debate has in the last few years often centered on the identification of sources, mitigation measures involving best management practices and the formulation of policies built on global and regional conventions (IPCC, 1990; IPCC, 2007; UN Report, 2007). Notwithstanding the widespread scientific evidence buttressing the existence of climate change, there are still dissenting views on the severity of the problem.

1.2 Gaps in the Literature Pertaining to the Role of Agriculture

Notwithstanding the belief on the linkages between agriculture and climate change, very little exists in the literature about the direct role of agricultural activities in fuelling climate change. To some degree, agricultural activities contribute directly to the emission of greenhouse gases through a variety of processes. Some of the major sources of methane emission attributed to agricultural activities come from rice cultivation and livestock farming (United States Administration, 1999; IPCC, 2007; UN Report, 2007). The other sources includes the following; enteric fermentation, domestic livestock, livestock manure management, cultivation, agricultural soil management and agricultural residue burning (United States Administration, 1999). In 1998 agricultural activities were responsible for the emissions of 148.4 MMTCE or 8 percent of total US greenhouse emissions. Methane C^{H4} and Nitrogen oxide N^{2O} were the primary greenhouse gasses emitted by agricultural activities. Methane emissions from enteric fermentation and manure management represent about 19% and 13 percent of total C^{H4} emissions from anthropogenic activities respectively. Of all the domestic animal production types, beef and dairy cattle were by far the largest emitters of methane. Rice cultivation and agriculture crop residue burning were other sources of methane. Agricultural soil management activities such as fertilizer applications and other cropping practices were the largest source of US N^{2O} emissions accounting for 71 percent. Manure management and agricultural residue burning were also smaller sources of N^{2O} emissions (United States Administration, 1999).

Aside from policy requirements on the various sectors of the economy to identify these trends, the periodic monitoring of methane gas emissions from agricultural activities particularly rice production in Mississippi using GIS is indispensable in the formulation of policies. As a decision support tool, it is essential in tracking the threats of greenhouse gas emissions at the national and state level. Considering that the state of Mississippi ranks fourth in rice cultivation and export among rice producing areas in the United States. Analyzing the role of agriculture in greenhouse gas emission using GIS provides valuable opportunity to assess the trend spatially at the local level. Policy makers and the industry rely on climate change data and its projections as essential components in the design of strategies for long-term decisions and planning. Government policies, regulations and legislation concerning environmental change also require adequate use of spatial information such as GIS in pinpointing the exact locations of greenhouse gas emission sources from the farm sector. This paper would supplement previous efforts in that direction by using GIS technology as analytical and decision support tool in tracking the predictors of methane gas emissions in the rice producing areas of the state of Mississippi.

1.3 Purpose and Organization

The study focuses on the use of GIS in analyzing the contribution of farming activities to climate change with emphasis on the issues, the assessment of methane emission from rice cultivation in the state of Mississippi as well as the relationship between the levels of

methane gas concentration and other variables associated with rice production. The temporal spatial patterns of the evolution of rice production variables associated with methane emission in the rice belt of Mississippi are also presented. Accordingly, the paper has five objectives; the first one is to contribute to the literature and to suggest mitigation strategies while the second one is to identify the current climate change issues in the agricultural sector. The third objective is to design a decision support tool for tracking the emission trends in the rice producing areas of Mississippi. The fourth objective is to analyze other elements in the agricultural sector driving the production of greenhouse gases. The fifth objective of the paper focuses on showcasing the applications of GIS technology in analyzing agriculture and climate change interface. The paper has five sections, the first portion presents the introduction with background information and issues in the literature. The second part describes the methodology and study area's background while section three presents the results and discussions on the temporal spatial analysis of changes in agricultural indicators associated with gas emission along with some recommendations for future lines of action. The fourth section highlights the contributions while the fifth part presents the conclusion with a closure to the paper.

2. MATERIALS AND METHODS

2.1 The Study Area

The State of Mississippi as shown in Fig. 1 is a predominantly rural state situated in the South East portion of the United States of America. With an estimated population of 3.2 million inhabitants and 82 counties, forest land (18.5 Million acres) cover 62 percent of the entire area of the state (MFA, 2000; 2010). Sites suitable for the production of different rice varieties are found in various areas of Mississippi. These sites are located throughout the state in larger and medium acreages within the Delta and the adjoining areas and other places in the state. In a place where rice ranks highly as a vital crop in Mississippi's farm economy. Between 1955 to 1999, the average yield per harvested acre for Mississippi and the US stood at 4,437 and 4,710 pounds respectively. Within the same period, Mississippi's rice yield grew by 4% per year. This is higher than the annual yield rate of 1.96 % for the US as a whole. With the average nominal rough rice prices for Mississippi and US estimated at \$7.33 and \$7.10 per hundred weights during that period. The average annual Mississippi and US rice production between 1959 and 1998 ranged from 7.2 million to 119.6 million hundred weight. At that time, Mississippi accounted for 6.84% of the average total US rice production (Table 1). During the period of 1987-1999, the rice produced in Mississippi represented about 25% of the total rice exports from the United States. While the state of Mississippi also produced about 15% of all long grain rice in the US, roughly 40% of this type of grain is exported to foreign markets such as Latin America and the Middle East (Hite, 2003).

Among the individual counties in the state of Mississippi that experienced increases in the production of rice and the associated methane gas emission, the information in Table 2 indicates that the trends associated with emission related predictors of number of rice farms, acres and weight of produced rice continued to be on the rise over the past years. Various counties most notably Bolivar, Grenada, Leflore and Sun Flower and Washington appear to stand out than the others. Having said that does not in any way diminish the intensity of rice production activities in the other counties such as Humphrey, Issaquena, Panola, Sharkey, Tallahatchie, Tunica, and Yazoo. The distribution of rice production associated with greenhouse gas emissions in Mississippi's counties, between 1994 and 2002, did point to

intense activities in the area (Table 2). In light of this, Mississippi's role as a major rice producing area known to generate greenhouse substances of methane merits attention in the ongoing debate on climate change and the role of the agricultural sector.

Overall, the number of rice farms showed a major increase in 10 out of 13 counties in the first two years, while in 1992 to 1997 all the rice producing counties experienced appreciable growth across the board. Between the years 2004, 1997 and 1992, see that the size of cultivated land as shown continued to grow. In the period 1999-2002, 6 of 13 counties posted numerous increases in the size of cultivated rice land acreages while in 1992-2002, 8 out of 13 counties experienced increases in agricultural rice production with more land under cultivation. Even in areas with decreases, the margin appeared negligible during these years. For more on these trends in the study area, see the Appendix.

