# 2008 CRESS National Water Conference, Sparks Nevada, February 3-7

## "Applications of Geo-Information Systems To Assess Water Quality Trends In The Mid Atlantic Region Within An Agricultural Watershed

**By**

Dr Edmund Merem

**Jackson State University, Mississippi**

06/02/08

# Scope of the Presentation

- Purpose of the Research
- Background Information and Issues
- Efforts
- Methodology and the Study Area
- Case Studies / Results
- Socio-Economic Factors
- Recommendations
- Conclusions

# Objectives of the Research

- To contribute to the literature on geo-information systems
- To device a support tool for decision makers
- To develop novel method for identifying water quality stressors in an agricultural watershed
- To provide a framework for efficient management of water resources
- To analyze the water quality in the Mid-Atlantic region of Maryland

# Background Information/the Issues

- In the area, the Chesapeake Bay watershed and other river systems in the state are threatened by various anthropogenic stressors
- In the Bay, where agriculture stands as a key source of pesticide and nutrient pollution of streams, the continuous discharge of surplus nutrients into the estuary poses grave hazards to the surrounding ecology.
- While higher levels of these substances can be harmful to humans and biodiversity, a USGS work on various agricultural watersheds in the country in the last decade ranks urban and agricultural point source chemical pollution to be major issues.
- Compounding the matter for managers is the role of several socio-economic factors in fuelling the problems and the lack of access to spatially referenced information on the location of stressors along the watersheds
- Knowledge of the dangers posed by degradation of water quality and declines in biodiversity demands a geo based assessment of management practices within agricultural watersheds.
- A geo spatial system anchored in GIS needs to be developed. to provide managers spatially referenced data with opportunities to locate stressors and changes threatening agro-watersheds of the Mid Atlantic region of Maryland

# Methodology and the Study Area

- The research stresses a mix-scale approach involving the use of descriptive statistics, correlation analysis and geo-spatial analysis of GIS

- **Step 1: Identification of The literature, Variables and Spatial data**

- Access to the relevant data bases containing the literature

- The spatial data on state of Maryland used in the study cover regions and watersheds in the area from the separate periods of 1970 through 2005.

-All these were acquired from the USGS, the US EPA and the USDA

- **Step 2: Mapping and Analysis of The trends with Geo-spatial data processing**

-Multi-temporal spatial data made up of shape files and maps were obtained for the study

- The spatial and temporal data was analyzed using software like Arc View and SPSS

- The output was visually compared with the trends evidenced in the area to see the changes across time and space along the tributaries of the major agricultural watersheds of the Mid Atlantic region of Maryland

# The Study area: Maryland

- The study area of Maryland is situated on the Atlantic coast of the Southern region of the United States
- From the most current Census data in 2007, Maryland ranks as the richest state in the United States, with a median household income of US$65,144
- In 2006, Maryland's population stood at 5,615,727. This represents an increase of 0.5%, from the previous prior year.
- Over the years, the state's size of built up areas designed to house the residents accelerated at the rate of 124% , which shows the consequences have profound impact on the ecology and the welfare of citizens
- Should the present growth patterns persist, ecological features such as the Chesapeake Bay watershed displayed will experience unprecedented changes such as conversion of over 3,500 square miles of forest, wetlands, and agricultural land to development
- The Bay is not only ranked as the largest freshwater estuary in the world, but also as the largest physical feature in Maryland.
- In the field of agriculture, while the Chesapeake supplies the state of Maryland its huge cash crop of blue crabs, the southern and eastern portion of the state are quite active in tobacco farming.
- In 2004, agriculture generated more than $1.7 billion for farmers in the state farmers. In the same period the state contained about 12,100 farms, with an average of 169 acres while the total land in farms were estimated 2,05 million acres; representing about one third of the entire land areas

# The Study area: Maryland - contd

- The measure of the pace at which agriculture impacts the watersheds in the study area can be manifested from the number of nuisance complaints in four major areas air, water, soil, animal and other associated with agriculture Table 1.1

- In 2005 alone, when 94 agriculture related complaints were received sediment, accounted for 28 percent of those cases while another 47% was attributed to, manure MDA 2005

- Between 1990-2000 the monetary expenditures for fertilizer in the state rose by 41.9%.

- The applications of pesticide use in region correlated with changing land use in various places.

- Some of the frequently applied pesticides in the Coastal Plain of the state consists of various types of herbicides outlined in Table1.2

- The mapping of these stressors and their impacts on water quality along the agricultural watersheds using GIS technology is vital for the wellbeing of the ecosystem

