Use of ICT to Assess Climate and Land Use Changes Impacts on Hydrological Responses and Sediment Yield in the Upper Ma River Basin, Northwestern Vietnam for future Land Use Planning and Sustainable Water Management

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Outline of presentation

- Introduction
- Objectives
- Study area
- Research Methodology
- Results
- Recommendations
- Limitations and Future Research
- Appendixes
- Acknowledgement

1. Introduction

- Land use and climate change are considered as the most important factors affecting on hydrology and sediment transport in watersheds
  - Rapid land use and land cover change
  - Demand of food
  - Population pressure
  - Urbanization
- Climate change
  - Increase in temperature and rainfall intensity
  - Uncertainty
  - Impacts on hydrological cycle, water availability, and transport of pollutants

Problem statement and Rationale

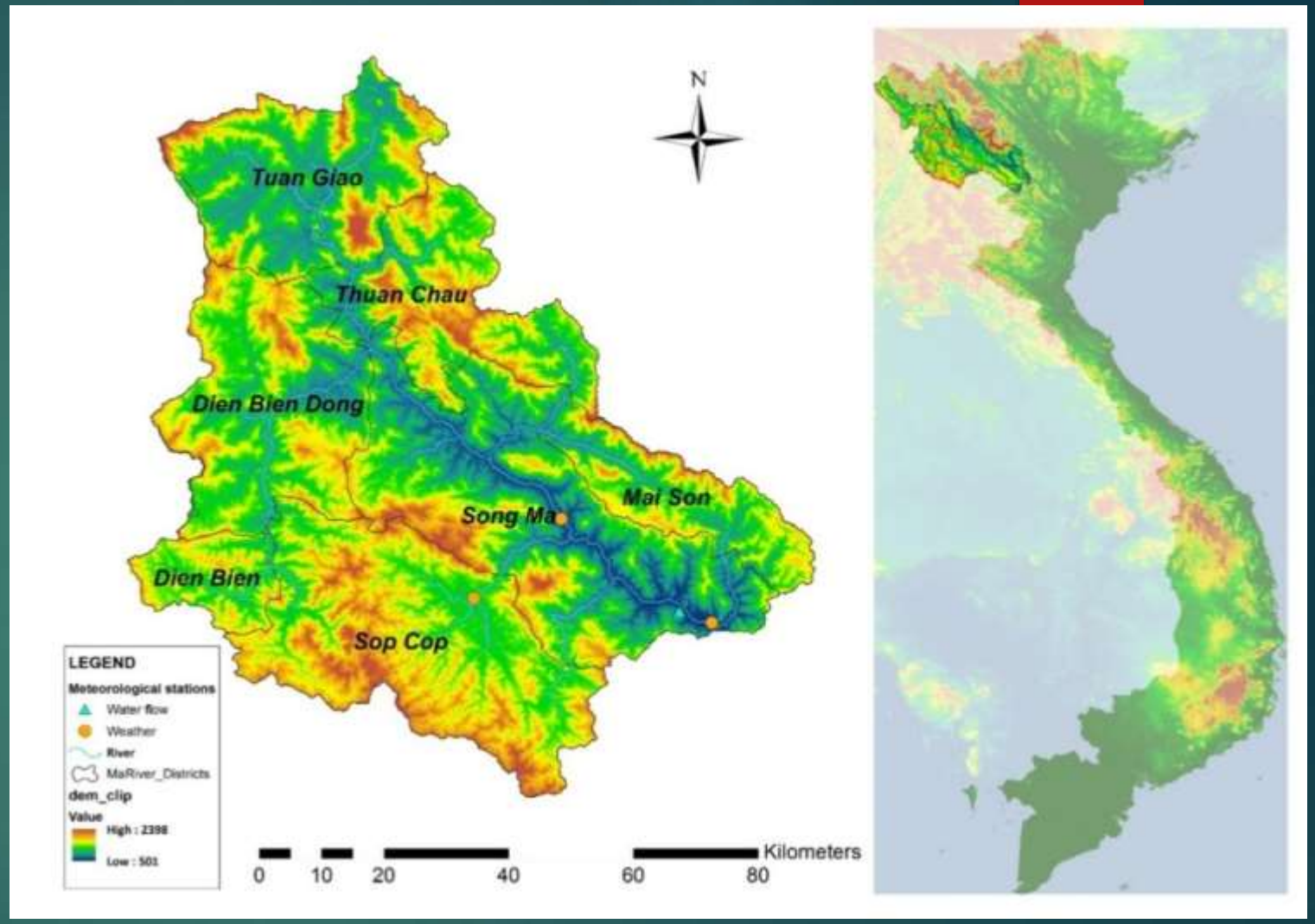
- Land use changes such as **inappropriate conversion of land** and **land use mismanagement** have created **negative impacts** on land and water resources.
- Climate change (precipitation and temperature) affects the **hydrological cycle**, and changes the **stream flow**, and modifies the transformation and transport characteristics of **sediment** as well as **water pollution**
- Impact assessments of land use and climate changes on hydrology and sediment transport are one of the **most important topics** in a basin;
- The Northwest of Vietnam (Ma river basin) has been undergone **significantly changes** in **hydrology and sediment transport**, mainly due to land use and climate change
- To the best of our knowledge, **no study** on impacts of land use and climate changes on soil erosion, water quality and quantity in these regions