2.2 Methodology

The study uses primary data in analyzing the contributions of farming activities to climate change with emphasis on the assessment of methane emissions from rice cultivation in the state of Mississippi. The determination of the relation between the levels of methane gas concentration and various variables related to rice production can help us visualize the present scenario. Changes in emissions over time will be estimated by treating emissions as a function of different variables (such as rice harvested areas, yields, price per unit and value of the production) for the state of Mississippi.

The method used in the study stresses the application of emission related statistics, correlation analysis, time series analysis and Geographic Information Systems (GIS) to display the trends spatially (Merem and Twumasi, 2008a, b; 2007a, b; 2005a, b; 2006a, b). Some of the relevant steps guiding the research consist of a preliminary stage that outlines the identification of variables, data gathering and design as well as a second stage on spatial information needed for GIS mapping and a third stage showing the description of data analysis. A detailed description of the steps now follows.

2.2.1 Stage 1: Identification of variables, data gathering and design

The initial stage guiding the research involves the identification of the 11 variables needed in the research at the state level from 1955-2002. The variables consist of socio-economic and environmental information in the form of cultivated rice land acreage, number of rice farms, methane emission from rice production, and weight of produced rice, harvested rice land area and sales from rice and others, (See Tables 1 to 4).

The various categories of data needed for the research were derived from primary sources such as government documents, newsletters and work found in the libraries. Accordingly, the data gathering process was facilitated by the information provided by the National Environmental Protection Agency office, the United States Department of Energy, Energy Information Administration, the United States Department of Agriculture (USDA) and Mississippi Automated Resource Information System (MARIS). That process was followed by the design of data matrices on socio-economic and environmental variables covering the census periods of 1992 to 2002.

Table1. The average rice yield and other indicators for Mississippi and the US

The Comparison of United and Mississippi -Average rice Production Yield Price and Harvested Areas 1955-1999												
	United States						Mississippi					
Year	Planted acres (x1,0000)	Harvested acres (x1,0000)	Yield lb/A	Price \$/cwt	Product (x1,0000) cwt	Product (x1,0000) \$	Planted acres (x1,0000)	Harvested acres (x1,0000)	Yield lb/A	Price \$/cwt	Product (x1,0000) cwt	Product (x1,0000) \$
1955-59	1573	1547	3192	5	50	236,824	44	42	2890	5	2	5,992
1960-69	1887	1871	4048	5	76	383,119	53	52	3795	5	2	10,552
1970-79	2364	2354	4546	8	112	930,055	110	105	4244	8	5	43,530
1980-89	2843	2811	5238	9	144	1,098,0771	290	2886	4755	9	11	86,588
1990-99	3063	2982	5756	9	178	1,402,390	255	250	5733	9	14	121,258
Mean	2443	2370	4710	7	120	870,673	155	152	4437	7	7	58,302
Max	3827	3792	6121	14	206	1,873,9007	340	337	6200	17	16	143,8546
Min	1370	1340	3061	4	47	209,425	32	31	2700	2	1	5,268
STD	647	619	884	2	48	497,059	101	99	974	3	5	47,521

Table 2. Counties of Mississippi with rice cultivated farms, acres, cwt and farm sales

County	Rice farms-2002	Rice farms-1997	Rice farms-1992	Rice acres-2002	Rice acres-1997	Rice acres-1992	Ricec wt-2002	Ricec Wt-1997	Ricec wt-1992	Farms ales-1997	Farms ales-1992
Bolivar	117	153	205	73,878	73526	80262	4,789,173	4167142	4 686 238	153	205
Coahoma	24	26	44	9,182	7652	15965	515,871	466099	1 010 195	26	44
Grenada		3	5		1470	992		88640	50868	3	5
Humphreys	9	14	26	3,465	4795	7449	174,352	256025	435311	14	26
Issaquena	4	5	5	3,097	5246	3081	219,085	331839	170525	5	5
Leflore	41	37	44	15,505	16257	12142	962,912	945378	692462	37	44
Panola	5	3	9	2,499	1178	1511	158,564	66706	85232	3	9
Quitman	35	39	54	13,735	14123	18007	798,333	801328	971883	39	54
Sharkey	11	17	31	3,369	5520	12107	157,883	328744	692276	17	31
Sunflower	76	81	124	42,664	33543	42838	2,603,430	1861954	2376267	81	124
Tallahatchie	29	41	42	11,223	16375	12246	734,960	870075	762352		
Tunica	30	22	49	22,460	15995	22396	1,399,955	881954	1152520	22	49
Washington	53	71	88	27,247	32849	36520	1,684,780	1969803	2270560	71	88
Yazoo	2	3	4		1117	1538		63100	88795	3	4

Table 3. The average acreages of rice production in some of the counties

The Distribution of Average Acres of Rice For Selected Counties Of Mississippi														
Year	Bolivar planted acres x 1000	Yield lb/A	Humphreys planted acres x 1000s	Yield lb/A	Leflore planted acres x 1000	Yield lb/A	Quitman planted acres x 1000	Yield lb/A	Sharkey planted acres x 1000	Yield lb/A	Sunflower planted acres x 1000	Yield lb/A	Tunica planted acres x 1000	Yield lb/A
1964-69	3809	4084	2353	4011	4104	4,042	3505	3,787	1168	4295	4832	4760	2785	3944
1970-79	6316	4277	5411	4128	7936	7936	3029	4143	2869	4293	10532	4306	7760	4187
1980-89	5850	4837	7098	4621	5887	5887	14,030	4639	6700	4820	12080	4566	15520	4735
1990-95	9470	5809	6650	5306	5645	8730	15,570	5483	8125	5710	14680	5593	19980	5677

2.2.2 Stage 2: Identification of spatial data needed for the GIS mapping

The second stage with focus on the design of spatial data needed for the GIS analysis required the identification of the appropriate digital county boundary lines covering the study periods of 1992, 1997 and 2002. This entailed the assemblage of the electronic version of available agricultural land and resource and land cover maps containing rice producing regions of the state of Mississippi for the years of 1992, 1997 and 2002. This was made possible by the retrieval of spatial data sets of shape files and grid files from the Mississippi Automated Resource Information System (MARIS) in digital form of ARCVIEW GIS. Given that the official boundary lines between several counties in the state stayed stable, it was possible to assign consistent geographic identifier code to the respective area units in order to maintain analytical coherency.

2.2.3 Stage 3: Data analysis

In the third second stage, basic descriptive agricultural statistics related to rice production and regression analysis was employed to transform the original data on environmental variables into relative forms of percentages or correlation coefficients. The purpose of this descriptive statistics and correlation analysis is to generate categories and matrices vital to the paper. Under this process, the parameters for establishing the temporal changes in the variables and their relationships to methane emission were generated for the state of Mississippi.