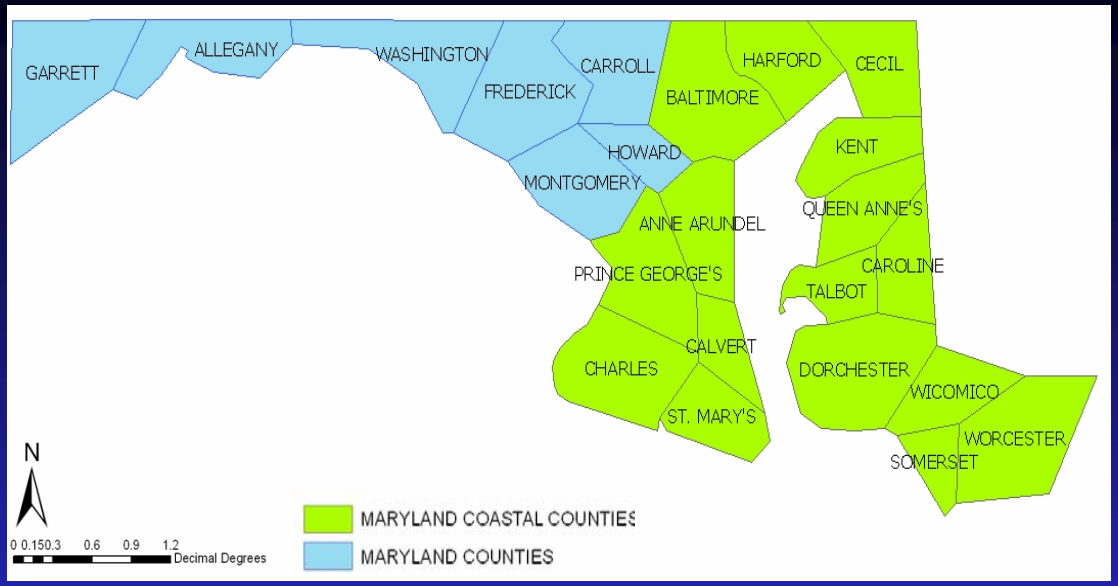



Figure 1.1: The Study Area- Mid Atlantic Region of Maryland

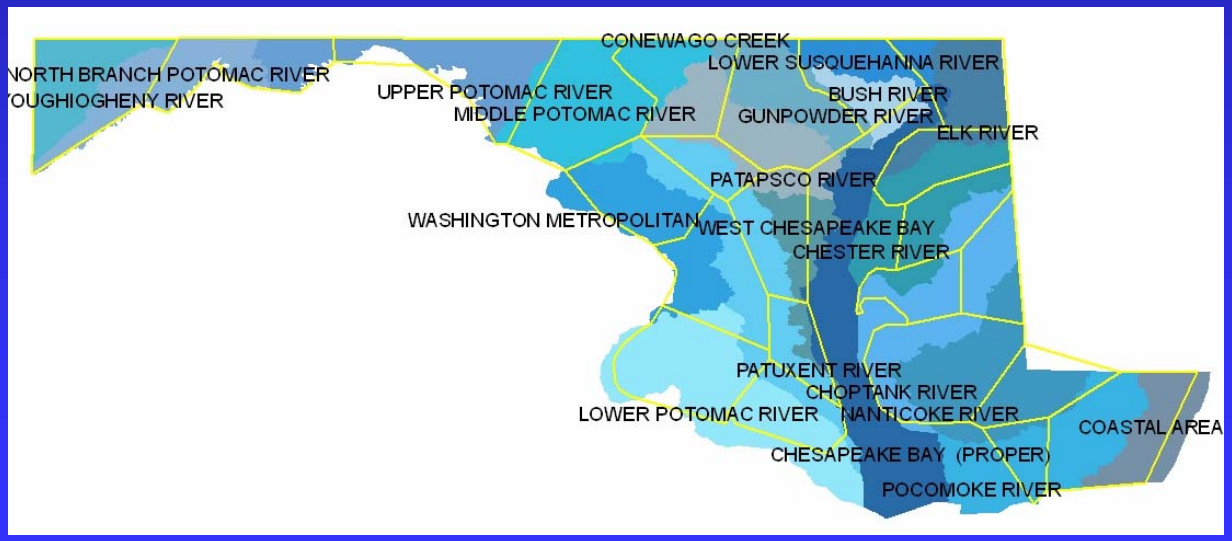



Figure 1.2: Maryland- Watersheds

Figure 1.3 The Chesapeake Bay Under the threat by Stressors

## Table 1.1 Cases of Complaints Related to Agriculture In Maryland

| Year | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|
| Complaints | 32981 | 34646 | 36170 | 35232 | 34929 |
| Counties Reporting | 17 | 18 | 18 | 18 | 21 |

## Table1. 2 Selected Pesticides in The Maryland Coastal Plain in 2000

| Compound | Type | Active Ingredient Applied (pounds) | Proportion on (percent) | Proportion on (percent) |
|---|---|---|---|---|
| Glyphosate | Herbicide | 719,000 | 70 | 30 |
| Metolachlor | Herbicide | 389,000 | 77 | 23 |
| Atrazine | Herbicide | 380,000 | 74 | 26 |
| Pendimethalin | Herbicide | 289,000 | 13 | 87 |
| Simazine | Herbicide | 183,000 | 87 | 13 |
| (Metam-Sodium) | Fumigant | 152,000 | 3 | 97 |
| (Isophenphos) | Insecticide | 143,000 | 5 | 95 |
| Glyphosate-trimesium | Herbicide | 143,000 | 97 | 3 |
| 2,4-D | Herbicide | 96,000 | 45 | 55 |
| (Paraquat) | Herbicide | 92,000 | 77 | 23 |
| Cholothalonil | Fumigant | 78,000 | 35 | 65 |
| S-Metolchlor | Herbicide | 53,000 | 84 | 16 |
| Chlorpyrifos | Insecticide | 47,000 | 35 | 65 |
| Imidachloprid | Insecticide | 17,000 | 5 | 95 |

aCaroline, Cecil, , , Queen Anne's, , Talbot, Wicomico, and .
bAnne Arundel, , Calvert, Charles, Harford, Howard, 's, and St. Mary's Counties, and .

# Efforts to Deal with the Problems

- **Management of Impaired Waters**

  - A sediment listing was designed with focus on watersheds identified as having comparatively elevated sediment yield attributed to agricultural intensification and growth

  - Sediment loads long term average annual point source for Maryland 8 digit watersheds were measured

- **Watershed Conservation**

  - In 2005, the various tributary panels upgraded their implementation strategies as a preamble to fulfilling conditions stipulated in the water quality objectives covered in the Chesapeake 2000 agreement at a price tag of $10 billion by 2010

  - In 2004, two Maryland counties were amongst 202 watersheds across the nation that benefited from a major conservation program designed to remunerate farmers for their long-standing conservation efforts

- **Data Monitoring**

  - The Maryland Department of Natural Resources carried out the Maryland Biological stream Survey between 1995 through 2004, to generate vital data concerning the status of the state's water bodies

  - The exercise relied on random selections of 300 stream segments in the state with the measurement of biochemical and physical parameters at every segment based upon a uniform technique

- **Policy Initiatives**

  - The Maryland water improvement quality act of 1998 attempted to limit nutrient emission from agriculture

  - State farmers required to apply nutrients in accordance with nutrient management plans

  - Several efforts to encourage compliance of The Federal Clean Water Act among various stakeholders representing local, state, federal and non public sector entities

# Environmental Analysis

- **Fertilized Acres of Agricultural Land**

- The use of fertilizer on rise in the counties adjacent to waterbodies

-The overall use of fertilizers point to a mix of gains and declines over the years for the individual counties

-When tallied for the entire state interns of the percentage of change, the use of fertilizer varied from -2.86% in 1987-1992 to -4.95 during 1997-2002 (Table 1.3)

- **Impaired Waters**

- The number of impaired water bodies increased in some of the years

-The amount of impaired water bodies attributed to agriculture, as table 1.4 shows 16 counties in the state had about 32 impaired bodies in 1998, 18 in 2002 and 2004

- **Farm land**

- The size of farmland in the entire state consisted of 1,443,677 in 1992, 1,385,741 in 1997 and 1,355,910 acres in 2002

- On the percentage of change, the size of agricultural land in the 17 counties of the state seems to be on a downward decline in most of the years as the table1.5 shows.