2. Objectives

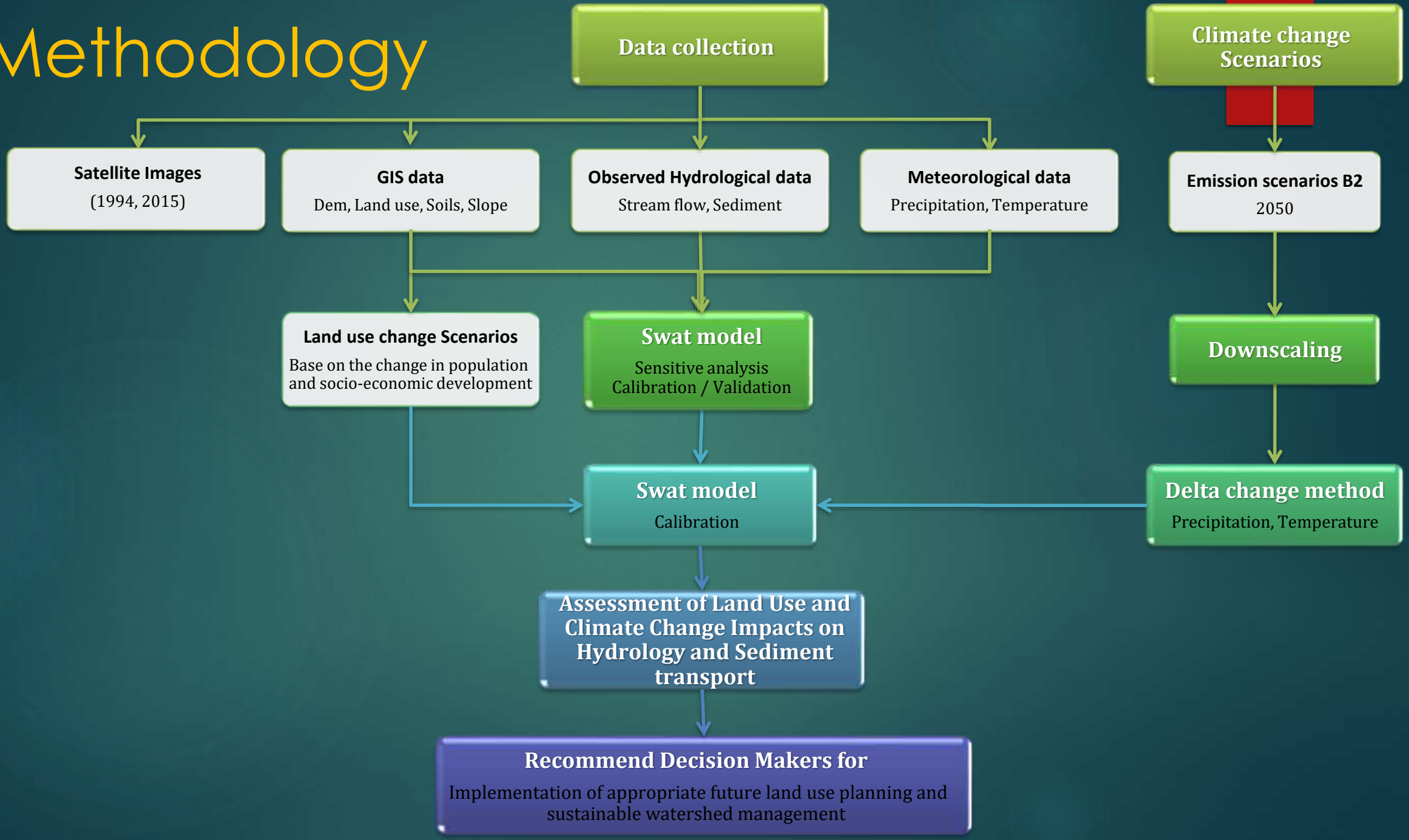
- General objective is to **assess the impacts of climate and land use changes** on **hydrological responses, sediment transport**, and future ecosystem functions of the Upper river system. In addition, it is intended to consolidate the scientific basis for the definition of adaptation and mitigation strategies in relation to changes in climate and land-use.
- The specific objectives are to:
  - to quantify the **major land use change** between 1994 and 2015 in the upper Ma river basin;
  - to assess the **individual impacts** of climate and land use changes on flow and sediment transport at the upper Ma river basin;
  - to assess **combined impacts** of climate and land use on major flow (surface runoff, base flow, percolation, evaporation, and water yield) and sediment transport;
  - to predict the **effects of the future land use and climate change scenarios** on flow and sediment transport; and
  - to provide **planners and decision-makers** with information to promote vegetation restoration, water resources management and sustainable development in the upper Ma River Basin.

Study area

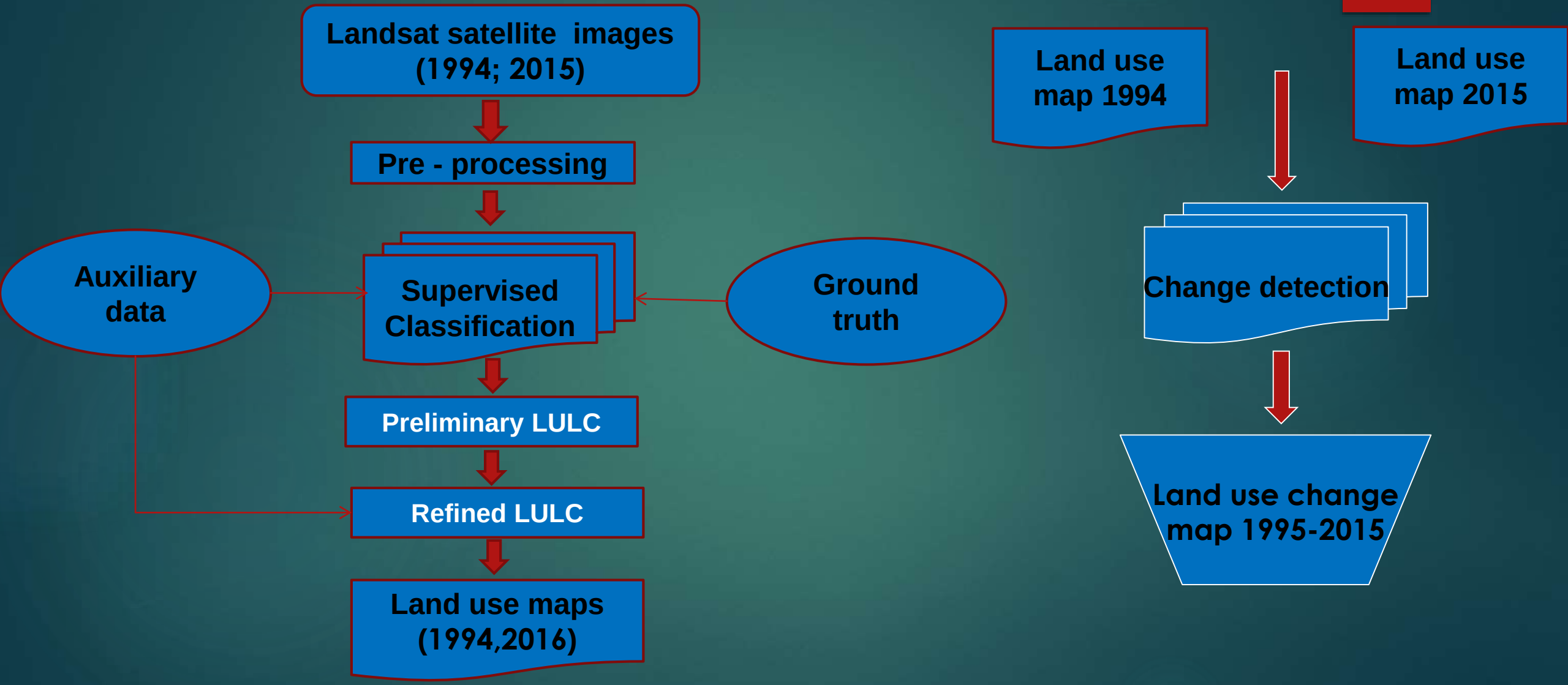
- Basin area 6688 km^2
- Climate: tropical climate, annual rainfall 900-1900 mm
- Topography: mountain, steep slope
- Population 598,000, ethnic groups, low education, poverty,
- Land use: mainly forest (59.05%), rapid land use changes, inappropriate conversion,
- Soil erosion and land degradation, flow variation