Emphasizing state level data analysis across time helps facilitate a gradual appraisal and comparison of the trends in the state over time. The time series approach is essential in pointing out the changes in the variables such as cultivated and harvested rice land areas and the others. This approach allows one to detect levels of change with the tables highlighting the trends and problems facing the study area.

The other aspects of the data analysis as mentioned before consist of GIS based spatial analysis and output in the form of maps, tables and textual information covering the study periods. The number of spatial units of analysis at the county level consisted of several units as shown in the study area map (Fig. 1). The 2009 study area map contains information on several objects such as polygons and lines indicating boundary limits of the counties and their geographic identification codes.

The statistical output of the rice land acreage distribution along with those of other variables from the spatial units were mapped and compared across time in ARCVIEW GIS. The process helped delineate the spatial locations and patterns highlighting agricultural and rice production indicators linked with methane emission in the study area.

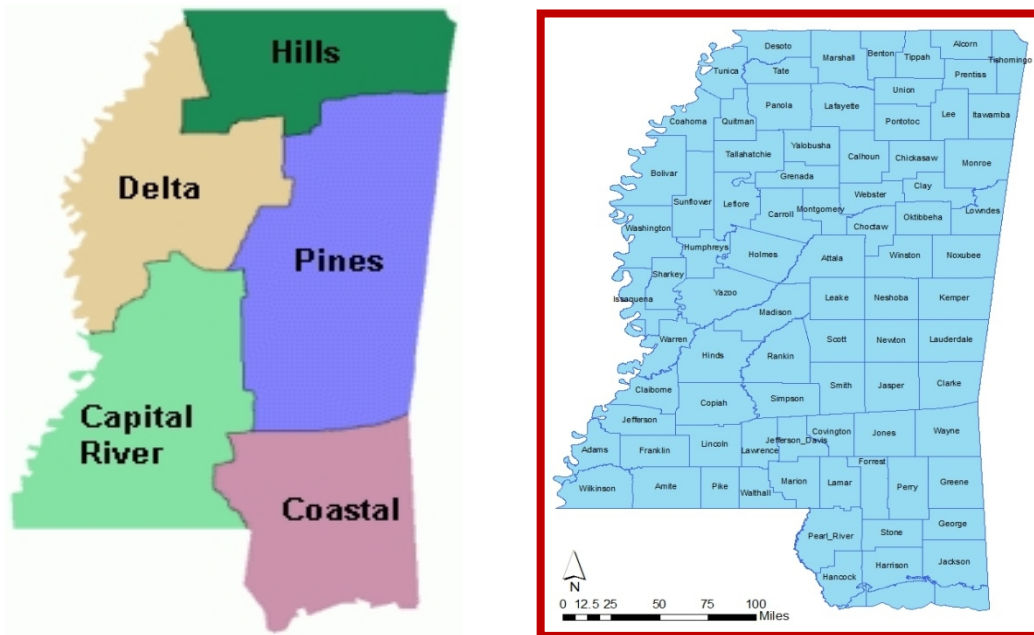


Fig. 1. Maps of the study area of Mississippi

3. RESULTS AND DISCUSSION

In this section, an analysis of the results and discussions based on temporal-spatial portrait of rice production trends is presented in three portions. The analysis initially touches on the acreage of produced and cultivated rice land areas and the percentage of burned rice land areas. The analysis covers the emission of methane from rice cultivation and correlation analysis using regression technique to identify the relationship between cultivated rice land area, rice exports and the distribution of methane emission from 1990 to 2006. Other segment of this section consists of spatial analysis of rice production factors associated with methane emission using GIS and some recommendations.

3.1 The Analysis of Rice Production Indicators

The size of cultivated land areas for rice has undergone sustained increase most of the years in the state of Mississippi. In the periods under analysis, the size of cultivated areas with rice rose from 101,174 acres in 1990 to 1995. In the ensuing years, cultivated land acres with rice grew from 88,223 in 2000 to 102,388 in 2001. Further along the years, in 2002 through 2003, the area of cultivated rice land fell to 94,699 acres but only to rebound again between 2004 through 2005 by 94,699 to 106,435 acres. In the period 2006, the acreages harvested stood at 76,487. In terms of the percentage of rice land areas burned as the table indicates, the rates of burned areas were between 8 to 10 percentage points during 1990, and 1995 through 2002. In the other ensuing years, the intense nature of burned areas associated with rice farming climbed from 40 to 65 percentage points in the periods 2000, 2001 and 2003. In the later years of 2004, 2005 and 2006, the percentage of burned areas varied by 23 to 25 percent (Table 4).

On the volume of methane gas emissions from rice cultivation, see that while the rates of discharge seemed relatively elevated most of the years above the twenty percentage points margin much of the time, in the first two fiscal periods of 1990, 1995, and through the following years. The emission rates varied by 21, 24, and 19 percentage points only to pick up again at 22 and 20 all through the periods 2001, 2002, 2003, 2004, 2005, until it dropped to 16 percent in 2006. Pertaining to the methane emission rate in the state, the information on the table shows they were relatively stable and identical between 1990 through 2000 before a slight drop in 2006 at 0.3. The overall breakdown of the emission rate distribution shows the state emitted 0.4 to 0.5 rates in 1990, 1995, 2001 through the years. The trends continued in a similar vein or levels at 0.5 and 0.4, 0.4 to 0.5 in the periods of 2002, 2003, 2004, 2005 until it dropped at 0.3 in 2006 (Table 5). In terms of the monetary equivalent of rice exports in some years, the figures for the state of Mississippi as a major rice producing area stood at about \$82.4 million dollars in 1997, \$98.9 million in 1998, \$97.3 million in 1999 and \$72.2 million in 2000 (Table 6). To buttress the linkages between the variables herein analyzed, the regression analysis in Table 7 shows that methane gas correlated positively with the area of land cultivated with rice in hectares with the values estimated at close to 1 (Table 7).

3.2 Spatial Analysis Using GIS

On the geographic diffusion of cultivated rice farm land acreages shown in figure 2 1992-2002, there seem to be a broad spread towards the North Central portion of the study area in various scales during 1997 and 1992. Notwithstanding, the initial similarities in patterns, the pattern slightly subsided in the year 2002 along the North West part of the state (Figure 2-4). In terms of rice cultivated farms in Mississippi, even though the situation remained quite identical in the initial years of 1992 to 1997 than the geographic dispersion of the number of cultivated farms in the subsequent year of 2002, see that the areas with most farms such as Bolivar and Sunflower appeared largely stable in the over 100 number of cultivated farm categories during these periods. Turning to the 1992/1997 period, the spatial distribution of the number of cultivated rice farms point to a cluster of farms largely concentrated on the North West part of the state with much of the farms numbering over 100 present in Bolivar and Sunflower counties. This was followed by the counties of Washington and Quitman with each having farms classified under the 76-100 category. The lower farm category totaling 51-75 represented in light green were more active in Issaquena and the remaining rice producing areas. Note also the slight spreading of smaller farms in light green towards the North Central portion of the study area in 1992 (Figs. 5-7).

