INTEGRATED WATERSHED MANAGEMENT AS AN EFFECTIVE TOOL FOR SUSTAINABLE DEVELOPMENT

Using Distributed Hydrological Models in Policy Making

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AGENDA

1. **INTRODUCTION**
2. **STATEMENT OF PROBLEM**
3. **HISTORY AND CURRENT DISCOURSE ON DEVELOPMENT AND SUSTAINABILITY**
4. **LITERATURE REVIEW OF THE CONCEPTS USED IN THIS RESEARCH**
5. **RESEARCH QUESTION**
6. **METHODOLOGY**
7. **POSSIBLE RESEARCH DIFFICULTIES**
8. **THEORETICAL FRAMEWORK**

INTRODUCTION

- Current mode of development is unsustainable.
- No consensus on the definition of sustainability.
- Some have already written it off.
- But the discourse on sustainability is still in its infancy stage.
- Sustainability is
  - Resource specific
  - Region specific
  - Time specific
- Yet sustainability needs a holistic approach.

- Watershed management is managing land use, human activities to maintain the quality and quantity of water with watershed as a management unit.
- Watershed management can provide a holistic approach and thus is a strong link to sustainability
- Two facets:
  - Human Development (Developing nations' perspective)
  - Environment (Developed nations' perspective)

- Watershed systems are complex.
- Using distributed hydrological/water quality models with GIS.
- Used as an aid to policy making for the pursuit towards sustainability.
- This research uses distributed hydrological model – Soil and Water Assessment Tool (SWAT) to quantify sustainability from a watershed perspective.

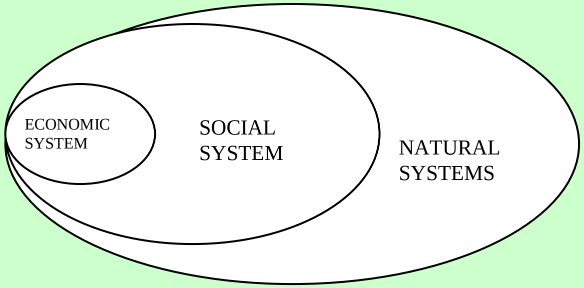
STATEMENT OF PROBLEM

- Sustainable development harder to achieve due to vagueness of its terms.
- Watershed management can be an effective tool for sustainable development
- The current mode of watershed management lack holistic approach
- Watershed management can be used as an ecological tool to help look at environmental and development issues under single umbrella.
- With the help of distributed hydrological models, it can help provide a sustainable solution to these issues.

BRIEF HISTORY OF DEVELOPMENT
&
CURRENT DISCOURSE ON SUSTAINABILITY

- Old mentality - economic development as human development.
- Controlling and maneuvering natural systems for betterment of humanity.
- Failed to recognize relationship between development and environment.
- Humanity still faces many social and environmental crisis.
- UNEP in 70s & World Bank in early 80s
- Stockholm Conference in Sweden – May, 1982.
- Our Common Future', by WCED in 1987.

- Each group looks at sustainability from its own perspective.
- Technocentric, Ecocentric and Sustaincentric paradigm.
- In terms of system (Kranz et al., 2004)



•In terms of capital – social, economic and natural.

Weak sustainability

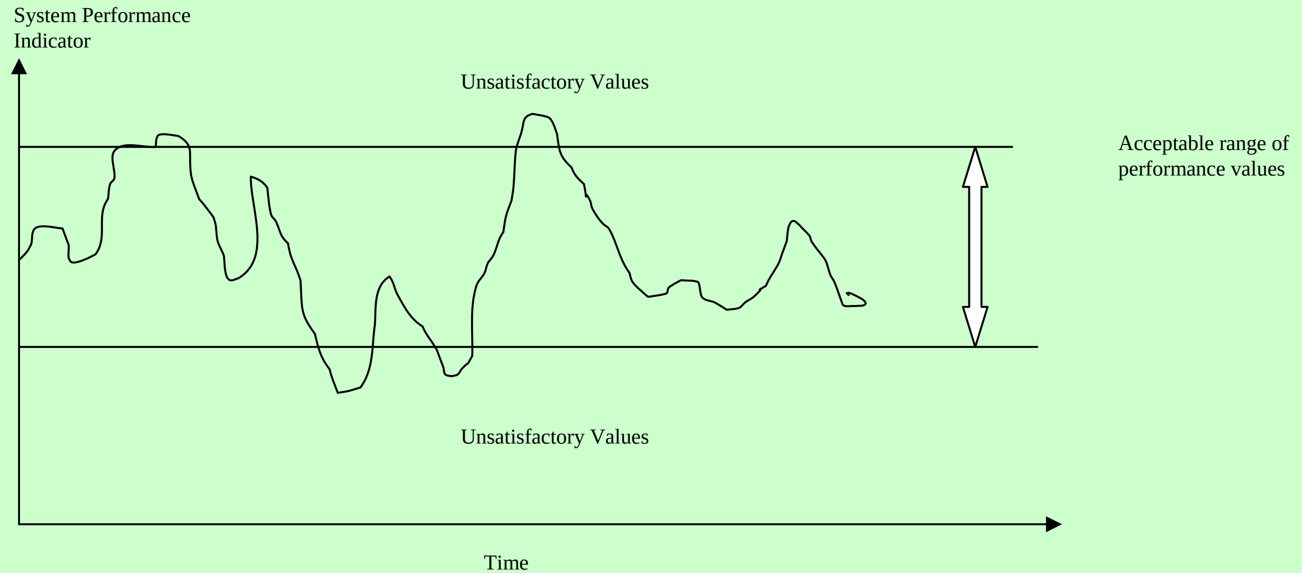
Strong Sustainability

CONCEPTS USED IN THIS RESEARCH

How to Measure Sustainability?

Reliability, Resilience, and Vulnerability

The development of a watershed can be called sustainable only when it can “cope with and recover” from the stresses of fluctuation of water quality and quantity.