3.Methodology



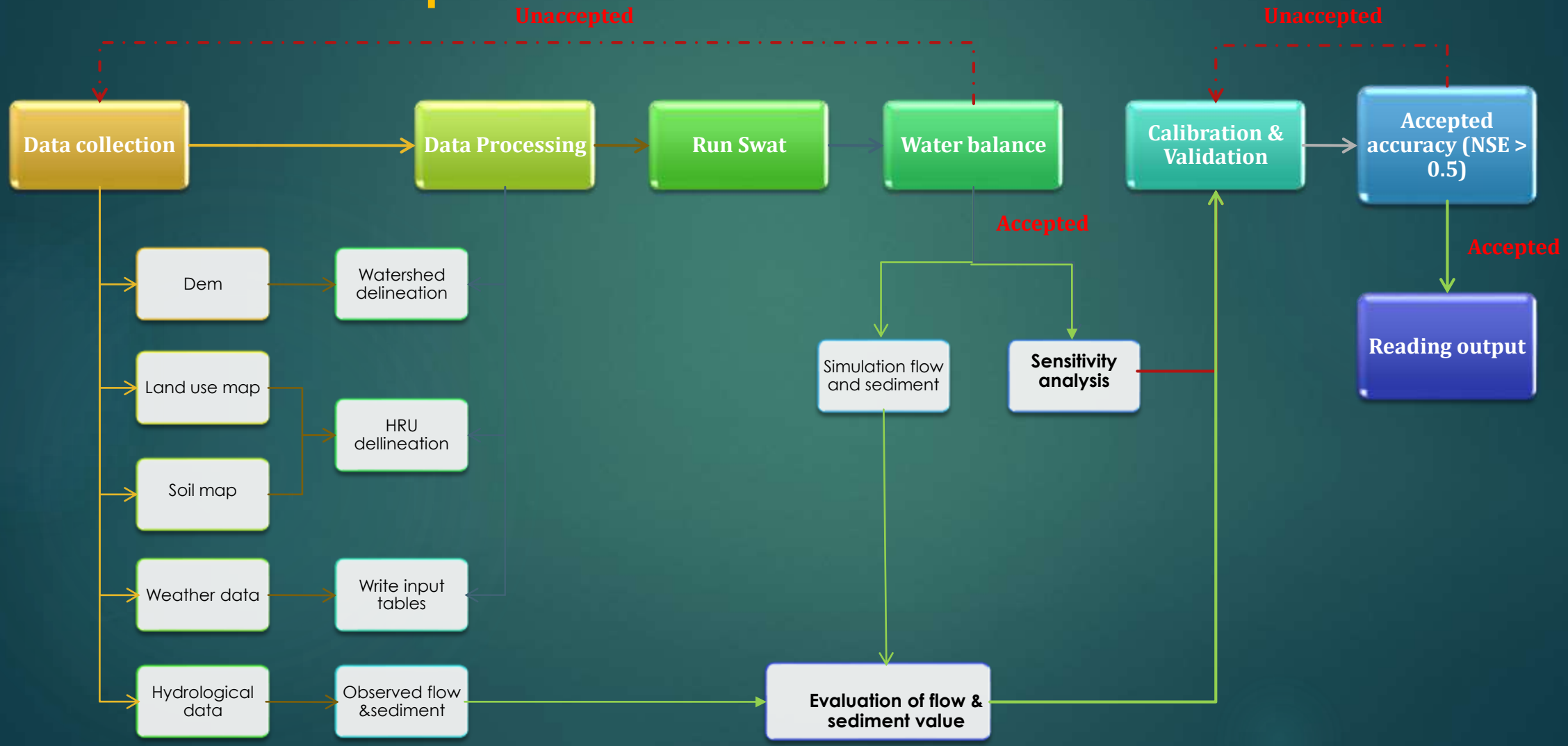
Task 1: Image analysis and processing



Land use Classes

Land use classes	Sub land use classes groups as single class
Forest	
Evergreen forest	Dense, multi-layered, and harbour many types of plants
Open forest	Mixtures of trees, shrubs and grasses
Mixed forest	Vegetational transition between coniferous forest and broad-leaved deciduous forest
Perennial crop	Bamboo, rubber plantation and perennial trees, e.g., orchards
Paddy field	Paddy field
Urban area	Cities, towns, villages, highways and transportation areas
Water body and aquaculture	Lakes and manmade reservoirs, shrimp farms, fish farms and other types of aquaculture
Field crop	Corn, Cassava, sugarcane, etc.

Task 2: Application of SWAT model to assess the impacts of land use and climate changes on hydrology and sediment transport