-The overall percentage change for the state shows farmland decline from 1992-1997 at -4.0%; -2.15% in 1997-2002.

- **Regression Analysis**

- The results on the matrix presented in Table 1.6 indicate the impaired waters are positively related to fertilized acres, farmland and population.

-As was mentioned before, most of the coastal counties have 2 or more number of impaired waters in 1998 and they continued to have at least 1 impaired water areas till 2004

# Table 1.3 Acres Treated With Fertilized Farmlands

| COUNTIES | 1987 | 1992 | 1997 | 2002 | 1987-1992% Change | 1992-1997% Change | 1997-2002% Change |
|---|---|---|---|---|---|---|---|
| ALLEGANY | 15917 | 8776 | 18279 | 16568 | -44.86 | 108.28 | -9.36 |
| ANNE ARUNDEL | 47184 | 54216 | 39670 | 53852 | 14.90 | -26.82 | 35.74 |
| BALTIMORE | 103144 | 127494 | 109860 | 147580 | 23.60 | -13.83 | 34.33 |
| CALVERT | 39369 | 33656 | 56151 | 33318 | -14.51 | 66.83 | -40.66 |
| CAROLINE | 235106 | 265492 | 275285 | 303043 | 12.92 | 3.68 | 10.03 |
| CARROLL | 255057 | 227469 | 296424 | 267048 | -10.81 | 30.31 | -9.91 |
| CECIL | 147555 | 147485 | 129222 | 144256 | -0.04 | -12.38 | 11.63 |
| CHARLES | 62715 | 66695 | 53487 | 49268 | 6.34 | -19.80 | -7.88 |
| DORCHESTER | 231766 | 191213 | 284410 | 195708 | -17.49 | 48.73 | -31.18 |
| FREDRICK | 291045 | 320195 | 309968 | 326897 | 10.01 | -3.19 | 5.46 |
| GARRETT | 62942 | 66821 | 68021 | 62104 | 6.16 | 1.79 | -8.69 |
| HARFORD | 134288 | 159803 | 150878 | 114226 | 19.00 | -5.58 | -24.29 |
| HOWARD | 60114 | 66006 | 62106 | 80287 | 9.80 | -5.90 | 29.27 |
| KENT | 256180 | 261153 | 306495 | 243725 | 1.94 | 17.36 | -20.47 |
| MONTGOMERY | 119315 | 117721 | 124989 | 151920 | -1.33 | 6.17 | 21.54 |
| PRINCE GEORGE'S | 154608 | 46456 | 70184 | 34519 | -69.96 | 51.07 | -50.81 |
| QUEEN ANNE'S | 341716 | 417438 | 399969 | 354533 | 22.15 | -4.18 | -11.35 |
| ST. MARY'S | 99601 | 85869 | 94347 | 77699 | -13.78 | 9.87 | -17.64 |
| SOMERSET | 101982 | 72582 | 65781 | 83099 | -28.82 | -9.37 | 26.32 |
| TALBOT | 256740 | 244269 | 212328 | 237724 | -4.85 | -13.07 | 11.96 |
| WASHINGTON | 196677 | 194828 | 169445 | 198091 | -0.94 | -13.02 | 16.90 |
| WICOMICO | 150136 | 144806 | 203015 | 166522 | -3.55 | 40.19 | -17.97 |
| WORCESTER | 235782 | 175402 | 223159 | 197153 | -25.60 | 27.22 | -11.65 |
| Total | 3598939 | 3495845 | 3723473 | 3539140 | NA | NA | NA |

# Table 1.4 Counties with Impaired Water Bodies

| COUNTIES | 1998 | 2002 | 2004 |
|---|---|---|---|
| ANNE ARUNDEL | 2 | 1 | 1 |
| BALTIMORE | 3 | 1 | 2 |
| CALVERT | 2 | 1 | 1 |
| CAROLINE | 1 | 1 | 1 |
| CECIL | 2 | 1 | 1 |
| CHARLES | 1 | 1 | 1 |
| DORCHESTER | 3 | 2 | 2 |
| HARFORD | 3 | 0 | 1 |
| KENT | 2 | 1 | 1 |
| PRINCE GEORGE'S | 2 | 1 | 1 |
| QUEEN ANNE'S | 2 | 2 | 1 |
| ST. MARY'S | 3 | 2 | 1 |
| SOMERSET | 2 | 1 | 1 |
| TALBOT | 2 | 1 | 1 |
| WICOMICO | 1 | 1 | 1 |
| WORCESTER | 1 | 1 | 1 |
| TOTAL | 32 | 18 | 18 |

# Table 1.5 The Temporal Portrait of Agricultural Land Use Change

| COUNTIES | 1992 | 1997 | 2002 | %change 92-97 | %change 97-02 |
|---|---|---|---|---|---|
| ANNE ARUNDEL | 43,320 | 34,679 | 35218 | -19.946 | 1.55 |
| BALTIMORE | 83,232 | 75,795 | 71227 | -8.93 | -6.02 |
| CALVERT | 37,320 | 33,450 | 30032 | -10.36 | -10.21 |
| CAROLINE | 126,981 | 111,316 | 114843 | -12.33 | 3.16 |
| CECIL | 80,241 | 85,702 | 77089 | 6.80 | -10.04 |
| CHARLES | 59,389 | 55,928 | 52056 | -5.82 | -6.92 |
| DORCHESTER | 123,762 | 122,928 | 125385 | -0.67 | 1.99 |
| HARFORD | 97,312 | 94,112 | 81409 | -3.28 | -13.49 |
| KENT | 131,283 | 117,526 | 117372 | -10.47 | -0.13 |
| PRINCE GEORGE'S | 54,459 | 47,572 | 45462 | -12.64 | -4.43 |
| QUEEN ANNE'S | 165,349 | 167,957 | 155566 | 1.57 | -7.37 |
| ST. MARY'S | 77,491 | 71,890 | 68153 | -7.22 | -5.19 |
| SOMERSET | 55,657 | 54,823 | 56650 | -1.49 | 3.33 |
| TALBOT | 109,108 | 109,572 | 105729 | 0.42 | -3.50 |
| WICOMICO | 91,254 | 90,656 | 88470 | -0.65 | -2.41 |
| WORCESTER | 107,519 | 111,835 | 131249 | 4.01 | 17.35 |
| TOTAL | 1,443,677 | 1,385,741 | 1355910 | NA | NA |