Adapted from Loucks and Gladwell, 1999

RESEARCH QUESTIONS

RESEARCH QUESTION

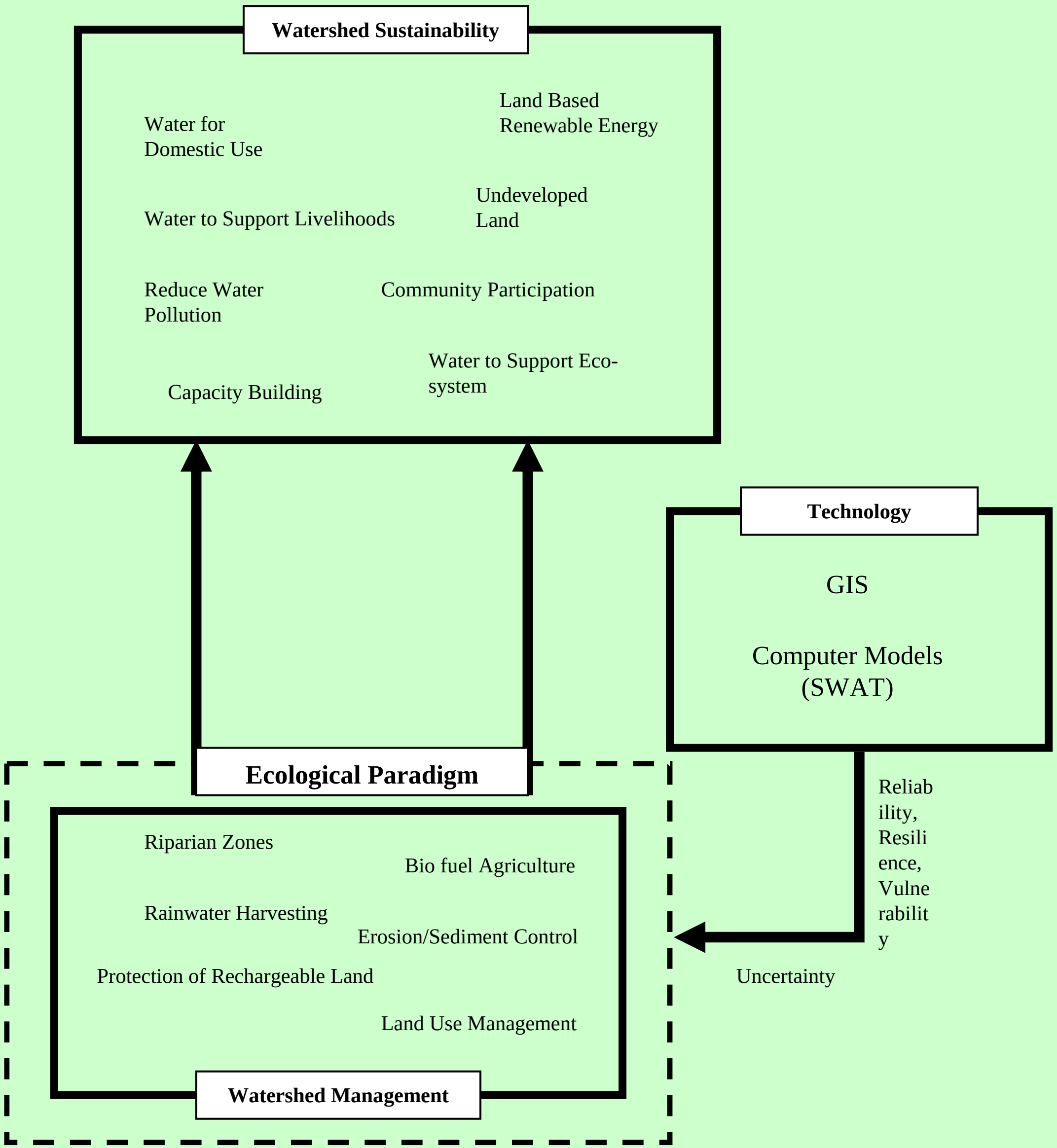
- How to define sustainable development in the context of watershed management?
- How can hydrological models be used in making policies for sustainable watershed management?
- What are the uncertainties involved with using hydrological models and what are the policy implications?