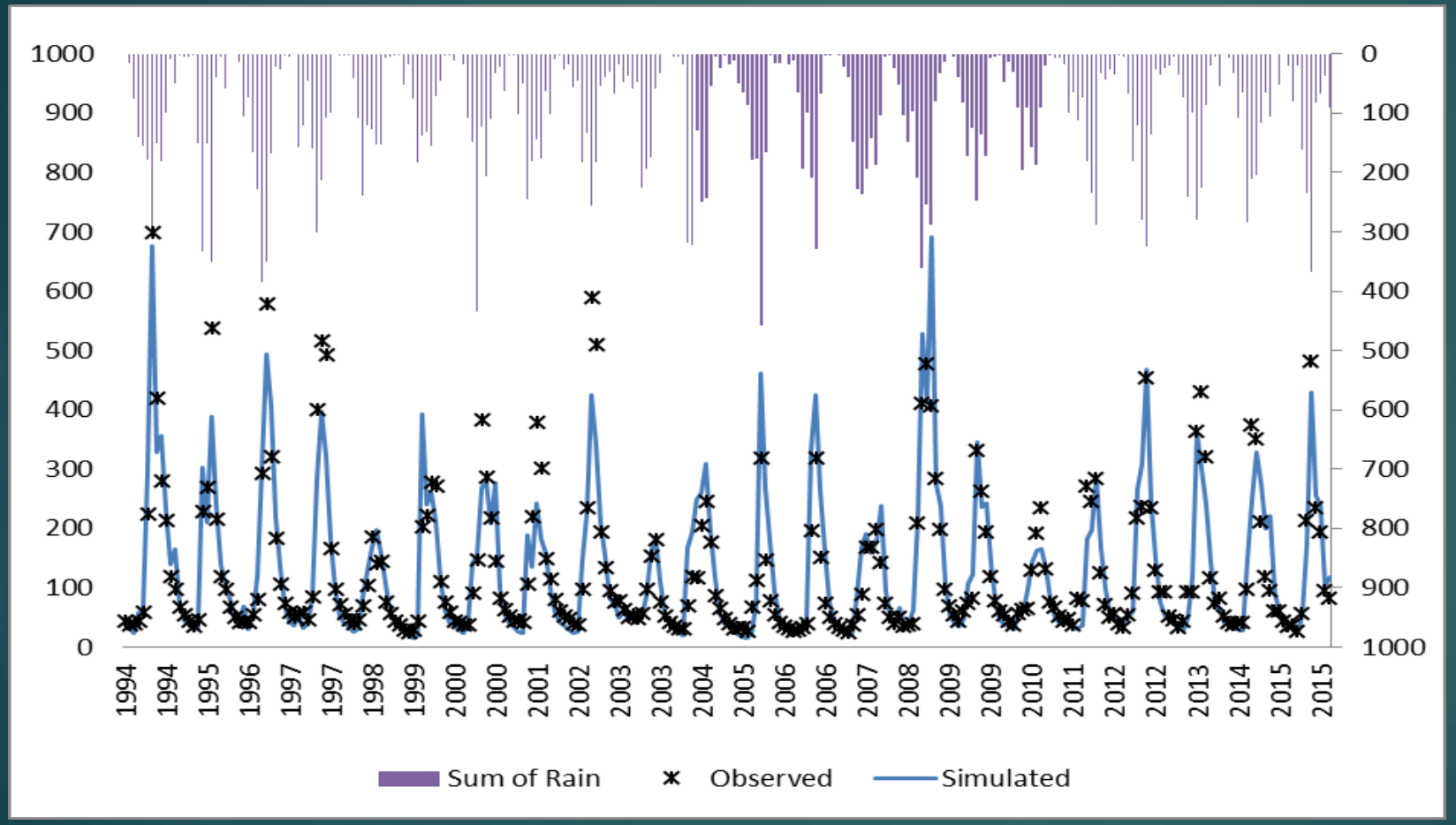


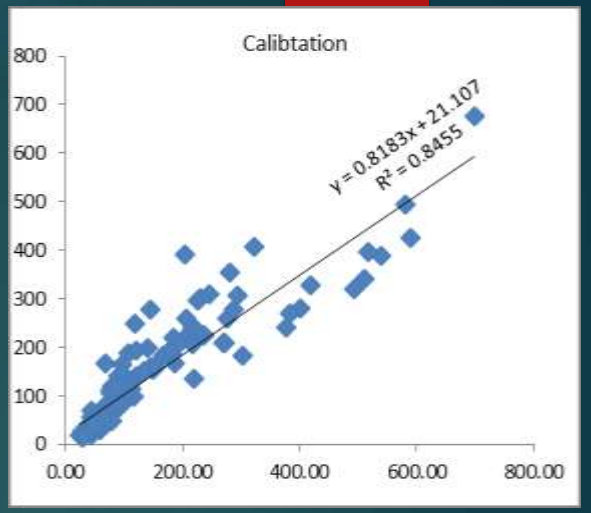
Task 3. Model application

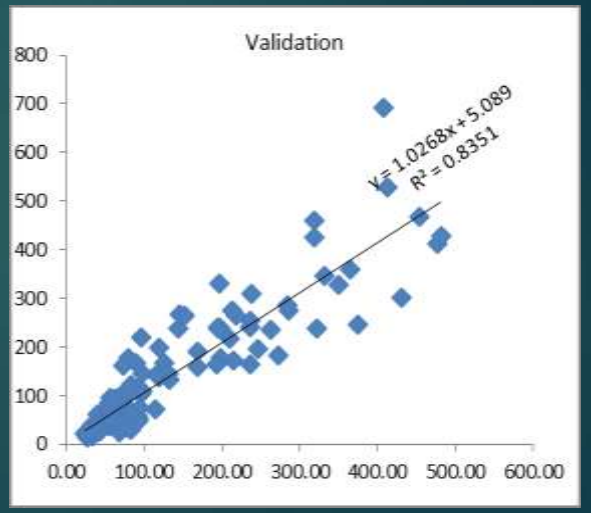
- S1: 1994 land use and 1994–2004 climate.
- S2: 2015 land use and 1994–2004 climate.
- S3: 1994 land use and 2005–2015 climate.
- S4: 2015 land use and 2005–2015 climate.
- S5: 2050 land use and 2016-2050 climate (based on future land use and climate change scenarios)

