Report for 2004MI50B: Use of Spatial Data and GIS in Evaluating Manure Application Risk Index (MARI)

There are no reported publications resulting from this project.

Report Follows

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FY 2004 Non-Federal Funds: $15,100

Title: Use of Spatial Data and GIS in Evaluating Manure Application Risk Index (MARI)

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Project Type: Research
Focus Categories: WQL, NU, AG
Congressional District: Eighth
Keywords: Water Quality; Animal Manure; Nutrients; Risk Index; GIS; Non-point Source Pollution; Modeling.

Abstract:
Proper manure management is essential to the profitability of livestock producers, and must also address environmental concerns about nutrients, microorganisms, and organic matter from manure/sediment potentially polluting water resources. The Manure Application Risk Index (MARI), as developed by NRCS specialists, is used by farmers and agency personnel to evaluate fields for winter spreading of manure in an environmentally responsible manner. The MARI is based on 12 weighted field factors, including soil groups, soil test P value, concentrated water flow, vegetative buffer width, and manure application rates and methods. The MARI is used in Michigan as a part of the state-recognized Generally Accepted Agricultural Management Practices (GAAMP). It has the potential for use throughout the region to assist livestock operators in evaluating areas to determine whether the level of environmental risk associated with manure applications is acceptable or unacceptable. However, wider use of the MARI approach requires additional, broad-scale field verification of its usefulness in various soil types, landscapes, and manure management systems to facilitate its application throughout the Midwestern region. This study uses spatial data and GIS technology in assess the manure application risk index in Sycamore Creek Watershed in Michigan. Potentially risk areas are identified in the watershed where precaution has to be made when spreading manure, particularly in the water season.
Keywords: Water Quality; Animal Manure; Nutrients; Risk Index; GIS; Non-point Source Pollution; Modeling.

Introduction:
The environmental risk of manure applications is greatest when applications are made on frozen, snow-covered, or saturated soils during winter months. However, daily hauling and application of manure is a common practice. In much of Wisconsin, for example, daily hauling is the most common means of application, and over 70 percent of Michigan livestock operators, as estimated by NRCS staff, use daily hauling for manure management. The comparative cost differential between daily hauling and liquid manure 8-month storage is significant and varies according to the scale of operations: six times

greater cost per cow for long-term storage in a 60-cow operation, five times greater for 120-cow operations, and three times greater for 250-cow operations.

Manure storage facilities can also be difficult to manage in terms of environmental risk. And even in using liquid-manure holding facilities, the need to apply manure on potentially frozen ground during the winter and/or spring under various climate conditions may still arise. However, these practices have in many cases resulted in runoff with excessive concentrations of manure causing environmental damage to water resources. As a result, many Midwestern legislatures have prohibited manure applications when frozen ground is likely.

In Michigan, the Manure Application Risk Index was developed to evaluate fields and determine whether manure applications are safe and appropriate throughout the year on those fields. Management practices such as appropriate setbacks and rates of application with consideration of climatic conditions, i.e. snow, predicted rainfall, etc., are incorporated in the risk analysis/index.

Proper manure management is essential to the profitability of livestock producers, and must also address environmental concerns about nutrients, microorganisms, and organic matter from manure/sediment potentially polluting water resources. The Manure Application Risk Index (MARI), as developed by NRCS specialists, is used by farmers and agency personnel to evaluate fields for winter spreading of manure in an environmentally responsible manner. The MARI is based on 12 weighted field factors, including soil groups, soil test P value, concentrated water flow, vegetative buffer width, and manure application rates and methods. Daily hauling of manure remains a common practice in the Midwestern region as an economically viable method for winter manure application. In addition, the cost impacts of alternative manure management options are significantly higher. Liquid manure management 8-month storage systems, for example, are 3-6 times more costly depending on operation size.