Table 4. The distribution of rice production indicators linked with methane emission in Mississippi

Rice Indicators	Year and Size								
Year	1990	1995	2000	2001	2002	2003	2004	2005	2006
Rice Acre Harvested	101,174	116,552	88,223	102,388	102,388	94,699	94,699	106,435	76,487
% of Rice Area Burned	10	10	40	40	8	65	23	23	25

Table 5. The distribution of methane (CH₄) emissions from rice cultivation in Mississippi

Methane Emission	Year and Volume and Rate of Emission								
Year	1990	1995	2000	2001	2002	2003	2004	2005	2006
Emissions from Rice Cultivation	21	24	19	22	22	20	20	22	16
Rate of Emissions From Rice Cultivation	0.4	0.5	0.4	0.5	0.5	0.4	0.4	0.5	0.3

Table 6. Assorted data on cultivated rice land, and methane gas used in the regression analysis

Year	Rice cultivated in hectares	Rice Export (Million dollars)	Methane gas emissions from rice cultivation
1990	101174	No data	21
1995	116552	No data	24
1996	84176	No data	18
1997	96317	82.4	20
1998	108458	98.9	23
1999	130716	97.7	27
2000	88223	72.2	19

Table 7. Correlation analysis between rice cultivation and methane gas emissions in Mississippi

	Rice cultivated in hectares	Rice Export (Million dollars)	Methane gas emissions from rice cultivation
Rice cultivated in hectares	1	0.844	0.996
Rice Export (Million dollars)	0.844	1	0.854
Methane gas emissions from rice cultivation	0.996	0.854	1

Note: There exists a strong correlation as the coefficients of rice cultivation and methane gas emissions show a value that is nearing 1.