# Table 1.6 The correlation Matrix on Selected Variables

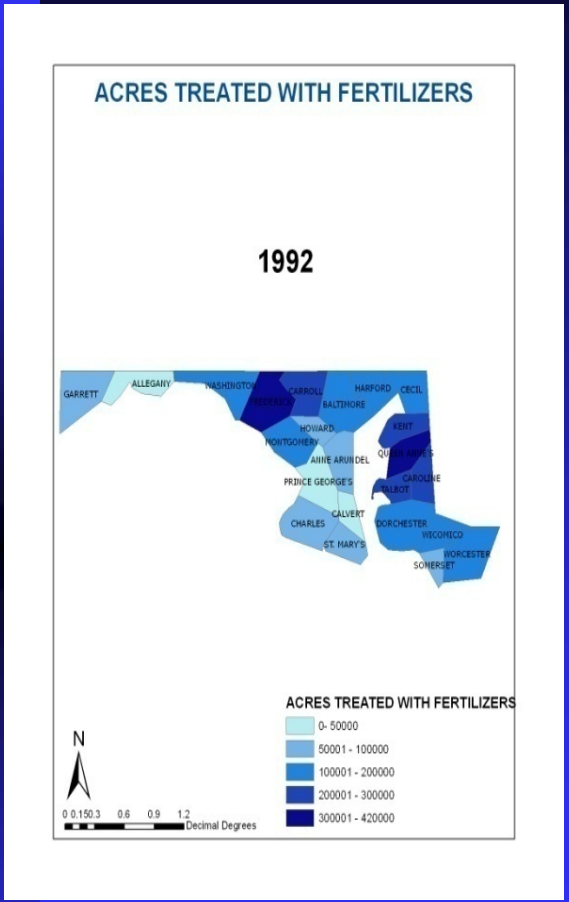
Correlations

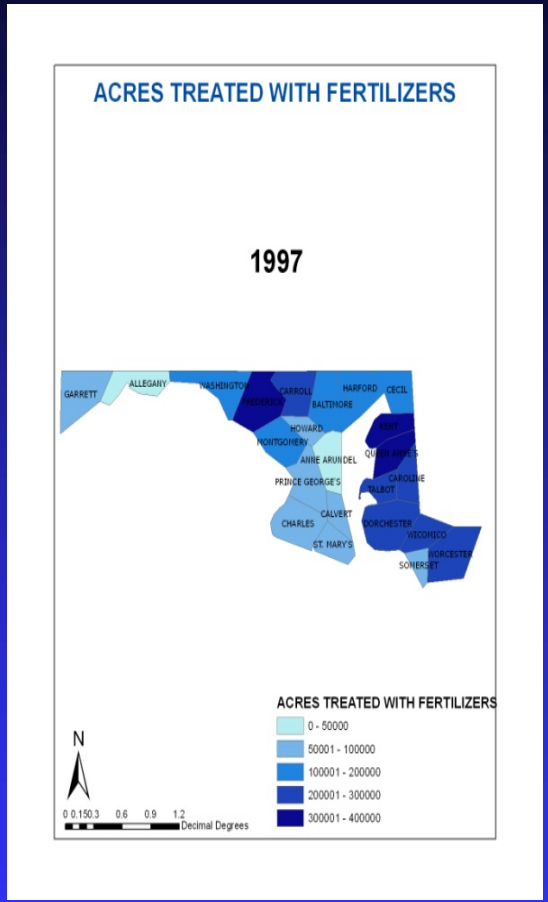
| | | Agrosales | Fertilizedacres | Farmland | Population | Impairedwaters |
|---|---|---|---|---|---|---|
| Agrosales | Pearson Correlation | 1 | .484** | .480** | -.347* | -.180 |
| | Sig. (2-tailed) | | .000 | .001 | .016 | .220 |
| | N | 48 | 48 | 48 | 48 | 48 |
| Fertilizedacres | Pearson Correlation | .484** | 1 | .945** | -.422** | .065 |
| | Sig. (2-tailed) | .000 | | .000 | .003 | .660 |
| | N | 48 | 48 | 48 | 48 | 48 |
| Farmland | Pearson Correlation | .480** | .945** | 1 | -.444** | .154 |
| | Sig. (2-tailed) | .001 | .000 | | .002 | .295 |
| | N | 48 | 48 | 48 | 48 | 48 |
| Population | Pearson Correlation | -.347* | -.422** | -.444** | 1 | .056 |
| | Sig. (2-tailed) | .016 | .003 | .002 | | .704 |
| | N | 48 | 48 | 48 | 48 | 48 |
| Impairedwaters | Pearson Correlation | -.180 | .065 | .154 | .056 | 1 |
| | Sig. (2-tailed) | .220 | .660 | .295 | .704 | |
| | N | 48 | 48 | 48 | 48 | 48 |

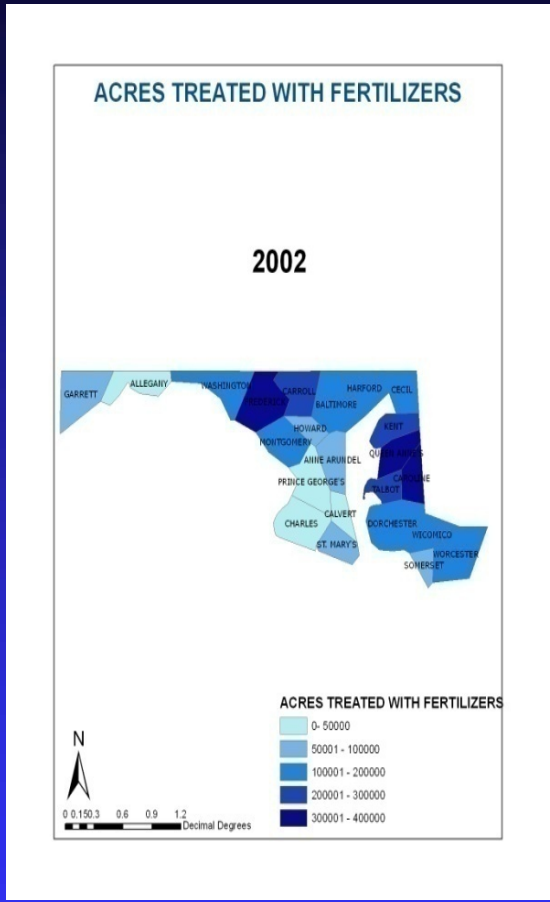
**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