Methods:

The project approach is to use GIS technology such as using DEM to calculate slopes and other GIS data layers such as Soil Survey Geographic Database (SSURGO) in processing some input data that are required by MARI. The MARI is based on 12 weighted field factors, including soil groups, soil test P value, concentrated water flow, vegetative buffer width, and manure application rates and methods. Soil testing phosphorus data were provided by the MSU Soil Testing Lab. The GIS layers including digital elevation model (DEM), soil management group, nitrogen leaching index for soil hydrologic group were used to perform an analysis of MARI for the selected watershed. Weighting factors for the 12 MARI factors were used in the assessment.

Table 1. The weighting factors for the 12 MARI parameters:

Field Feature Factors	Very Low (1)	Low (2)	Medium (4)	High (8)

1. Soil Hydrologic Group (1.0)	A	B	C	D
2. Soil Management Group (1.0)	5.0	2.5-4.0	1.5	0-1.0
3. Percent Slope (1.0)	0-1.9	2-3.0	3.1-6	>6
4. Soil Test P Value (lbs/ac) (1.5)	Medium (<79)	High (80-149)	Very High (150-300)	Excessive (>300)
5. Concentrated Water Flow or Surface Inlet Discharge (1.5)	Ponds in flat field or no runoff	Few No direct flow offsite into surface water	Some Enters surface water through a designed buffer	Many Ephemeral channels discharges directly into surface water, no buffer
6. Nitrogen Leaching Index for Soil Hydrologic Group (1.5)	N/A	Low	Medium	High
7. Residue/Cover or Perennial Cover (1.0)	> 40% residue good perennial grass alfalfa or cover crop	30-39% residue fair perennial grass legume, small grain	10-29% residue poor grass legume	<10% residue fall tillage or no cover
8. Surface Water Setback (1.0)	> 300 ft. to edge of stream	150-299 ft. to edge of stream	<150 ft. incorporates manure	<150 ft. surface applies manure does not incorporate
9. Vegetative Buffer Width (1.5)	>100 ft. or if not applicable to the site	66-99 ft.	20-65 ft.	<20 ft.
10. Manure Application Rate (P_2O_5 lbs/ac) (1.0)	< 30	30-60	61-99	>100
11. Manure N Application Rate (lbs/ac) (1.0)	<60	61-130	131-200	>200
12. Manure Application Method (1.0)	Injected	Surface applied and incorporated within 48 hr.	Surface applied and incorporated within 3	Surface applied and unincorporated for at least 3

			months	months.

We used the spatial data to created several GIS layer in grids and then calculated the composite layer by applying those weighting factors. Specifically, the following ratings are used in grid creation and calculations:

For Soil Hydrologic Groups, we rated it as follows:
A = 1 (very low)
B = 2 (low)
C = 3 (medium)
D = 8 (high)

For Soil Management Group:
5.0 = 1 (very low)
2.5-4.0 = 2 (low)
1.5 = 4 (medium)

For Percent Slope:
<2% = 1 (very low)
2-3% = 2 (low)
3-6% = 4 (medium)
>6% = 8 (high)

For Soil Test P value, we used a constant of 2 (low) based on the soil testing P values provided by the MSU Soil Testing Lab.

For Concentrated Water Flow, we used a constant of 8 (high) which is Discharges directly to surface water.

For Nitrogen Leaching Index for Hydrologic Groups, we rated Group C = 2 (low), Groups A & B = 4 (medium).
For Residue/Cover Crops, we used a constant of 4 (medium) for the study watershed.

For Surface Water Setback, we used a constant of 8 (high) for the study watershed.

For Vegetative Buffer Width, we used a constant of 8 (high) which is less than 20 ft. wide for fields within 100 ft. of surface water.

For Manure Application Rate of P2O5, we used a constant of 8 (high) which is greater than 100 lbs/ac applied.

For Manure Application Rate N, we used a constant of 8 (high) which is greater than 200 lb/ac applied.

For Manure Application Method, we used a constant of 8 (high) which is surface applied and not incorporated for at least 3 months.

MARI index can be calculated using the following equation:

MARI = (factor 1) + (factor 2) + (factor 3) + (factor 4) x 1.5 + (factor 5) x 1.5 + (factor 6) x 1.5 + (factor 7) + (factor 8) + (factor 9) x 1.5 + (factor 10) + (factor 11) + (factor 12)

Results and Discussion:
By calculating the composite grid layer based on the spatial data layers and assumed the constants for other factors, we have generated the MARI grids (see figure 1).