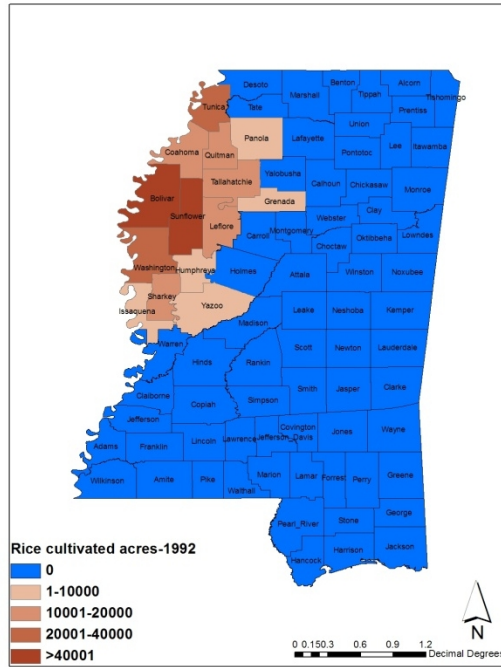


Fig. 2. Map showing number of rice cultivated acres in Mississippi-1992

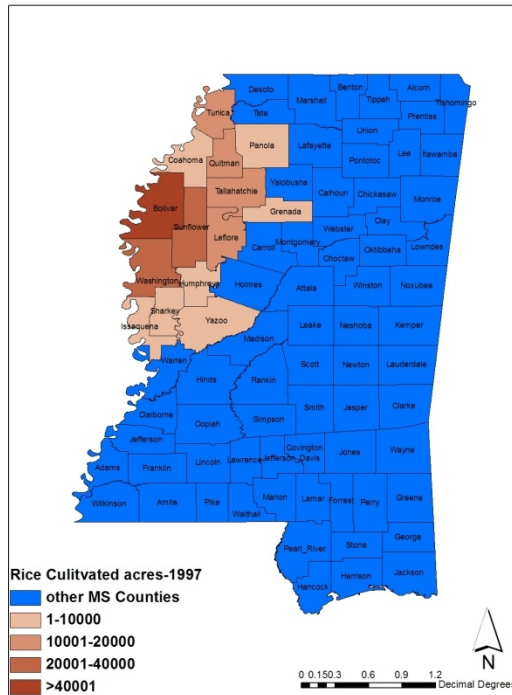


Fig. 3. Map showing number of rice cultivated acres in Mississippi-1997

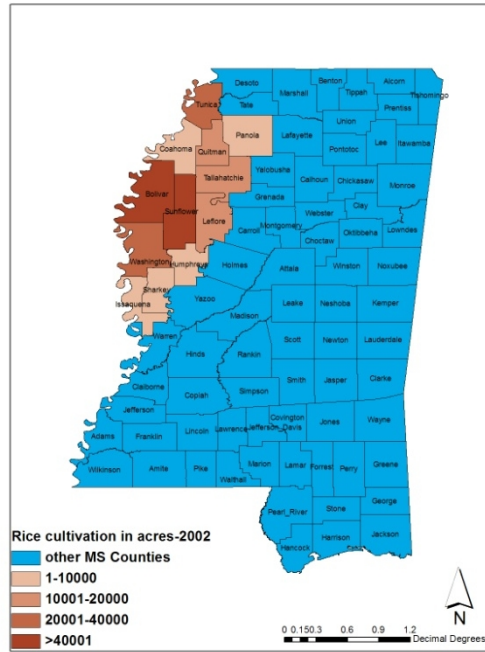


Fig 4. Map Showing number of rice cultivated acres in Mississippi-2002



Fig. 5. Map showing number of rice cultivated farms in Mississippi-2002

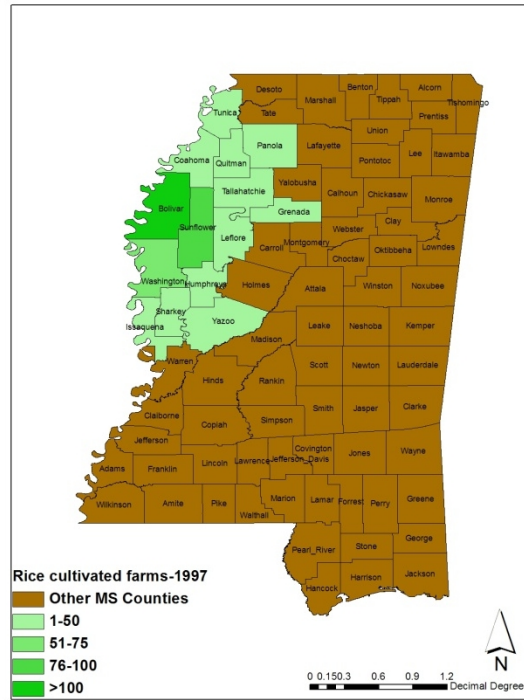


Fig. 6. Map showing number of rice cultivated farms in Mississippi-1997

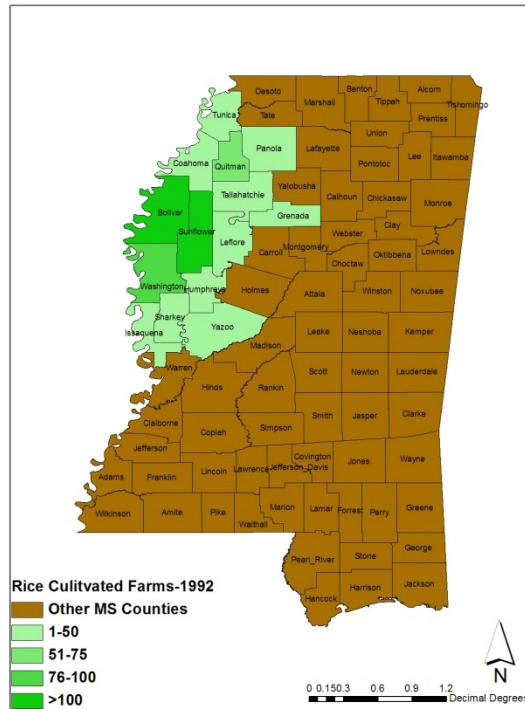


Fig 7. Map showing number of rice cultivated farms in Mississippi-1992

Regarding rice farm sales among the counties in the blue color, the spatial distribution of the trends from 1992-1997 in the study area seemed somewhat identical. It shows a pronounced evidence of large returns from rice trading more evident once again in north east Mississippi. The sales categories exceeding \$100,000 and above 51-100 farm types were more visible in Sunflower and Bolivar, Washington and the Quitman county side along the north west area of the state. As time went on, there emerged a cluster of counties with farm sales estimated at 1-\$50,000 within north Central Mississippi (Figs. 8-9).

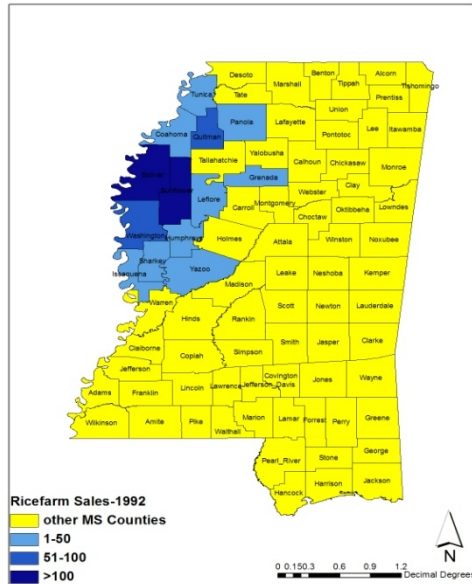


Fig. 8. Map showing number of sales from rice commodities in Mississippi-1992

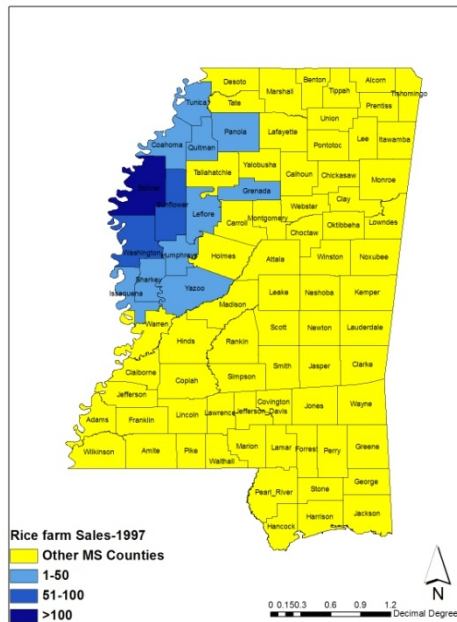


Fig. 9. Map showing number of sales from rice commodities in Mississippi-1997

On the mass or weight of cultivated rice in Mississippi, see that Bolivar county presented in the dark pink color remained visible under the over 300,0001-5,00,0000 category in 1997-2002 most of the time. Aside from a gradual spread of the trend to Sunflower in 2002, note how the large volumes of produced rice locations clustered in the north central part of the state in 1997 gradually receded towards the North West in 2002 (Figs. 10-11).



Fig. 10. Map showing hundred weight of rice cultivated in Mississippi-1997

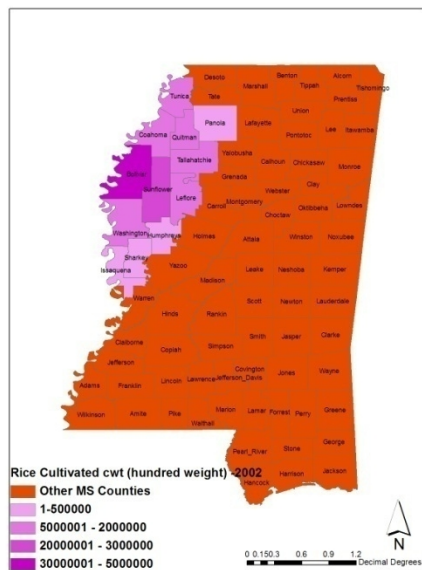


Fig. 11. Map showing hundred weight of rice cultivated in Mississippi-2002

3.3 Discussion

Just as the various sections of the paper rightly noted the widespread buildup of chemicals and the concentration of greenhouse gases in the last the several years, there exists the

growing presence of primary gases most notably carbon dioxide, methane and nitrous oxide associated with farming as well. With mounting evidence on the role of these chemicals in climatic variability, very little exists in the literature about the role of agricultural activities in fuelling climate change. To some degree, agricultural activities contribute directly to emissions of greenhouse gas through a variety of processes. The major source of methane emissions attributed to agricultural activities comes from rice cultivation and livestock farming. To locate the extent to which agricultural activities trigger methane gas emission, the paper offered a profile of the study area in Mississippi. This was followed by a highlight of the activities involving predictors of rice cultivation made up of the number of rice farms, cultivated areas, weight of produced rice and the sales from rice exports through some selected counties in the periods of 2002, 1992 and 1997.

Additionally, the empirical analysis of the contributions of agriculture to greenhouse gas emission in Mississippi, presented so far shows that greenhouse gas related agricultural activities in rice production are on the rise in the state. The time series analysis of rice production indicators such as cultivated area in hectares, weight or mass of produced rice point to a tremendous rise in the rice producing areas of the state. A measure of the rate of ensuing greenhouse gas emissions from farming shows that rice cultivation in the rice regions of the state contribute to methane emission. To buttress the relationship between rice production indicators of burned areas, and cultivated areas, regression analysis showed a positive correlation of near or close to 1 between some of the rice production activities. A spatial analysis of the trends indicates visible concentration of rice production activities associated with methane in the major counties of Bolivar, Sunflower and Washington along the North West portion of the state. Because the geographic cluster of rice production indicators appeared relatively similar over the years between 1992, 1997 and 2002, it is safe to view the North West and central part of the state as the rice belt region partly associated with the emission of methane gas in Mississippi.