# Spatial Analysis



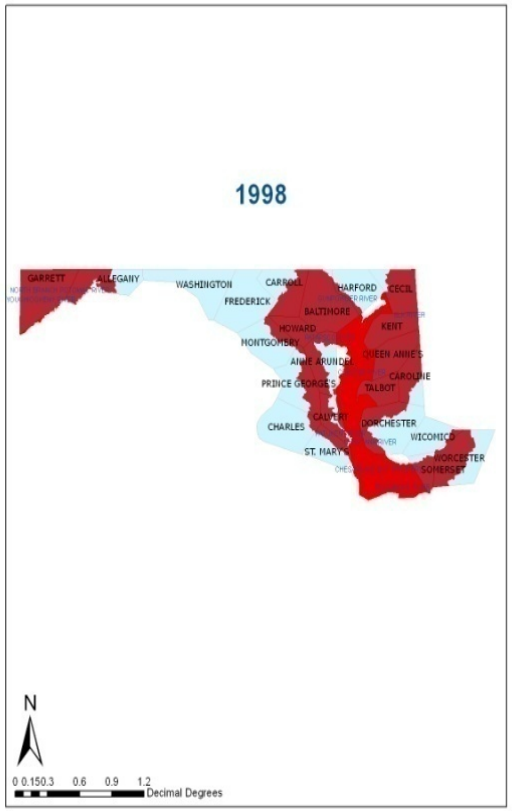



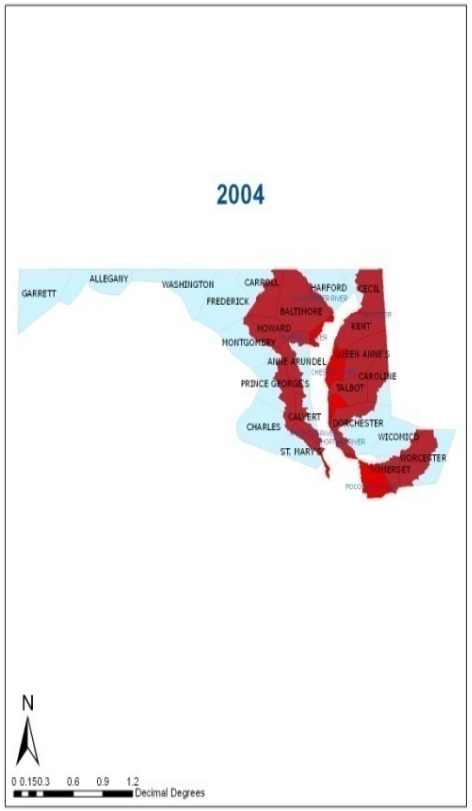

The Geographic Diffusion of Fertilized Acres

The acreages of land treated with fertilizers presented in blue appeared quite enormous and visible in every scale from 1987, 1992, 1997 and 2002. Also, note how fertilizer treatment exceeding 100,000-400,000 acres remained visibly concentrated in different parts of the state most of the time