The MARI map demonstrates the potentially high risk areas where precaution is needed when manure is applied. It has the potential for use in the watershed to assist livestock operators in evaluating areas to determine whether the level of environmental risk associated with manure applications is acceptable or unacceptable. However, wider use of the MARI approach requires additional, broad-scale field verification of its usefulness in various soil types, landscapes, and manure management systems to facilitate its application throughout the Midwestern region.

Field vulnerability for manure loss is rated based on the composite MARI ratings. The following table shows how the MARI is rated.

Table 2. Field Vulnerability for Manure Loss

Manure Application Risk Index for a filed	**Generalized Interpretation of Manure Application Risk Index**
<19	"VERY LOW" potential for manure movement from the field. If manure is managed, there is a low probability of an adverse impact to surface water. These fields have good potential for winter spreading.
19-37	"LOW" potential for manure movement from the field. The chance of organic material and nutrients getting into surface water exists. Buffers, setbacks, lower manure rates, cover crops, and crop residue practices alone or in combination may reduce impact. These fields have good potential for winter spreading.
38-75	"MEDIUM" potential for manure movement from the field. The chance of organic material and nutrients getting to surface water is likely. Buffers, setbacks, lower manure rates, cover crops, crop residues, etc. in combination may reduce impact. These fields have limited potential for winter spreading and only a partial area of the field may be acceptable.
> 75	"HIGH" potential for manure movement from the field and an adverse impact on surface water. Winter Spreading should not be done on these fields.

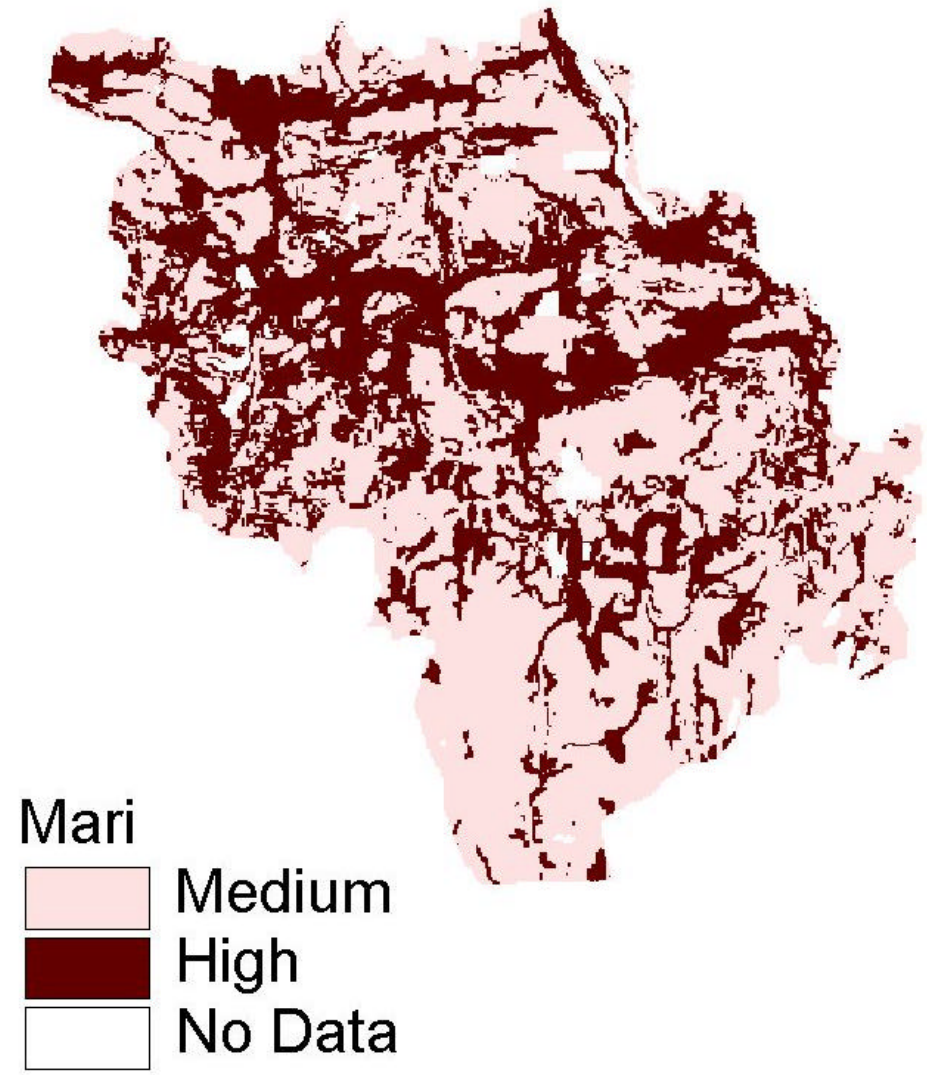
As shown on the map, most areas fall in the categories of Medium and High risk in the study watershed. There may be a limited potential for winter spreading of manure in the fields.