THEORETICAL FRAMEWORK

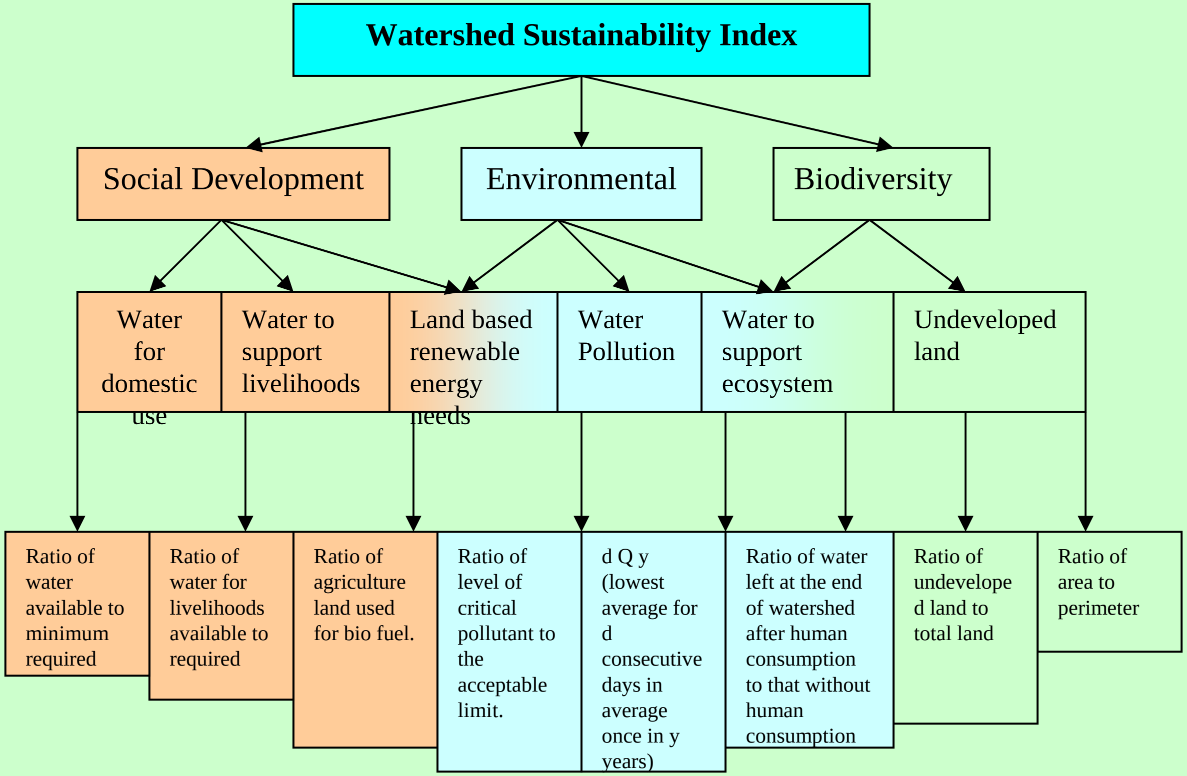
THIS FRAMEWORK COMPRISES OF THE FOLLOWING FEATURES

- Sustainable Development Means Better Environment
- The Ecological Approach to Sustainable Development
- Watershed Management Paradigm – An Ecological Approach
- Role of Technology in Watershed Management Approach
- Watershed Sustainability
- Indicators of Watershed Sustainability

GRAPHICAL REPRESENTATION OF THE FRAMEWORK



INDICATORS USED IN THE FRAMEWORK



THEORATICAL FRAMEWORK – INDICATORS (CONT..)

- Social Development
  - Water for Domestic Use (I_{WD})
    - Requirement based on culture
    - Bare minimum required from the health and sanitation perspective is 50 liters/day per capita (Gleick, 1996)

$$I_{WD(Monthly)} = \frac{\text{Water available for domestic use}}{\text{Minimum water required for domestic use for that region}}$$

Characteristics:

- Calculated monthly
- Range of values – 0 to 1

  0 - no water available for domestic use

  1 – ratio equal to or greater than 1
- Indicator on annual basis

$$I_{WD} = \frac{\sum_{m=1}^{m=12} I_{WD(Monthly)}}{12}$$

THEORATICAL FRAMEWORK – INDICATORS (CONT..)

- Social Development (Cont..)
  - Water to Support Livelihood (I_{WL})
    - Requirement based on culture and regional occupation
    - Water requirement would vary seasonally.

$$I_{WL(Seasonally)} = \frac{\text{Water available for livelihood use}}{\text{Minimum water required for livelihood use for that region}}$$

Characteristics:

•Calculated seasonally

•Range of values – 0 to 1

0 - no water available for livelihood use

1 – ratio equal to or greater than 1

•Indicator on annual basis

$$I_{WL} = \frac{\sum_{s=1}^{s=4} I_{WL(Seasonally)}}{4}$$

THEORATICAL FRAMEWORK – INDICATORS (CONT..)

- Social Development (Cont..)
  - Land Based Renewable Energy ((I_{RE})
    - Requirement based on culture and region
    - From watershed perspective – only bio fuels are considered
    - Bio fuels can be resource intensive (land, water, fertilizer, energy).

$$I_{RE} = \frac{\text{Bio fuel source produced within the watershed}}{\text{Bio fuel source required for that region}}$$

Characteristics:

•Calculated annually

•Range of values – 0 to 1

0 - no bio fuel source produced within the watershed

1 – all the bio fuel source produced within the watershed.

THEORATICAL FRAMEWORK – INDICATORS (CONT..)

- Environment
  - Water Pollution (I_{WP})
    - In spite of having sufficient water, water scarcity can also be because of polluted water
    - Point and non-point source (critical from watershed perspective) pollution

$$I_{WP} = \frac{\text{Length of stream that is not impared} * \text{No. of months it is not impared}}{\text{Total length of stream in the watershed} * \text{No. of months considered}}$$

Characteristics:

Calculated annually (thus number of months considered = 12

Range of values – 0 to 1

0 – all streams impaired all the time

1 – no stream impaired any time of the year

THEORATICAL FRAMEWORK – INDICATORS (CONT..)

- Environment (Cont..)
  - Water to Support Ecosystem (I_{WE})
    - Minimum water required for the ecosystem services.
    - Various regions require different low-flow standards.
    - 7Q10 used for this research

$$I_{WE(Monthly)} = \frac{\text{Water available for ecosystem (i.e. water left after domestic and livelihood use)}}{\text{Minimum water required (7Q10)}}$$

Characteristics:

Calculated monthly

Range of values – 0 to 1

0 – no water available

1 – ratio equal to or greater than one

Indicator on annual basis

$$I_{WE} = \frac{\sum_{m=1}^{m=12} I_{WE(Monthly)}}{12}$$

THEORATICAL FRAMEWORK – INDICATORS (CONT..)