3.4 Recommendations

This portion of the paper offers some suggestions on how to remedy the problems associated with greenhouse gas emission from rice production in counties located in the state of Mississippi. The recommendations range from education, the tracking of emission, the strengthening of policy, the design of a regional agricultural and environmental information system and the institution of an emission trading scheme. These recommendations are examined in detail below.

3.4.1 Raise awareness through education

The effects of greenhouse gas emissions and the linkages with agricultural activities are now well documented, but not everyone is aware of the enormous ecological costs. In a setting in which most agricultural producers in the rice farm belt of Mississippi lack an understanding of how environmental externalities from their activities threaten ecosystem health. The paper recommends a coordinated awareness program through agricultural education. This should include workshops and seminars focusing on the links between farm operations and the emission of greenhouse gases of methane and others (Ning, 2003). Such a program should also involve enlightenment campaigns anchored in the dissemination of information to the public through brochures and printed materials highlighting the risks of methane gas emission from rice production and the role in climate change.

3.4.2 Track emission

The production and dispersion of greenhouse gas emission particularly from farming activities does not respect geographic boundaries of any kind. Considering that most emitters of greenhouse gas do not necessarily know of the chemical compositions and the scale of their concentration in the atmosphere and surrounding ecosystem where rice production occurs. There is an urgent need for decision makers to track the daily volumes of emitted greenhouse gas from producers of rice in the state of Mississippi. This would enable producers recognize maximum and minimum thresholds of emission levels in a manner that would safeguard the carrying capacity of the ecosystems and ensure environmental protection. This proposed approach can be attained by installing reliable set of devices capable of tracking the volumes, location and sources of emission from farm producers in the rice producing counties of Mississippi.

3.4.3 Strengthen regulations

The linkages of the agricultural sector and others to greenhouse gas emissions and climate change has long been established. Yet, cynics still dismiss it as a myth in mainstream policy discourse. This type of stance not only undermines the adoption of best management practices among agricultural producers to mitigate the impacts, but it works against the formulation of effective policies and action plans to stem the tide of climate change. For there to be effective mitigation of greenhouse gas impacts from agriculture, regulators must strengthen existing policies by applying environmental policy instruments based on command and control mechanisms. Doing so would require clearly laid out emission standards and permissible levels and a green tax scheme to which agricultural operations must adhere to. Under this proposed framework, regulators should reserve the options to impose sanctions against producers not deemed in compliance of best management practices to curb the emission of greenhouse gases.

3.4.4 Design regional climate change information system

During the writing of this research paper, we did not come across a common farm data system for Mississippi. Surely, the state of Mississippi lacked a centralized regional agricultural and environmental information system detailing the extent and location of agricultural operations and more especially rice farms known to produce greenhouse gases such as methane and the associated impacts on the environment. The absence of such data infrastructure as a decision support tool in the fight against greenhouse gas emissions in rice producing areas not only stifles mitigation, but it keeps policy makers unprepared in confronting the threats climate change pose to society. The proposed regional environmental information system must contain valuable temporal-spatial information on the agricultural and rice production indicators from number of rice farms, cultivated areas and the volume of greenhouse gas emitted from rice operations. Other elements for the proposed system should include socio-economic factors driving rice production in the market place. This would enable policy makers gauge how certain elements drive the emission of greenhouse gas. In light of that, the paper supports the design of a regional information infrastructure.

3.4.5 Institute emission trading scheme

Emission trading in the last several years has been widely used by regulators, utility and power companies in policy settings. This led to a sharp reduction in the discharge of toxic pollutants into the atmosphere. With such level of success, the agricultural sector should

institute the adoption of emission trading schemes as practiced in the other sectors of the economy. This would help minimize the impacts of greenhouse gas in rice producing areas and society in general. With agricultural operations structured along farm types of large and small and medium scales, regulators should assign emission advance credits relative to the size and intensity of farm activities to accommodate projected emission quota. Under the proposed emission credit scenario, farm types that exceed their allowable emission quota may be allowed to purchase emission credits from other operations or organizations where rice production does not result in large volumes of methane emission. For these reasons, the paper supports the design of greenhouse emission trading scheme for the farm sector.

4. THE CONTRIBUTIONS OF THE RESEARCH TO THE LITERATURE

There are several important contributions that have emerged in this study. The fact that green house gases are induced partly by human factors such as rice farming activity does re-echo the human-nature interface debate that has lingered on over the years. Highlighting the essence of sequential mapping in this interface, alongside new insights into the climate change debate through education and the links between climate change and farming, are major contributions to the literature. Regarding the other contributions, one need not forget the appropriateness of the methods used and the significance of the study as a template for future applications. Having come this far, in the context of the study area, the themes herein presented stand as some of the major contributions of the research. The detailed analysis of these themes is highlighted in the following paragraphs.

4.1.1 Showcased the essence of sequential mapping for policy makers

The sequential mapping and appraisal of the locations of emission sources using GIS serves as an effective decision support tool for managers in the rice producing areas of Mississippi craving for the right devices for attaining a livable environment. With the growing stress inflicted on ecosystems by climate change predictors such as methane emissions, ecological consciousness and policy requirements have created a need for analyzing the interface between the rice farm economy and the environment. In this setting, locating emission sources for ecosystem protection is regarded by most managers as a necessary ingredient for effective environmental decision making. Whether the goal is pollution prevention or some broader notion of sustainability, there is a widespread belief that the sequential mapping of methane emission sources and sites helps in the implementation of desirable policy innovations. Moreover, environmental regulation is evolving toward public policies that rely mostly on the collection and reporting of environmental information based on the analysis and mapping of stress sources and locations such as rice farming fields.

4.1.2 Echoed the virtues of climate change theme in public discourse and research

In US public policy, regardless of the political season and the party in power, climate change debate has always ignited polarizing positions from each side of the ideological spectrum. People on the right end of the political spectrum see it as a myth, while the left regard it as a reality that should not be neglected by policy. Yet some of the scenarios outlined in the paper showed how climate change predictors partly emanate from human activities such as farming. The fact that this paper devoted sizable attention to it in the literature reaffirmed the acceptance of climate change theme as an integral part of debates in policy and research. The analysis of various trends including mapping and the correlation between various elements associated with climate change, as presented in this paper echoed the essence of

the theme. The contribution stems from the potentials of elevating the debate through a road map acceptable to all stakeholders longing for new directions in policy research. This helps stimulate discussions and new ideas necessary for the improvement of policy making.