The MARI is used in Michigan as a part of the state-recognized Generally Accepted Agricultural Management Practices (GAAMP). The long-term impact of this project is a more economically-viable and environmentally-sustainable agricultural system. The

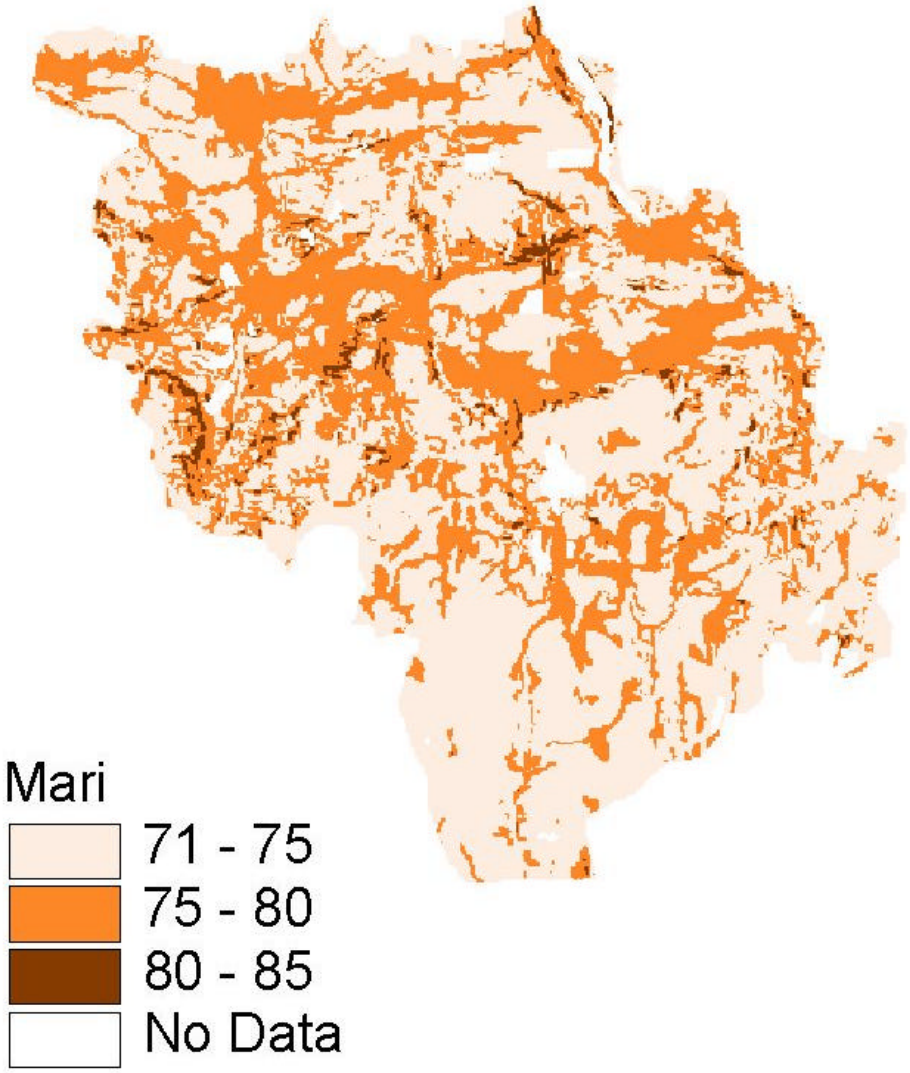
Manure Application Risk Index (MARI) identifies areas that may safely receive manure applications under specified weather conditions and during which seasons. This index enables operators to make informed decisions about their manure management systems and avoid potentially heavy capital costs where expensive storage systems are not necessary. Use of this index at the landscape level will result in long-term environmental benefits, specifically, protecting valuable water resources. Finally, more effective manure application techniques based on scientific knowledge of transport, runoff, and concentrations of potential nutrient loadings will increase the public's confidence in the ability of agricultural/ livestock operators to practice responsible stewardship of productive agricultural lands and precious water resources.