# Spatial Analysis



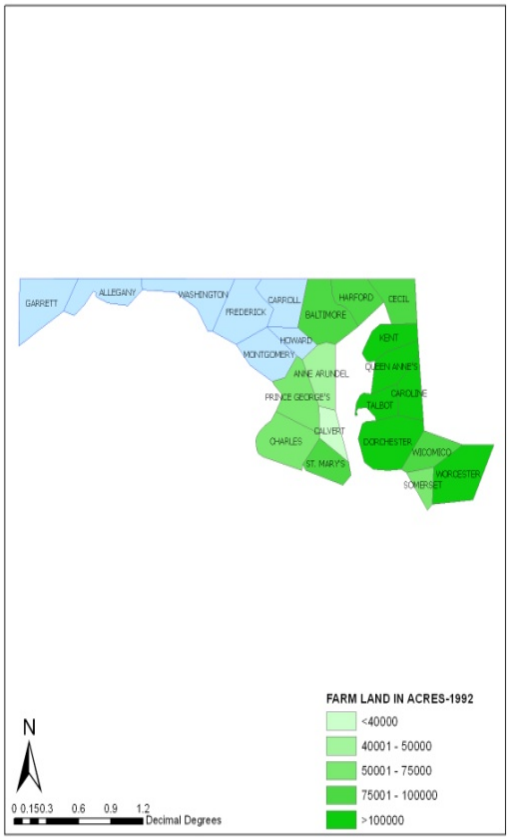


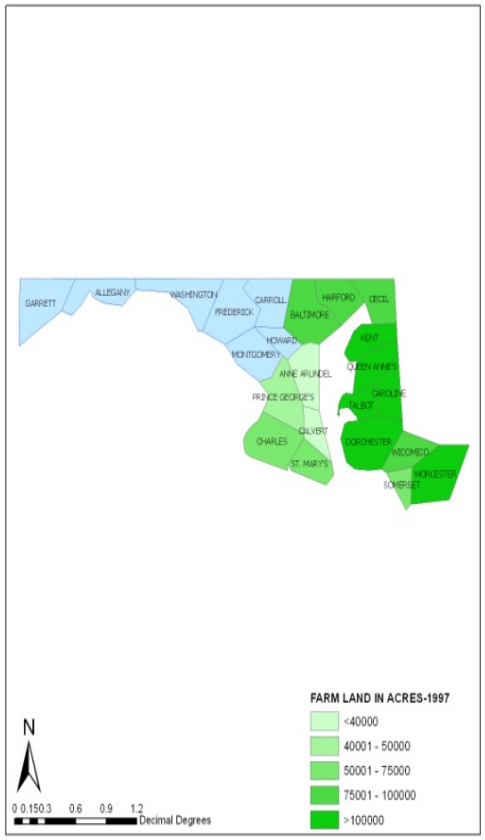


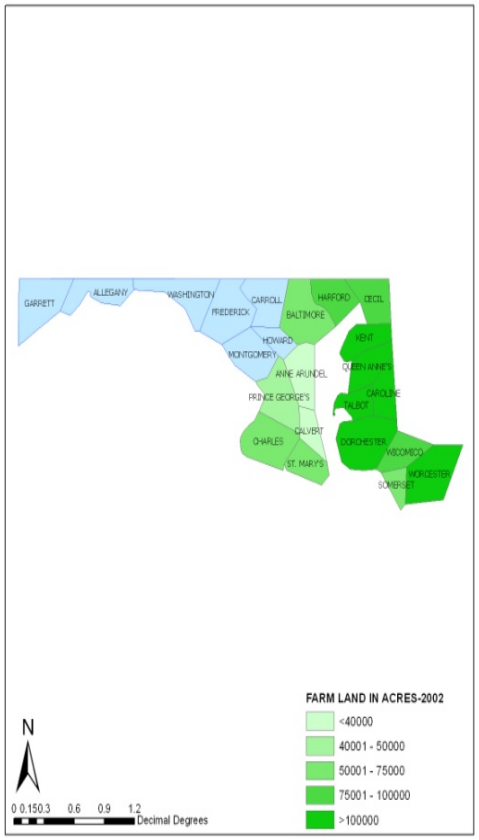

Spatial Distribution of Impaired Waters In Maryland

These impaired water bodies appeared most of the time in 1998, 2002 and 2004.
Even though the patterns of 1998 and 2002 spatial distribution seemed somewhat similar, notice how the slight patches of impaired areas in the Southeast area of the state faded lightly in 2002 and 2004