4. Results

- Calibration and Validation

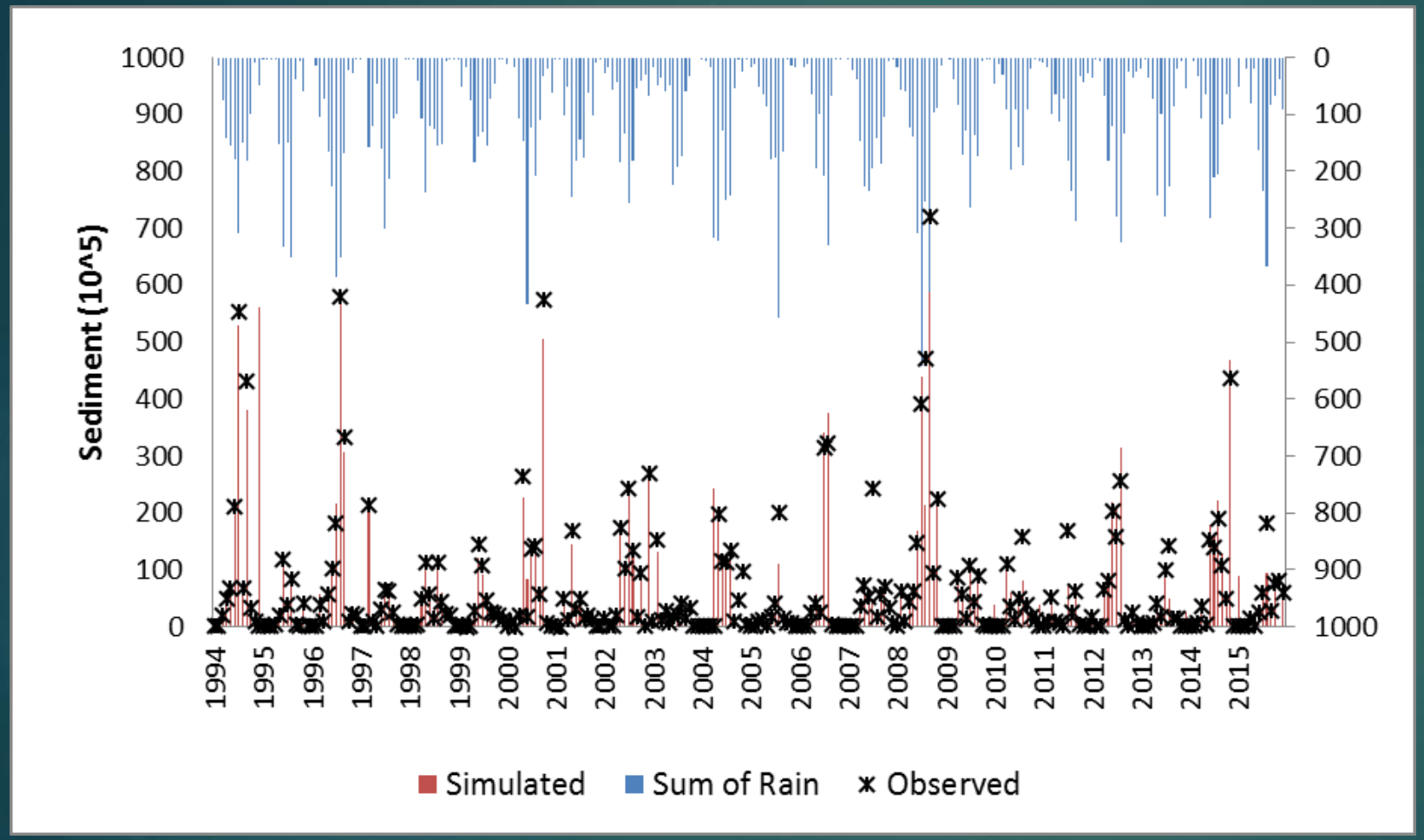


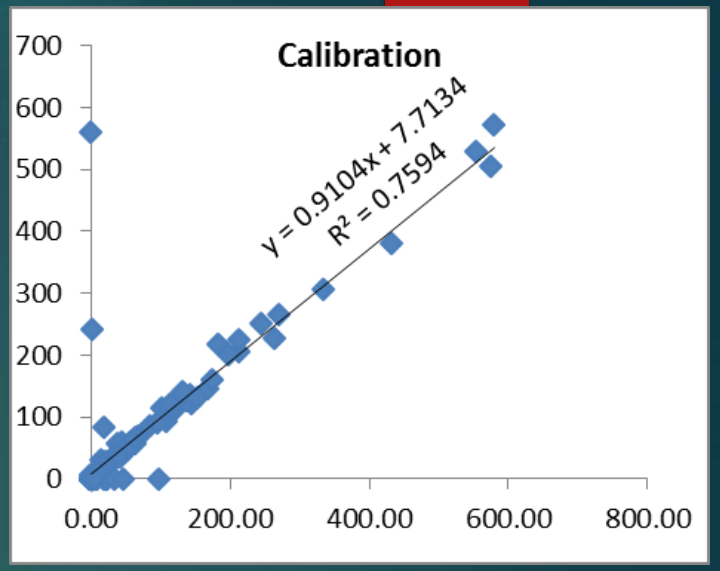


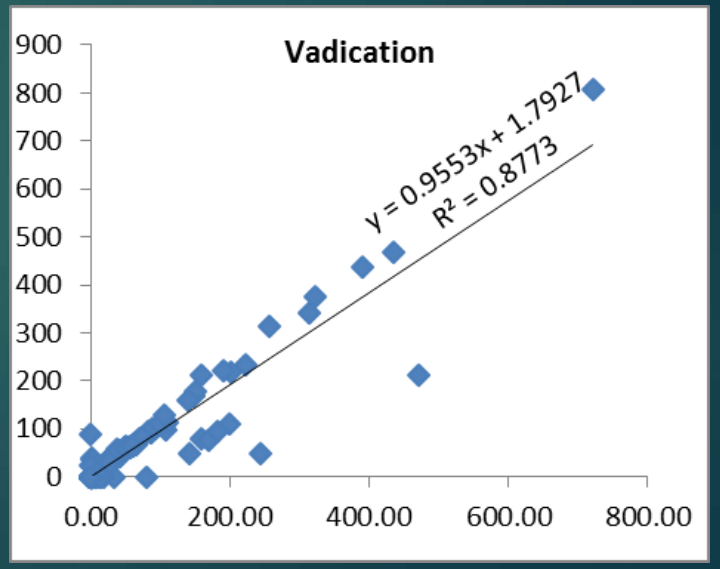


Monthly Observed and simulated flow from 1994 to 2015

Sediment Yield

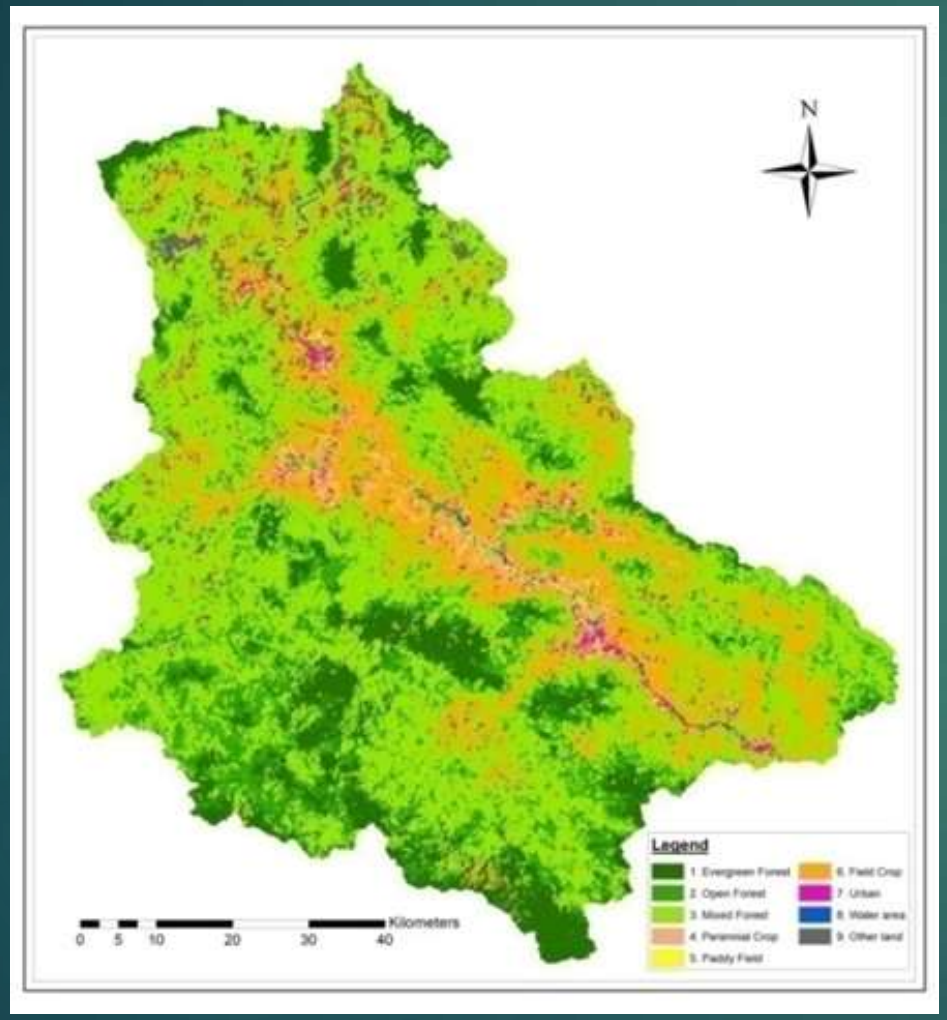