Other layers that were created for MARI are included in the Appendix.

Manure Application Risk Index (MARI) in
Sycamore Creek Watershed



Manure Application Risk Index (MARI) in
Sycamore Creek Watershed



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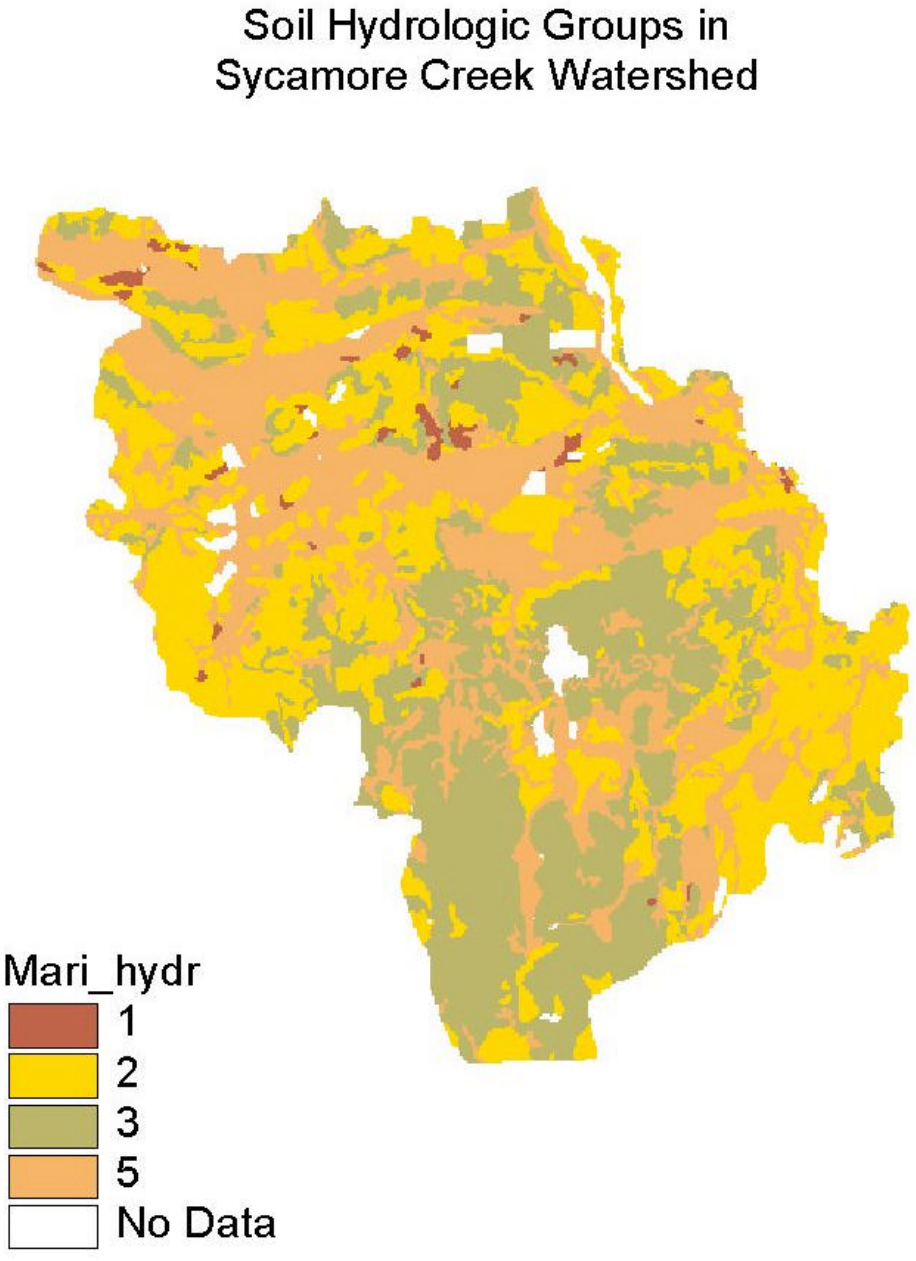
Grigar, J., J. Lemunyon, 1998. A Procedure for Determinging the Land Available for Water Spreading of Manure in Michigan. NRCS, USDA.