# Spatial Analysis



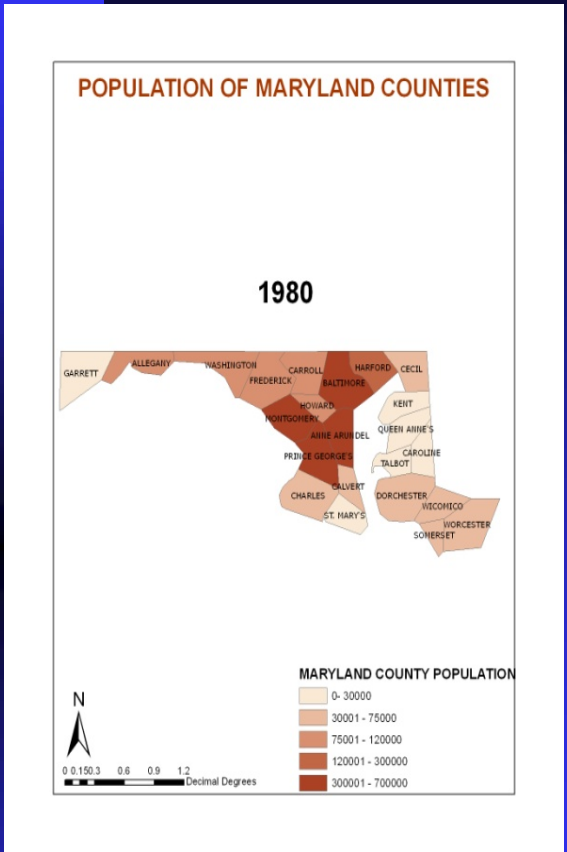



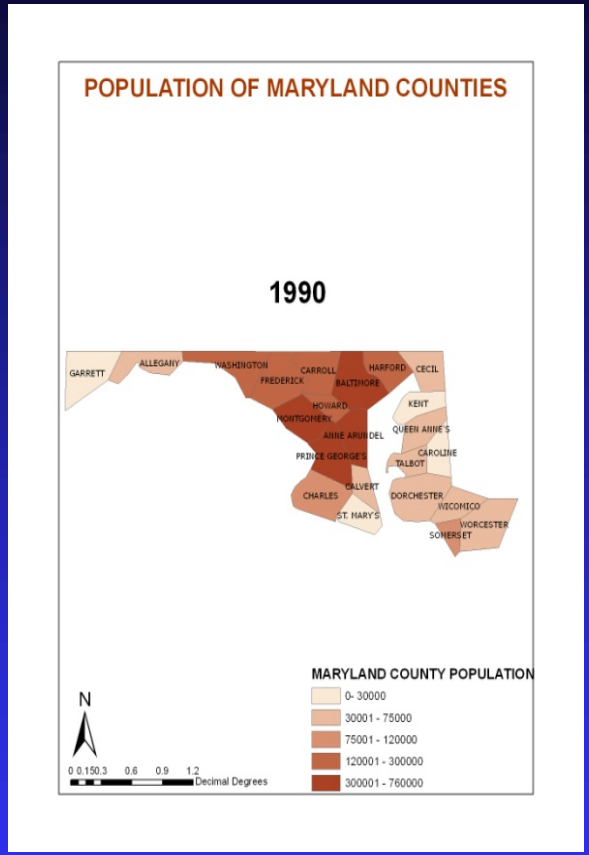



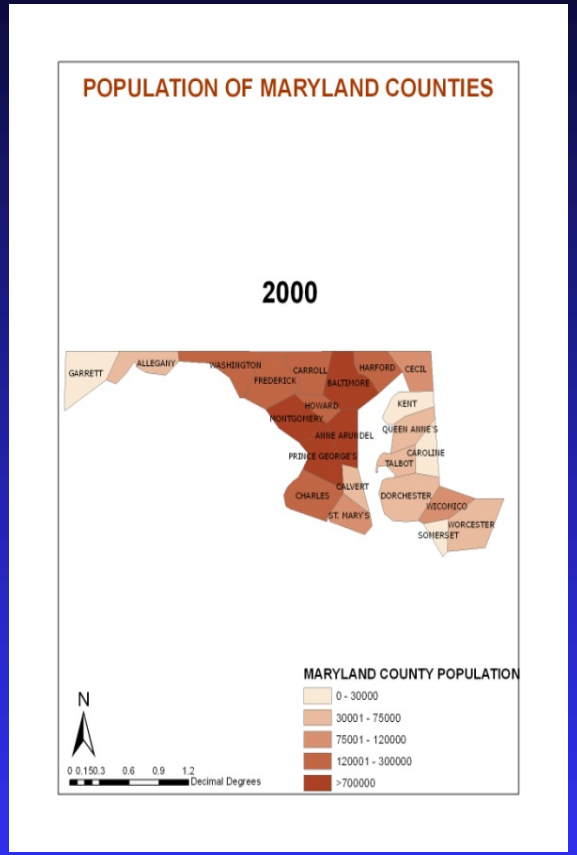

The Geographic Distribution of Intense Farmland Use in Acres

Despite the changes that occurred over the years in the size of agricultural land use, note that the South East portion of the state adjacent to the Chesapeake Bay had large clusters of farmland areas depicted in dark green measuring more than 100,000 acres in the periods of 1997, to 2002

# Spatial Dispersion of Socio-Economic Factors



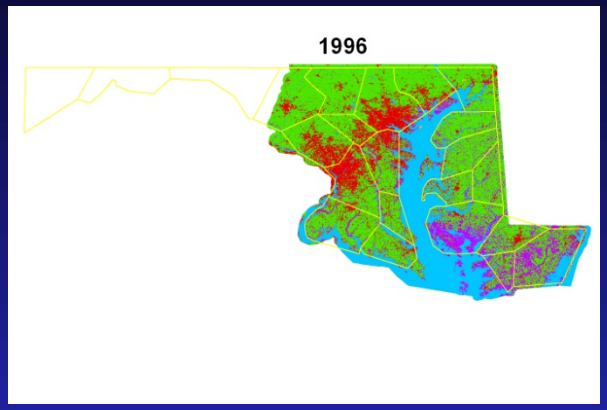



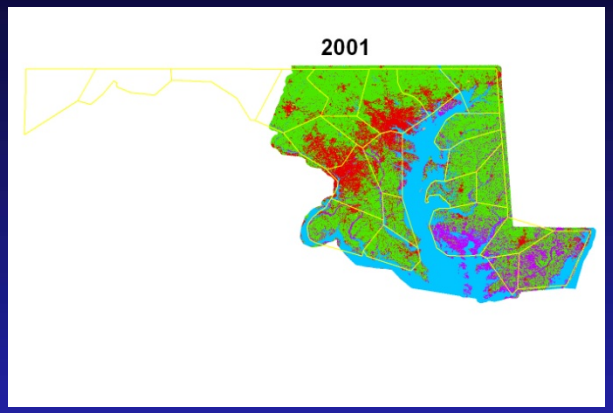

## Geographic Diffusion of Population Pressure Impacting Water Quality

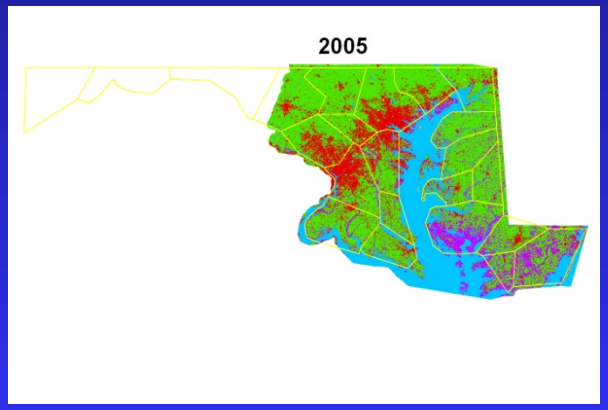
- Large population concentration of over half a million were quite notable in 3 major urban centers – Baltimore, Prince George's and Montgomery.

This increase has brought high population concentration along the coasts adjacent to the basins at the expense of watershed ecosystem protection