- Biodiversity
  - Undeveloped Land (I_{UL})
    - Unaltered habitat (Amount of land left undeveloped)
    - Fragmentation (perimeter to area ratio)

$$I_{UL} = \frac{\text{Land left undeveloped} * \text{perimeter to area ratio}}{\text{Minimum land required as undeveloped for the region} * \text{acceptable perimeter to area ratio}}$$

Characteristics:

Calculated annually

Range of values – 0 to 1

0 – all land developed

1 – ratio equal to or greater than one

WATERSHED SUSTAINABILITY INDEX

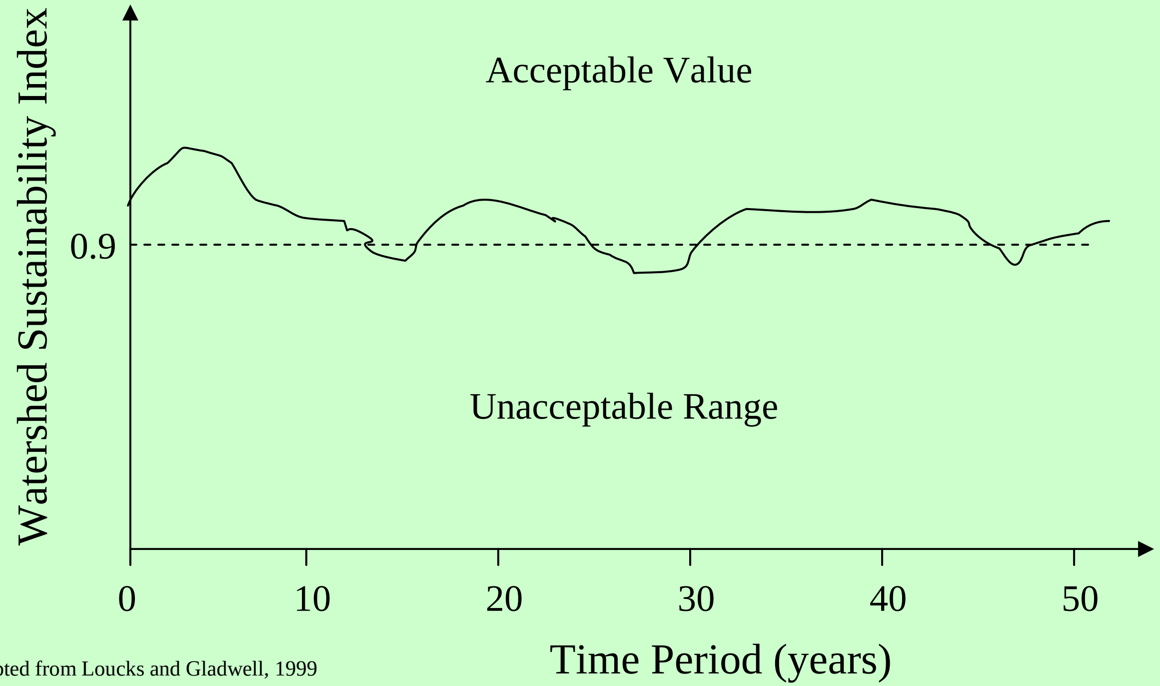
Watershed Sustainability Index

$I_{WS} = W_{WD*}I_{WD} + W_{WL*}I_{WL} + W_{RE*}I_{RE} + W_{WP*}I_{WP} + W_{WE*}I_{WE} + W_{UL*}I_{UL}$

Where:

I_{WS} is indicator for watershed sustainability.
I_{WD} is indicator for "water for domestic use"
I_{WL} is indicator for "water to support livelihoods"
I_{RE} is indicator for "renewable energy"
I_{WP} is indicator for "water pollution"
I_{WE} is indicator for "water for ecological services"
I_{UL} is indicator for "undeveloped land"
W_{WD} is weight of indicator for "water for domestic use"
W_{WL} is weight of indicator for "water to support livelihoods"
W_{RE} is weight of indicator for "renewable energy"
W_{WP} is weight of indicator for "water pollution"
W_{WE} is weight of indicator for "water for ecological services"
W_{UL} is weight of indicator for "undeveloped land"

Reliability, Resilience, and Vulnerability



Adapted from Loucks and Gladwell, 1999

Reliability, Resilience, and Vulnerability (Cont..)

$$\text{Reliability}(S_{REL}) = \frac{\text{Number of satisfactory values}}{\text{Total number of values}}$$

$$\text{Resilience}(S_{RES}) = \frac{\text{Number of times a satisfactory value follows an unsatisfactory value}}{\text{Number of unsatisfactory values}}$$

$$\text{Vulnerability}(S_{VUL}) = \text{Expected extent given unsatisfactory value}$$
$$+ \text{ Expected Duration given unsatisfactory values}$$

Where

$$\text{Expected Extent Given Unsatisfactory Value} = \frac{\text{Cumulative extent of failure}}{\text{Number of individual failure events}}$$

$$\text{Expected Duration Given Unsatisfactory Value} = \frac{\text{Total number of failure periods}}{\text{Number of continuous series of failure events}}$$

WATERSHED SUSTAINABILITY

$$S_{WATERSHED} = S_{REL} * S_{RES} * (1 - \text{Relative } S_{VUL})$$

Where

$$\text{Relative } S_{VUL} = \frac{\text{Vulnerability}}{\text{Maximum vulnerability among all alternatives}}$$

METHODOLOGY

Step 1: Create Watershed Sustainability Index based on indicators

Step 2: Create “best case” land use scenario for the watershed by measuring watershed sustainability:

a. First create a watershed index on annual basis
b. Define the acceptable range of watershed sustainability index
c. Based on the range of watershed sustainability index, reliability, resilience and vulnerability is measured.
d. The scenario with the highest watershed sustainability is selected as the best-case scenario.