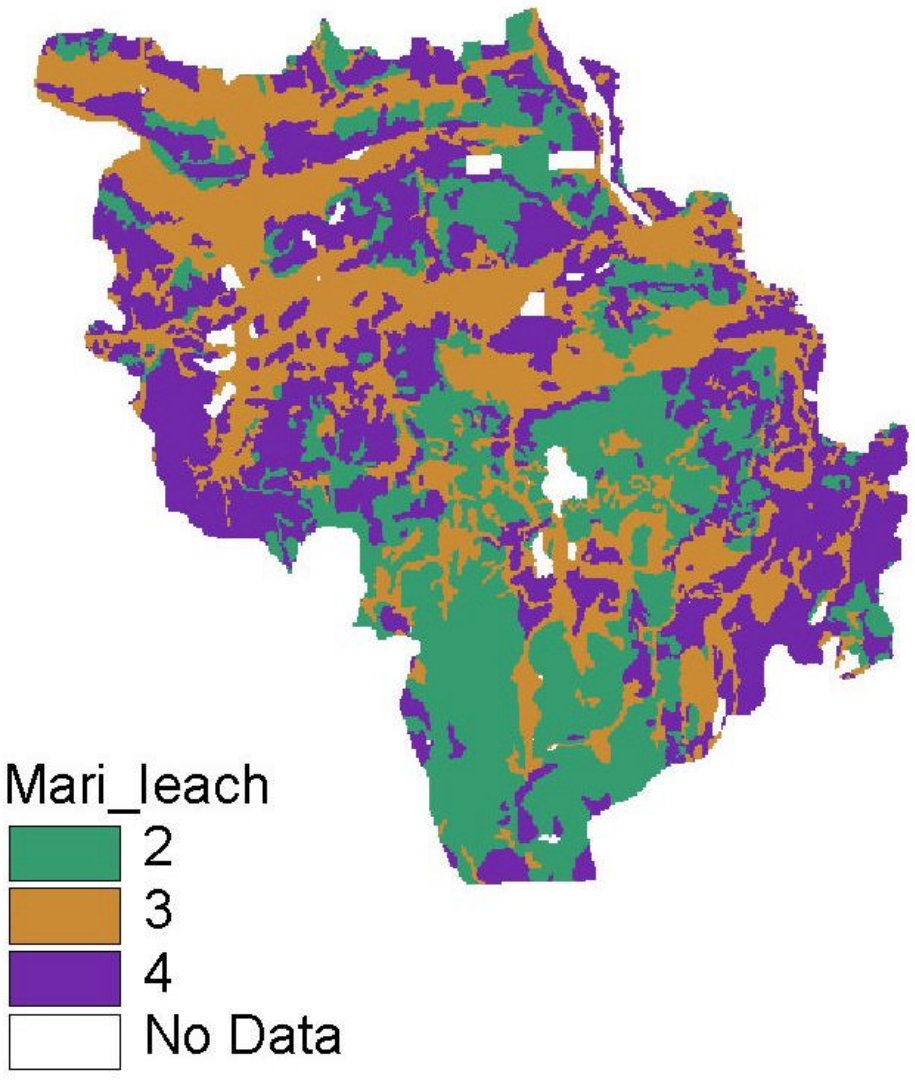
Laboski, C.A.M. and J.A. Lamb. 2003. Changes in soil test phosphorus concentration after application of swine manure or inorganic phosphorus. Soil Sci. Soc. Am. J. 67:544-554.