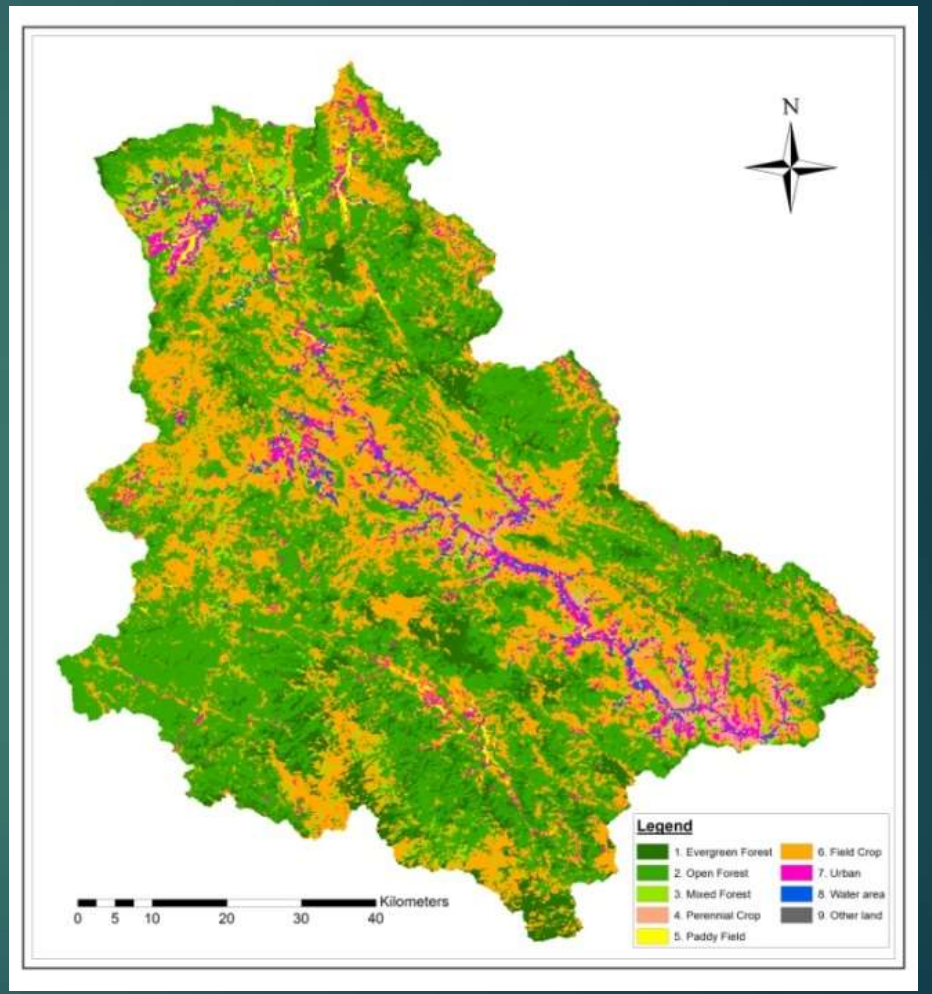


Monthly Observed and simulated Sediment yield from 1994 to 2015

Land Use Changes

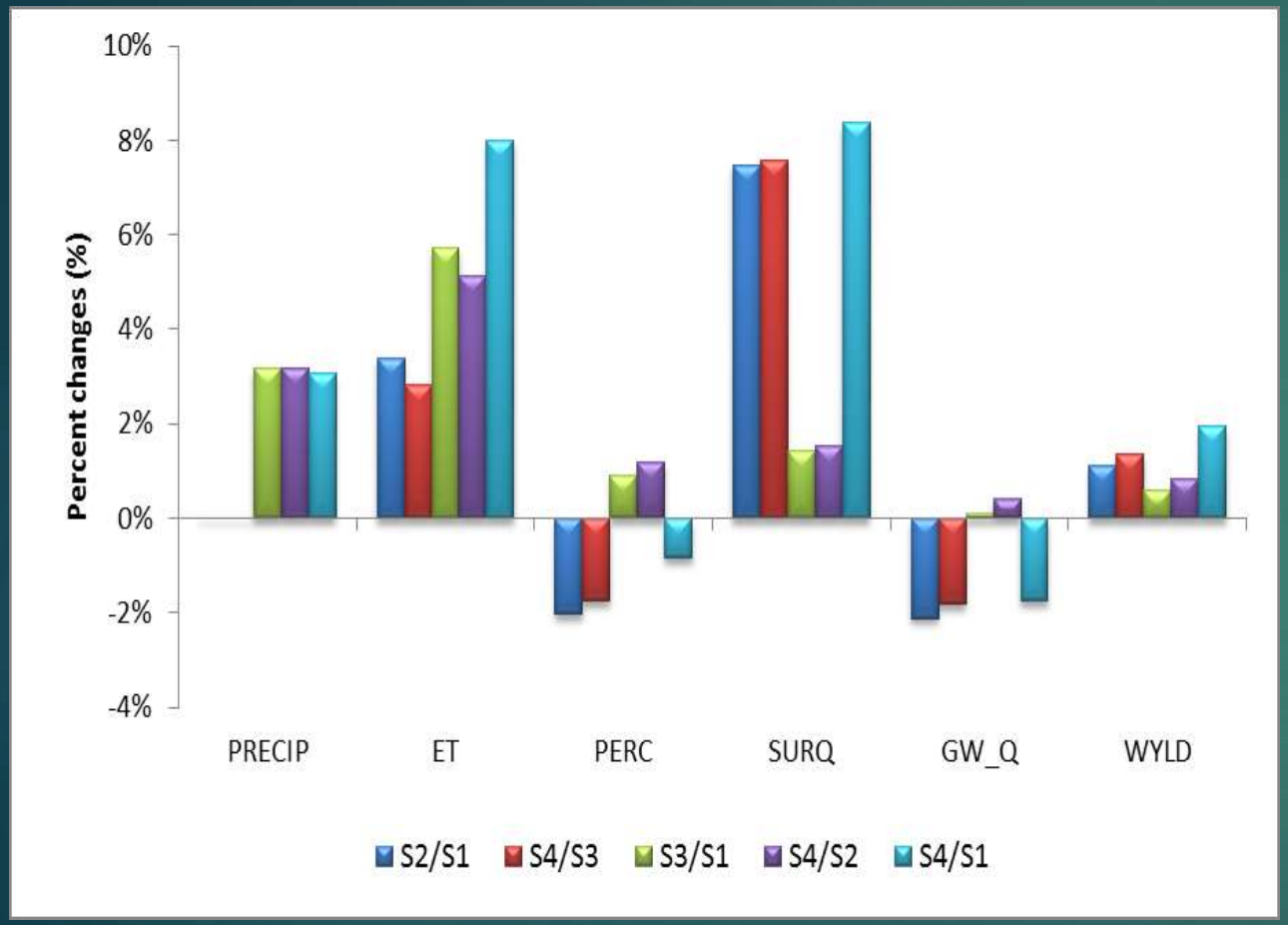


Land Use Map 1994

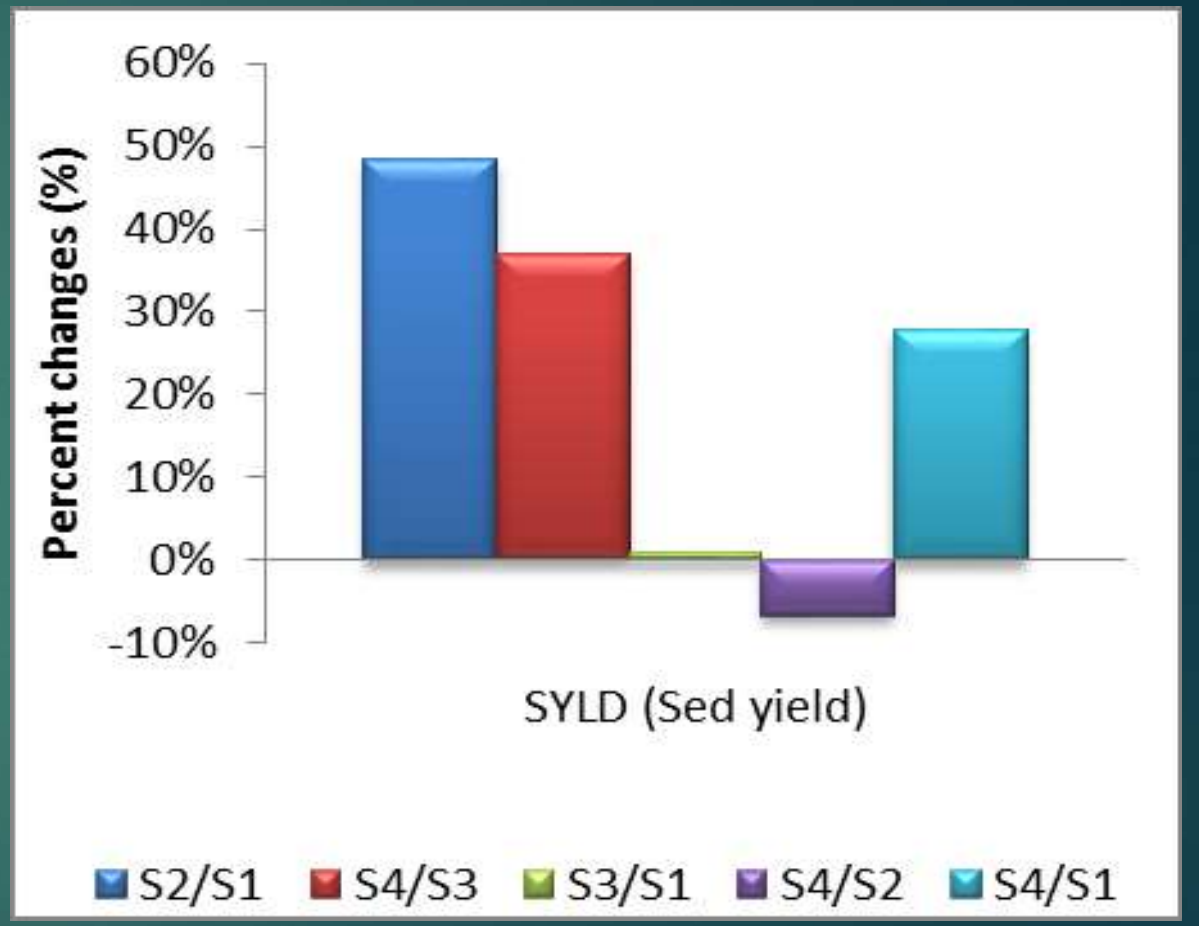


Land Use Map 2015

Impact of land use and climate changes on Hydrology and Sediment Yield