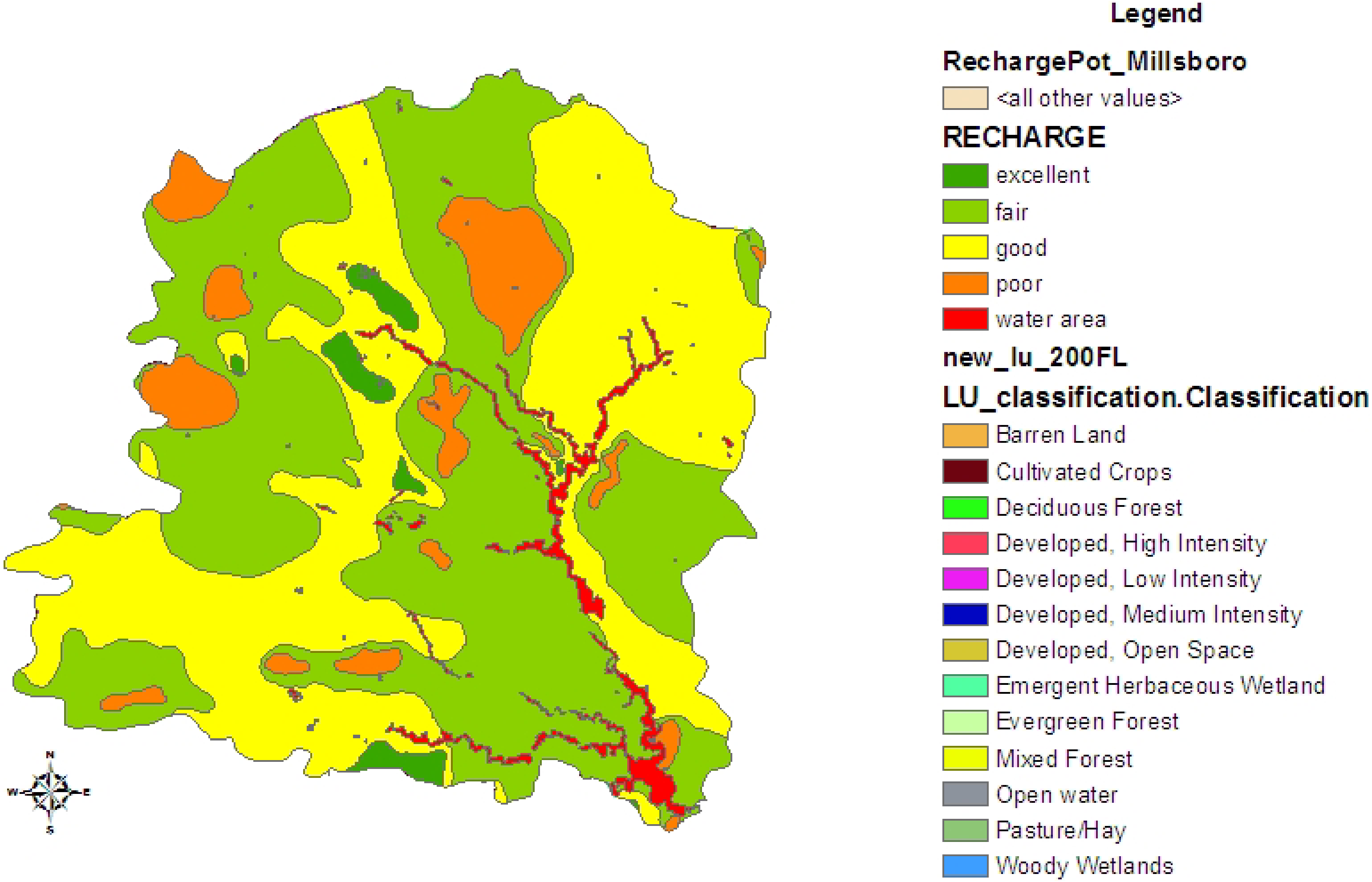
Step 3: Discuss Uncertainty with this Approach and Propose Policy

POSSIBLE RESEARCH DIFFICULTIES

- Indicators cannot capture the whole complexity
- Minimal indicators used
- Difficulty in coming up with the best land-use scenario.