4.1.3 Helped reaffirm the links between rice farming and climate change

In a world in which not all the average readers of popular and scholarly journals recognize the links between farming and climate change. The idea of GIS analysis of green house gas emissions from rice farming, as presented in the paper helps stimulate the interest and opportunities that are currently driving the contours of research in environmental change. Additionally, the theoretical underpinnings of human-environment interaction as shown from rice farming and greenhouse gas emission did widen the methodological options for planning and policy. This is relevant in addressing the ecological problems central to good decision making and for improving our understanding of the climatic risks of rice farming. The familiarity with devices such as GIS in showing the spatial diffusion of various predictors associated with rice production and green house gas emissions in the study area can set the stage for continuous use of these approaches in future studies. The models used here can be instrumental in encouraging the adoption of GIS technology in identifying the spatial patterns of rice farming activities and the resulting stressors such as greenhouse gases.

4.1.4 The use of appropriate methods

The GIS mapping highlighted the spatial distribution of rice production and climate change predictors and the proximity between sites of production and the surrounding ecology of the state as well. In the current study, the availability of temporal spatial data and analysis played a vital role in assessing the trends and the potential ecological risks emanating from rice farming activities. The assemblage of information and analysis using the mix scale methodology, not only quickened the data processing stage of the study, but it unveiled the location of stress sources in the rice producing region of Mississippi essential for effective management and mitigation. Accordingly, GIS technique as used here in contributing to the literature stands as a relevant decision support tool that pinpoints high risk areas and counties vulnerable to the concentration of methane gas in the atmosphere. In the study area, this involved the generation of maps that identified rice producing counties know for methane gas emission. Visualizing counties and natural areas prone to green house gas concentrations in these settings, not only help focus the scope of GIS and environmental planning with records of change in affected areas, but it furnished information on the pace at which rice farming activities can influence climate change.

4.1.5 Provided a template for future applications

The study also serves as a template for future applications of GIS in rice producing areas in other states or regions. This then stimulates the growth of regional expertise and confidence which in turn enhances the capacity to make decisions in areas associated with rice farming activities and ecosystem impacts. This role in the context of future applications as decision support tool, can lead to a real consensus as more users, and those in charge of environmental management systems have faith in the approaches and make a conscious decision to increase their application in future. The applications of this technique in the research along with the findings, therefore makes a contribution to our understanding of GIS applications in the analysis of climate change risks and the literature. These techniques play a fundamental role in the impact analysis of rice farming activities. Certainly, the project has revealed the utility of GIS applications in environmental planning and emission tracking and

mitigation and thus serves as a template for future applications. This would inject some novelty in planning within areas vulnerable to green house gas concentration from rice farming activities. It is expected that they will serve a useful purpose in future research and will evolve further through utilization in a variety of situational settings in the study area and elsewhere under conditions that are compatible with the ideas of environmental planning.

5. CONCLUSIONS

This paper begun by tracing the problem of climate change and green house gas emission trends as it relates to agriculture. In highlighting the extent of rice production activities in Mississippi's farm sector between 1992 through 2006, the study showed how widespread production of rice emerged as a major contributor to methane gas emission at the state level. A Time series analysis and descriptive statistical analysis of the trend showed a spreading of large rice production activities across several counties with much of that concentrated along the North Western corner of the state made up of Bolivar, Sunflower as well as Washington and the other adjoining counties of the state.

The GIS mapping of the trends which captured the spatial diffusion of rice production indicators points to a visible cluster of rice cultivation activities centered around the North West. At the same time, production activities remained visible around the adjoining areas along the North central portion of the state over the years. By adopting a mix scale approach of descriptive statistics and GIS mapping, the paper reaffirmed the contributions of agricultural activities in the state of Mississippi to climate change risks with much of the methane emission coming from rice production in the rice farming counties of the state. To address these problems, this paper offered five recommendations ranging from the education of the public and producers, the institution of emission trading, the strengthening of regulations and the design of a regional agricultural emission climate change information system and the development of emission tracking mechanism to capture the temporal-spatial trends. The contributions of the research ranged from its ability in showing the essence of sequential mapping techniques to the development of a template for future research. Analyzing the contributions of agricultural activities to climate change in the state of Mississippi, will continue to assume greater importance in both policy and research in the years ahead.

ACKNOWLEDGEMENTS

We would like to thank the Dean of the College of Public Service at Jackson State University for approving a request for conference travel and participation and the various government agencies for making environmental and geospatial data available for the research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Agnihotri, S. (1998). New mitigation strategy to contain methane emission from rice fields, *Environmental Monitoring and Assessment*, 58(19), 95-104.

- Boriss, H. (2006). Commodity profile rice. 1-10. Davis, California: University of California Agricultural Issues Center.
- Duxbury, J. (1997). Climate change and agriculture promoting practical and profitable responses, soil carbon sequestration and nitrogen management for green house gas mitigation. Available On Line at: <http://www.climateandfarming.org/pdfs/F> (accessed on March 2008).
- Easterling, W. (2007). Food, fibre and forest products, climate change, impacts, adaptation and vulnerability contribution of Working Group 11 to the fourth assessment report of the Intergovernmental Panel On Climate Change. 237-313. Cambridge, UK: Cambridge University Press.
- Government of Alberta. (2005). Targeting greenhouse gas research for agriculture. 12, 1-4. Alberta: Government of Alberta.
- Government of Alberta. (2004). Greenhouse gas emissions of the agriculture and agri-food industry, 1, 1-2. Alberta: Government of Alberta.
- Government of Alberta. (2000). Agriculture food and rural development. Available on line at: [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/cl9706/\\$File/GHGBulletinNo5Cropping.pdf](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl9706/$File/GHGBulletinNo5Cropping.pdf). (accessed on september 2008).
- Government of Alberta. (2001). Climate change and agriculture. Alberta agriculture food and rural development. Available on line at: [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/cl9706/\\$FILE/ghgbulletinno7june_2001.pdf](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cl9706/$FILE/ghgbulletinno7june_2001.pdf). (accessed on september 2008).
- Hite, D. (2003). Economic and environmental benefits of rice production in the mississippi delta. 1-18. Starkville, Mississippi: Mississippi state university. Office of agricultural communication.
- IPCC. (2008). Special report on emissions. Available on line at: <http://www.grida.no/climate/IPCC/emission/076.htm>. (accessed on september 2008).
- IPCC. (2007). Mitigation of climate change. Oxford, UK: Oxford University Press.
- IPCC. (1990). Potential impacts of climate change, Report of Working Group 2. Oxford: UK Oxford University Press.
- Justus, J. (1996). CRS issue brief; global climate change. Washington, DC: Science Policy Research Division, CRS.
- Merem, E., Twumasi, Y. (2005a). GIS applications In land management: the loss of high quality land to land development in Central Mississippi from 1987-2002. *International Journal of Environmental Research and Public Health*, 234-244.
- Merem, E., Twumasi, Y. (2005b). GIS based analysis of growth management and environmental decline in seven counties of Central Mississippi Region. *International Association of Chinese Professionals in Geographic Information Science*, 130-137.
- Merem, E., Twumasi, Y. (2006a). Geospatial Information Systems Analysis of regional environmental change along the Savannah River Basin of Georgia. *International Journal of Environmental Research and Public Health*, 281-294.
- Merem, E., Twumasi, Y. (2006b). GIS and Remote Sensing applications in the assessment of change within a coastal environment in the Niger Delta region of Nigeria. *International Journal of Environmental Health and Public Health*, 98-106.
- Merem, E., Twumasi, Y. (2006c). Hydro-politics, a case of the Niger River Basin. *GIS Development: Africa*, 24-28.
- Merem, E., Twumasi, Y. (2007a). GIS applications in global environmental protection: the case of environmental monitoring of fossil fuel emission from oil and gas activities in Africa. *World Resources Review*, 657-680.