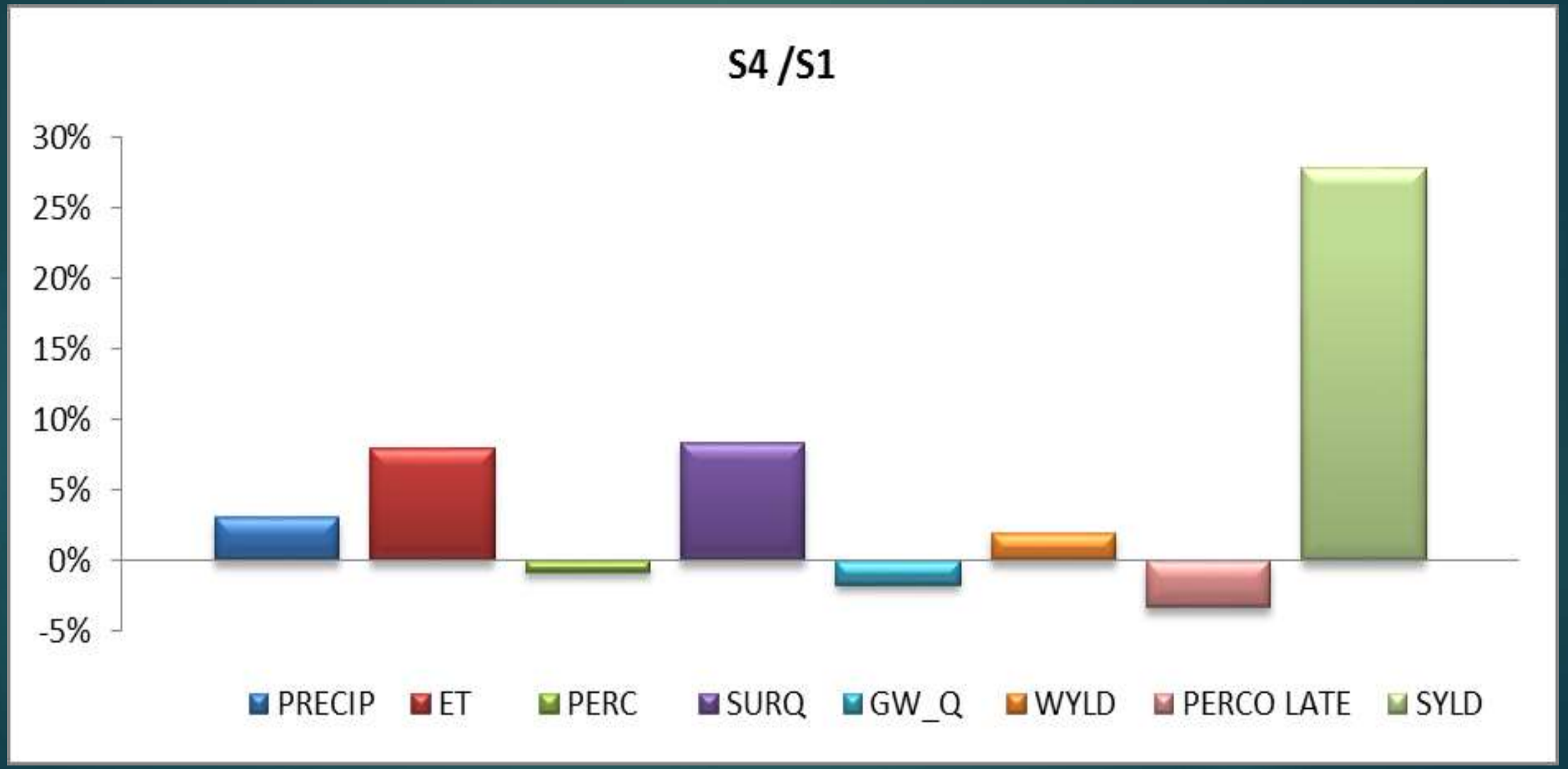


Impacts on hydrological components

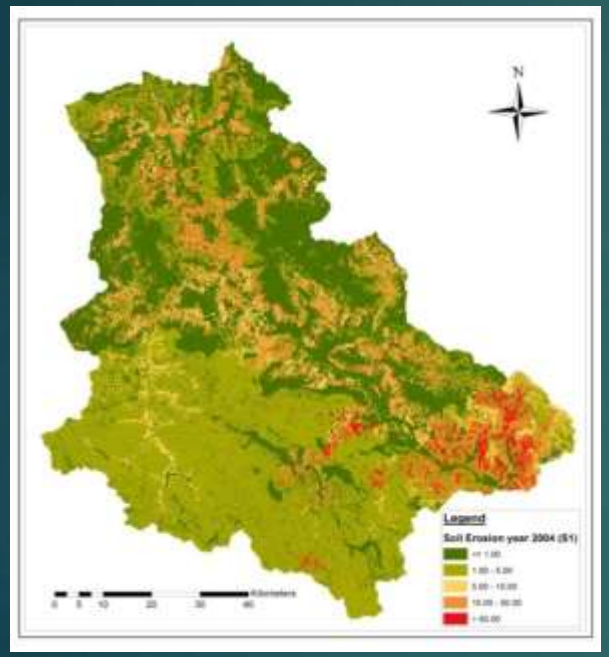


Impacts of sediment load

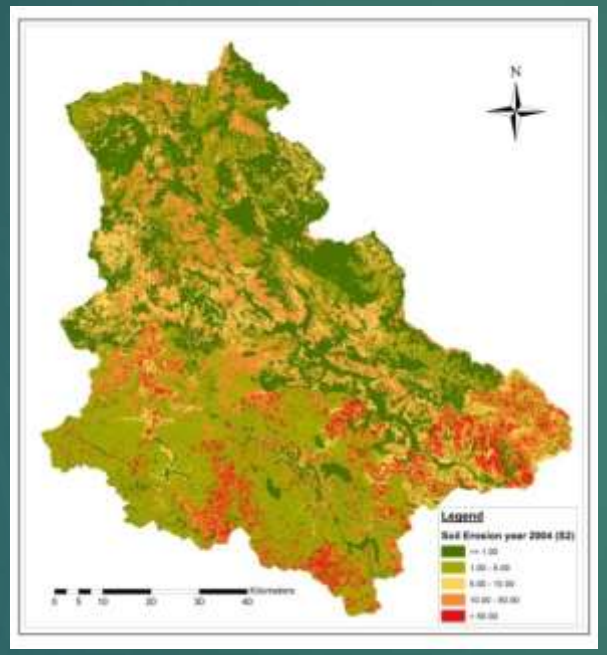
Combined Impacts of Land Use and Climate Change on Hydrological Responses and Sediment Yield



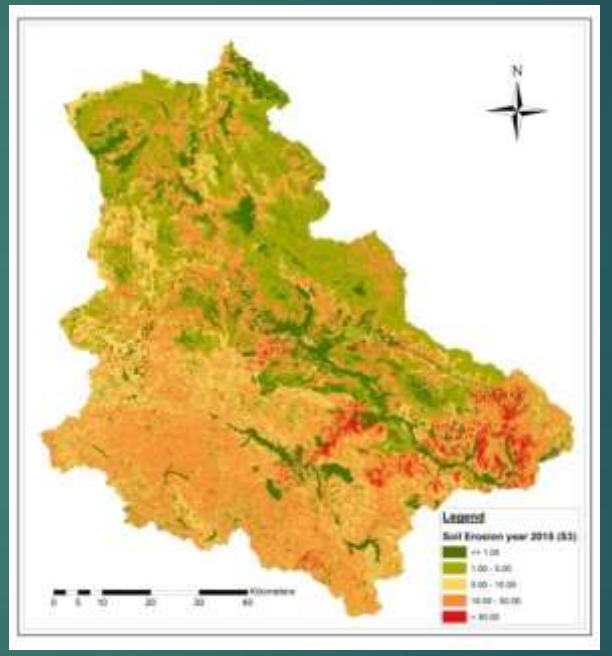