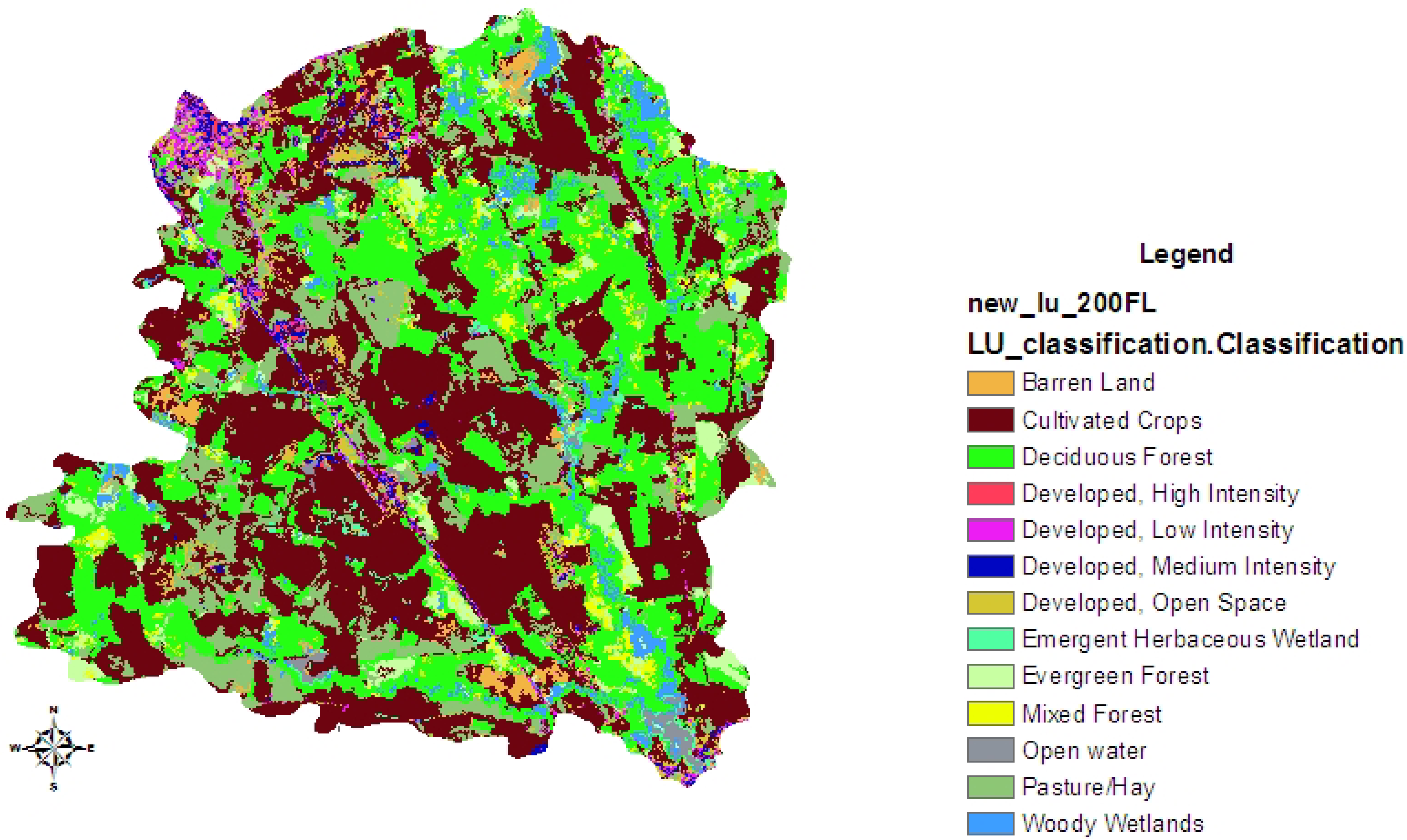
Land Use Based on Recharge Potential

Recharge Potential



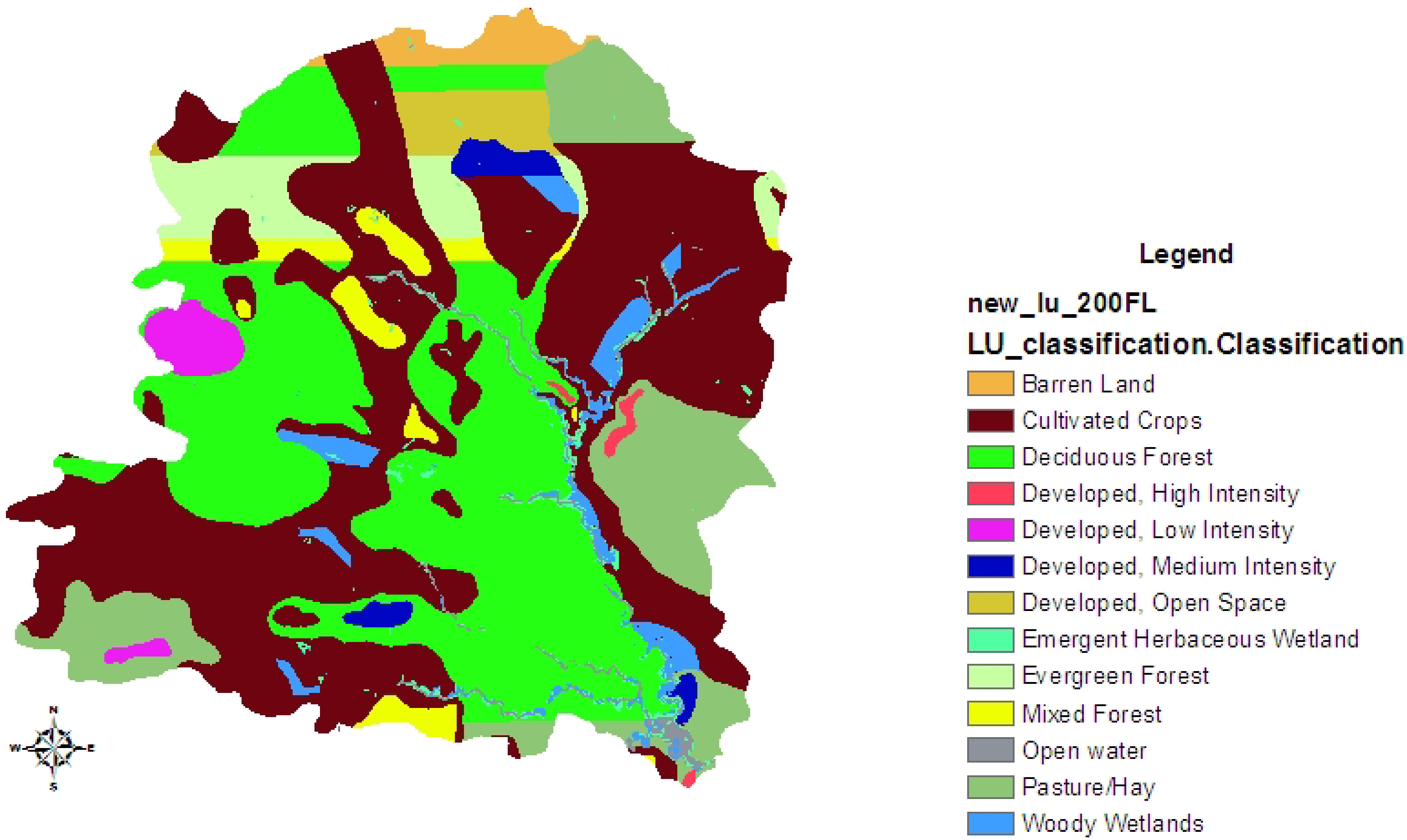
Land Use Based on Recharge Potential

Current Land Use



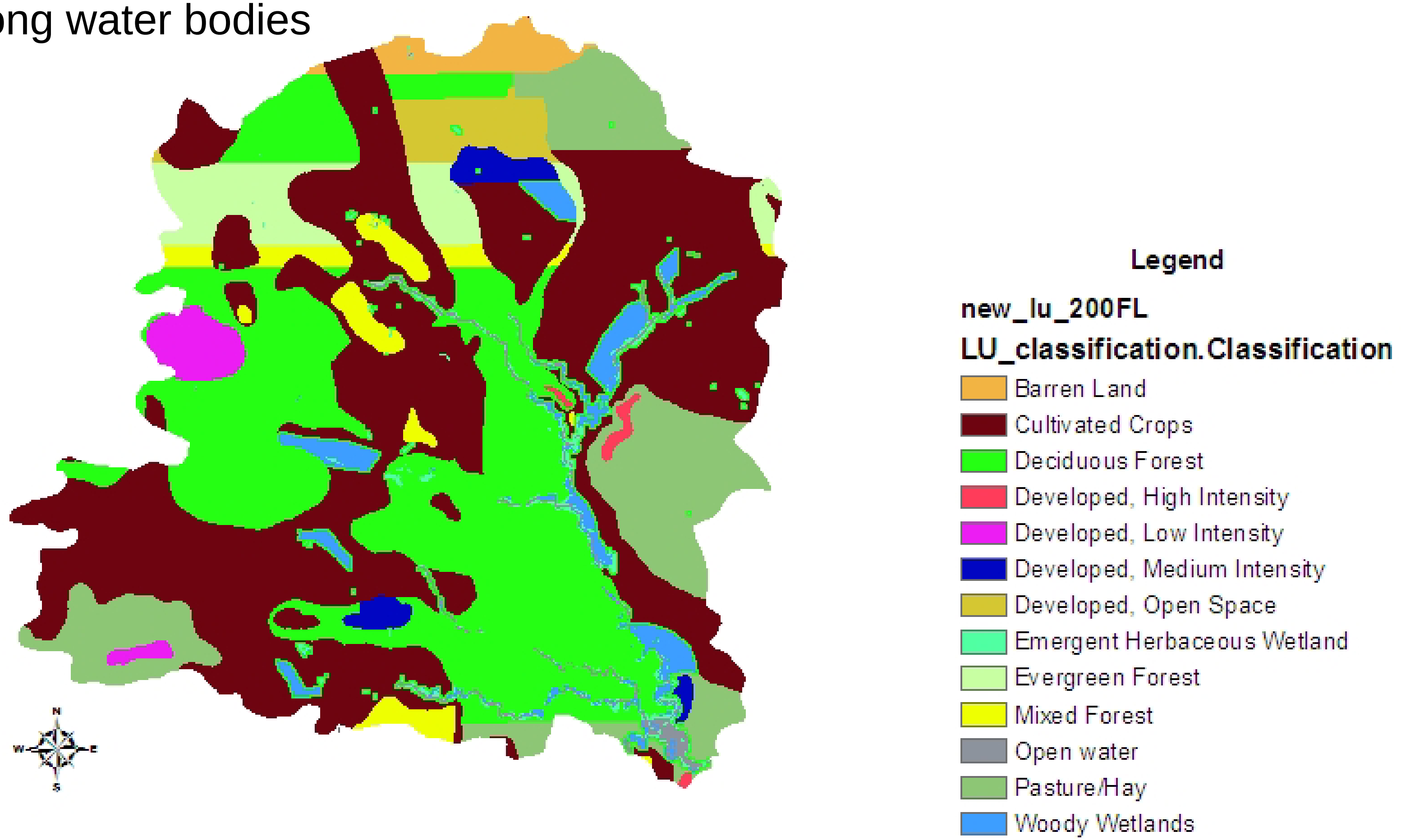
Land Use Based on Recharge Potential