R. C. Williams, 2002. Stony Creek Watershed Plan – Environmental Assessment. NRCS, USDA, MI.

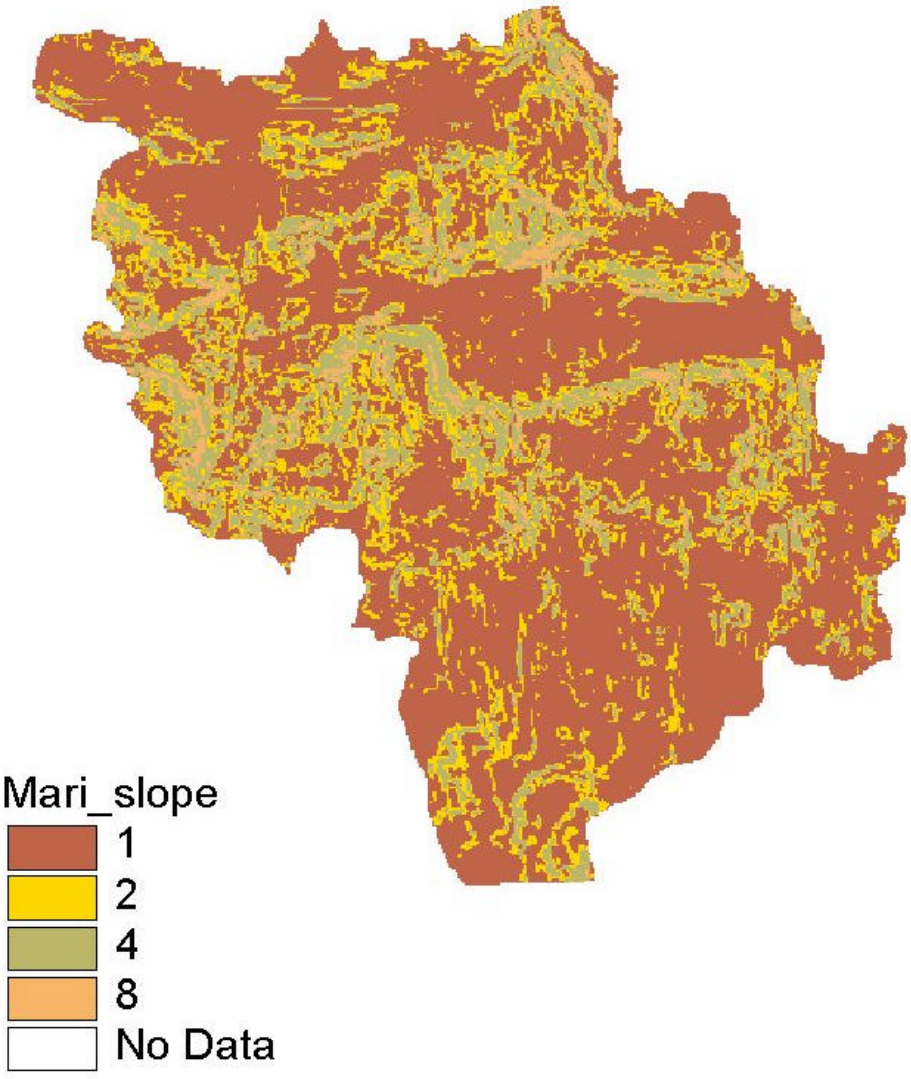
Appendix


Soil Hydrologic Groups in
Sycamore Creek Watershed
Mari_hydr
1
2
3
5
No Data

Nitrogen Leaching Index for Hydrologic Groups in Sycamore Creek Watershed



MARI Rating on Slopes in
Sycamore Creek Watershed



Soil Management Groups in
Sycamore Creek Watershed