# Spatial Analysis



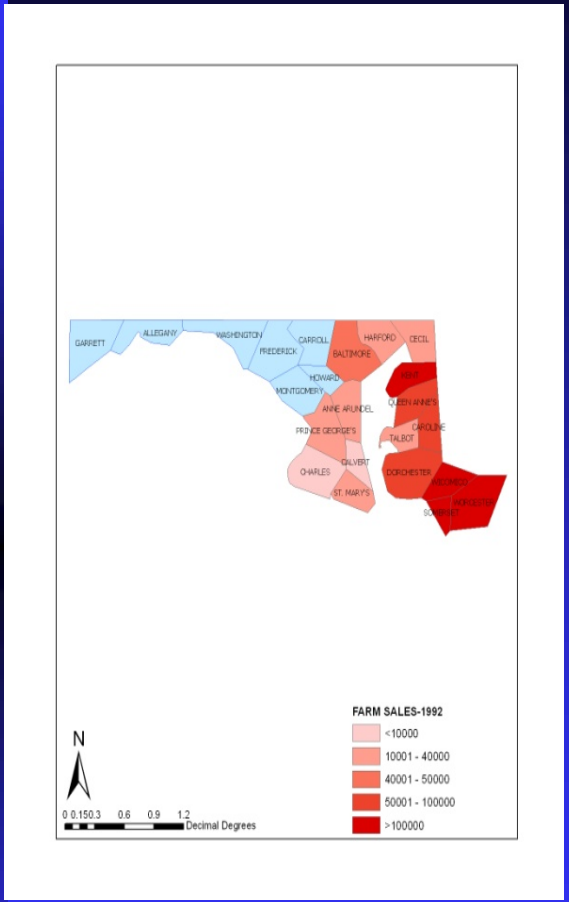



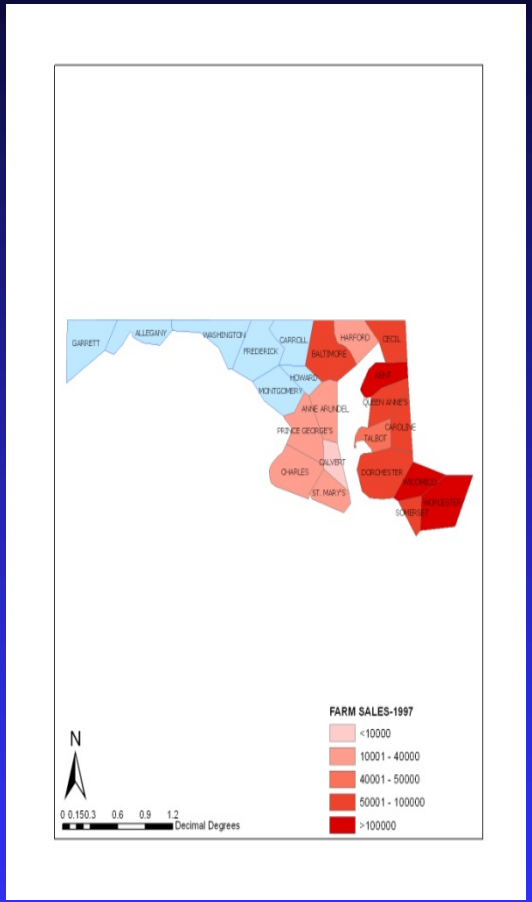



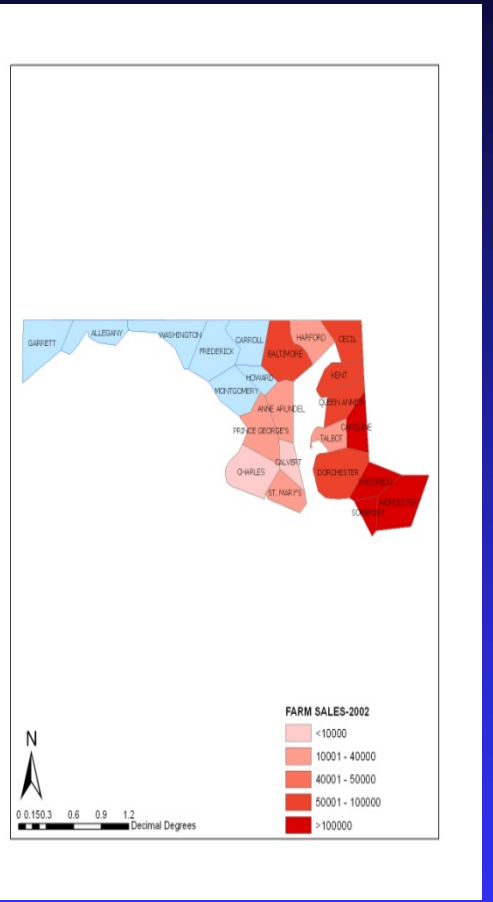

Land Cover Maps of Maryland

Even though most of the features experienced slight variation over the periods of 1996, 2001 and 2005, built up areas still appeared visible. Run-off from developed areas poses enormous threat to water quality

# Socio-Economic Factors




The Spatial Distribution of Agro-Sales In Maryland

- Large spatial concentration of counties with significant agricultural sales exceeding $100,000 represented in red appear much pronounced in the south east Maryland.
-This was quite common within areas adjacent to the coast and lower part of the state between 1992, 1997 and 2002
- Notwithstanding the gains from sales, the externalities from agriculture in the form of nutrient flow into watersheds threaten biodiversity habitats and water quality .

# Findings of the Research

- The large geographic diffusion of fertilizer applications along the counties in the agricultural watersheds of the mid Atlantic region threatens the quality of water systems
- The temporal distribution from in 1987-2002, indicate that the state of Maryland had a total of over 3.4 million acres of agricultural under fertilizer applications.
- While Queen Anne County fertilized over 300,000 acres of land, in five other counties (made up of Caroline, Carroll, Frederick, Kent, and Talbot,) use of fertilizer exceeding 200,000 acres appeared widespread than in other counties
- Socio-economic indicators of agricultural sales, farmland loss and population as a measure of the intensity of land use activities impacting water quality seemed quite pronounced.
- The geographic dispersal of nutrient flow sites seem fully concentrated along the watersheds such as the Chesapeake Bay and the tributaries of other river systems due to intense farming and human activities.
- Geospatial technology of GIS as demonstrated in this project has been quite effective in ensuring the mapping of water quality inhibitors and their impacts on the agricultural watersheds within a spatial reference system.

# Recommendations

- **Strengthen Current Policy on Land use**

  - Policy makers can deal with the problems by tightening the current polices through sanctions and enforcement.
  -They can achieve this task by using command and control mechanisms that ensures minimum distancing of agricultural activities from stream corridors

  -Devise a process that demands training and recertification of those applying agro-chemicals in the farm sector for safety reasons

- **Promote Water Quality Monitoring**

  - Monitoring provides opportunities to track fertilizer and pesticides use, the level of concentration in nutrient loads, toxic levels and the response of agro-ecosystems to the exposure

- **Develop Regional Agro Geo Spatial Information System**

  - This will help quicken capability of resource managers in predicting and locating water bodies under critical conditions

- Encourage watershed Approach in Planning

  - This approach supports research that cuts across disciplines with potentials for applying the principles of watershed restoration planning for the common good of communities at risk.

  -The emphasis should be on the integration of ecological-socio-economic studies by taking into account the human factors associated with agricultural watershed degradation

# Conclusions

- In the last decades, widespread level of nutrient loads in riparian corridors along agricultural watersheds triggered by farming and human activities has been eroding the environment and support systems along the Mid Atlantic region of the state of Maryland study area
- The results not only reveal that the study area experienced some significant changes in its watershed environments, but the quality of water bodies such as the Chesapeake Bay and others within the shores of Maryland are under stress
- Various ecological variables made up of fertilizer applications, number of impaired watersheds, the use of farmlands and nutrient flow were quite pronounced especially in areas adjacent to watersheds
- socio-economic factors of population, income from agricultural sales, grew in some of the areas. The pressures unleashed from these variables as the analysis shows puts enormous strain on the water quality along agricultural watershed ecosystem.
- Geospatial information technology adopted in current study has great potentials in assisting policy makers in the state assess the elements inhibiting water quality along the shores of agricultural watersheds in the Mid Atlantic State of Maryland.

# 2008 CRESS National Water Conference, Sparks Nevada, February 3-7

## "Applications of Geo-Information Systems To Assess Water Quality Trends In The Mid Atlantic Region Within An Agricultural Watershed

**By**

Dr Edmund Merem

**Jackson State University Mississippi**

06/02/08