Land Use based on Recharge Potential and no buffer



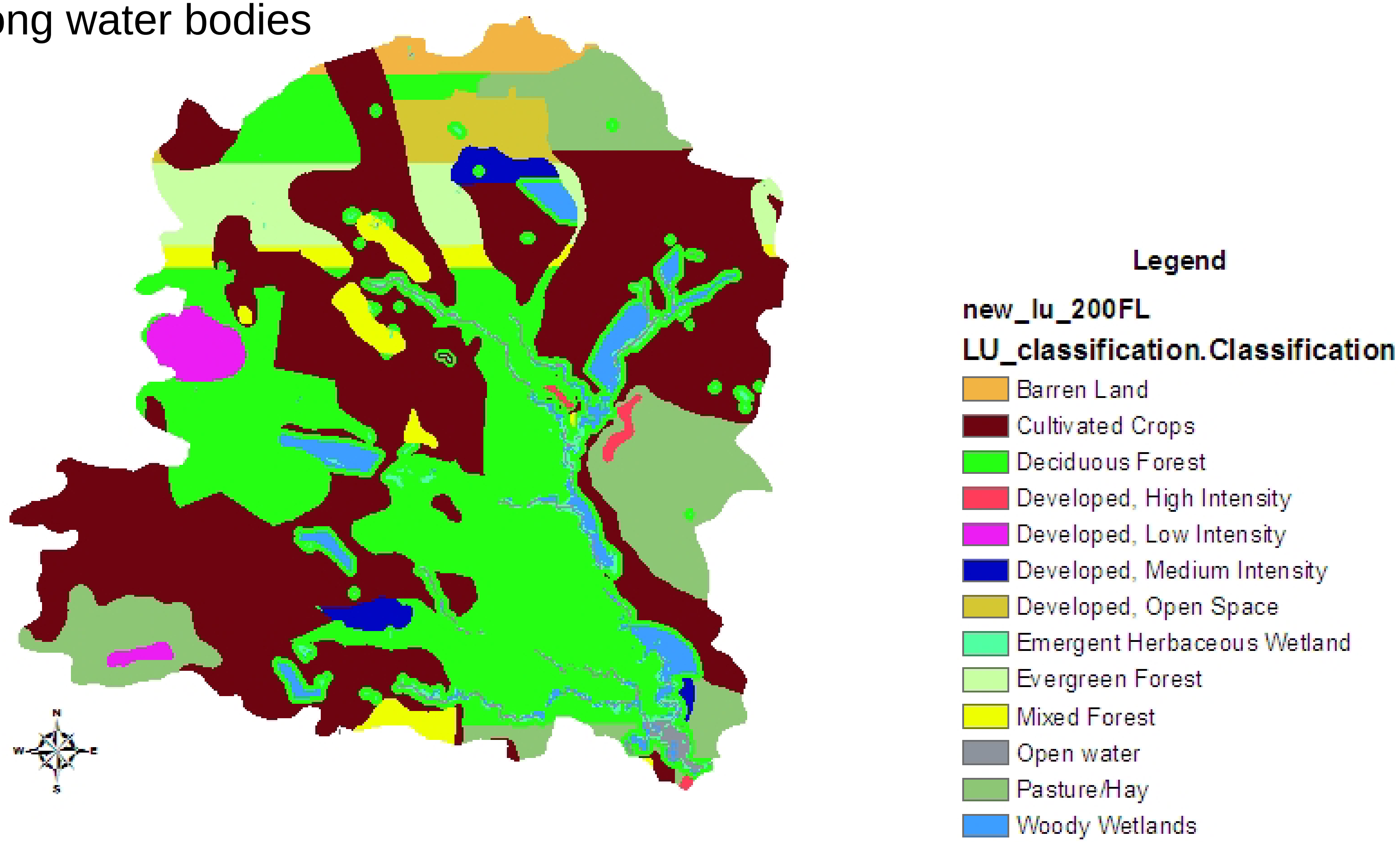
Land Use Based on Recharge Potential

Land Use based on Recharge Potential and 50 m buffer along water bodies



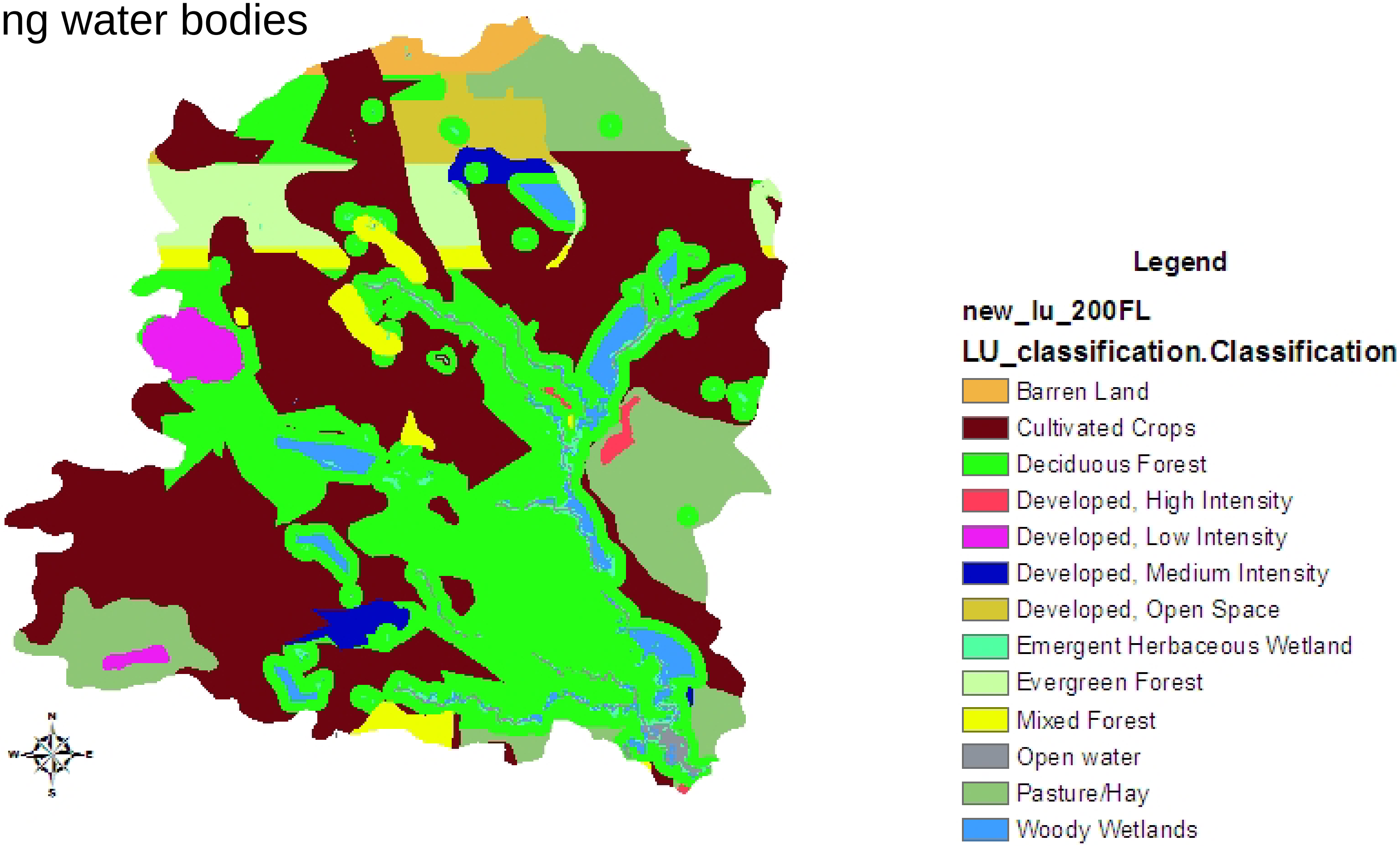
Land Use Based on Recharge Potential

Land Use based on Recharge Potential and 100 m buffer along water bodies



Land Use Based on Recharge Potential

Land Use based on Recharge Potential and 200 m buffer along water bodies



Land Use Based on Recharge Potential

Land Use based on Recharge Potential and 200 m buffer along flow lines