- Merem, E., Twumasi, Y. (2007b). Using geospatial information technology in natural resources management: the case of urban land management in West Africa. *International Journal of Environmental Health and Public Health*, 278-289.
- Merriam Webster Dictionary. (2012). Environmentalism Available on line at: <http://www.merriam-webster.com/dictionary/environmentalism>. (accessed on May 2012).
- MFA. (2000). Mississippi forest facts. 1-2. Jackson, Mississippi, MFA.
- MFA. (2010). Mississippi forest facts. Jackson, Mississippi, MFA.
- Munn, I., Cleaves, D. (1998). An analysis of losses to the Southern commercial timberland. In *Proceedings of the 1998 Southern forest economics workshop*. Triangle Park: North Carolina. Southern Research Station. 25 March, 198-202.
- National Center for Atmospheric Research. (2004). Science update climate change Impacts. 1-2. Boulder, Colorado: UCAR Communications.
- Ning, Z. (2003). Preparing for a changing climate, the potential consequences of climate change variability and change : Gulf coast Region. Baton Rouge, Louisiana : GCRCC- LSU Graphic Services.
- Reilly, J. (2001). Agriculture: the potential consequences of climate variability and change for the United States: US national assessment of the potential consequences of climate variability and change. New York: Cambridge University Press, 136.
- Rughooputh, S. (1997). Climate change and agriculture micro climatic considerations. In *Proceedings of the Annual Meetings of Agricultural Scientists of Mauritius (AMAS)*. Reduit, Mauritius. 12-13 August, 73-82.
- Rosenzweig, C. (1995). Potential impacts of climate change on agricultural and food supply. *Consequences*, 1(2), 1-3.
- Sass, R.L. (1995). Methane emissions from Texas rice fields. a five year study. *climate change and rice*. Berlin, Heidelberg: Springer Verlag, 45-59.
- UN Report. (2007). Climate change. Available online at: http://www.ipcc.ch/spm26_feb07pdf (accessed on May 25, 2008).
- USEPA. (1998). Climate change and Mississippi. DC, Washington: EPA office of Policy and Evaluation.
- U.S. Department of Agriculture. (2005). National Agricultural Statistics Service (NASS), crop production annual summary. Available on line at: <http://usda.mannlib.cornel.edu/reports/nassr/field/pcp-bban/>(accessed on July 2008).
- United States Administration. (1999). Emission of greenhouse gases in the United States; methane emissions. National Energy Information Administration Center (EIA). DC, Washington. US Department of Energy.
- United States Environmental Protection Agency. (1989). The Potential effects of global climate change on the United States. Washington: US EPA office of Policy, Planning and Evaluation.
- United States Government. (1996). Committee on environment and natural resources research, *Our Changing Planet: The FYI*. DC, Washington: United States office of Science and Technology Policy.
- United States Government. (1994). US climate action report, submission of the United States of America. The UN framework convention on climate change, 1-200. DC, Washington: US Govt Printing Office.
- Wightman, J. (1997). Climate change and agriculture promoting practical and profitable responses, production and mitigation of greenhouse gases. Available on line at: <http://www.climateandfarming.org/pdfs/FactSheets/IV.1GHGs.pdf>. (accessed on July 2008).

APPENDIX

The monitoring of agricultural land sales showed Bolivar county with transactions valued at \$153 million dollars in 2005. This was followed by Washington county's land sales of \$71 and 88 million and the estimates of sunflower county valued at \$81 to 124 million. The breakdown for the other counties points to \$37 and 44 million for Leflore while the land sales in Quitman totaled \$39 to 54 million. See the table for the dollar value of land sales of the other counties (Table 3). Having seen all these changes in rice farm indicators associated with methane emission, a general synthesis of the process under which emissions occur is necessary.

With much of the globe's rice crop along with the ones in the United States cultivated on swamped fields. Once these fields go flooded, the process of aerobic breakdown of natural material slowly drains the oxygen contained in the soil and floodwater. This makes the anaerobic conditions in the soil to grow. The emergence of an anaerobic environment is followed by methane production made possible through methane organic bacteria in the soil (Sass, 1995; Agnihotri 1998). Considering that a quantity of the methane is also filtered away as dissolved substance in the flood water percolating from the field. The left over un-oxidized methane is carried from the inundated soil to the atmosphere chiefly by diffusion through the rice plants. Certain portions of the methane also leak from the soil through bubbles triggered by flood waters (US EPA, 1989).

Furthermore, the applications of synthetic fertilizers have also been found to influence methane emission. Particularly, both nitrate and sulphate fertilizers (ammonia nitrate and ammonium sulfite) seem to influence methane formation. In the United States where several factors including soil types, soil temperature, cultivar types and production practices for rice differ from one area to another. The majority of farm operations also use organic fertilizers in the form of rice residue from the previous crops left behind. In as much as rice cultivation represents a partial cause of methane emission in the United States of just under the 2% range. Rice cultivation remains extensive in seven states made up of Arkansas, California, Florida, Louisiana, Mississippi, Missouri and Texas. Estimates of the total methane emission from rice cultivation range from 2.3 to 2.7 MMTCE (404 to 476 Gg Ch₄ for the years 1990-1998 (US EPA, 1989).

Even though the proportion of methane emission from rice production is lesser than those from other sources, the impacts of greenhouse gas and the rice production sources should concern us. Analyzing the contribution of agriculture to climate change in Mississippi in this context remains a timely research as policymakers deal with the challenges of identifying the right set of mitigation measures to minimize the trends.