Identification of the critical soil erosion in the upper Ma river basin under the past land use and climate change scenarios



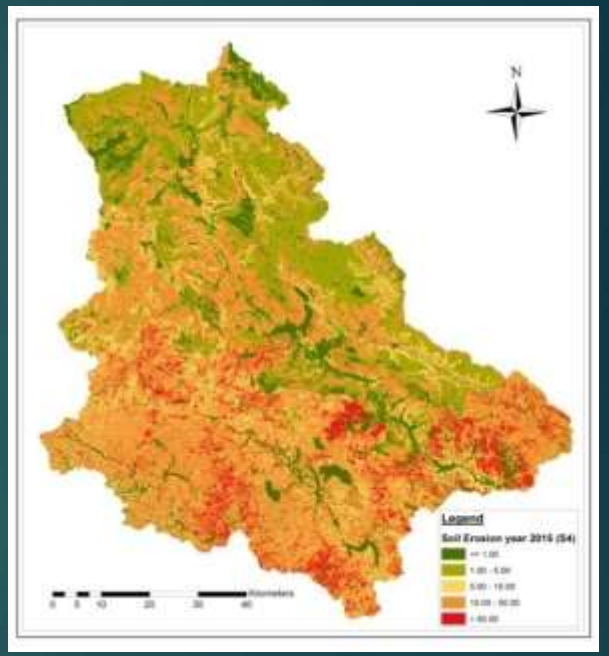
S1



S2



S3



S4

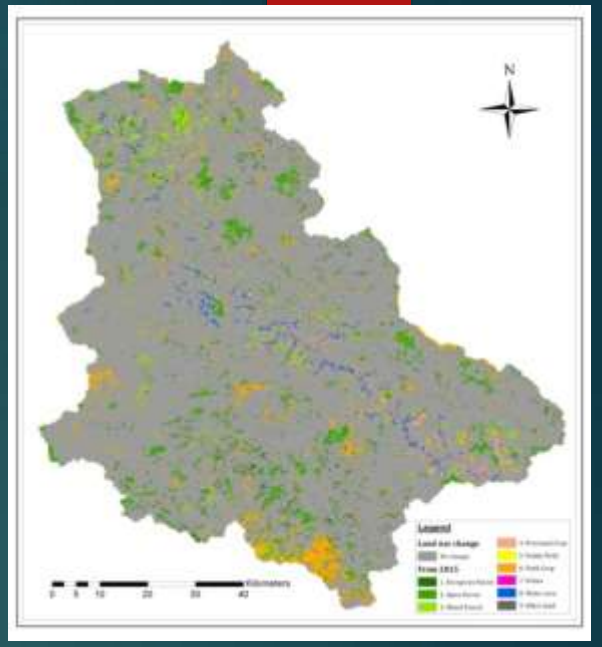
Characteristics and percent area of soil loss classes

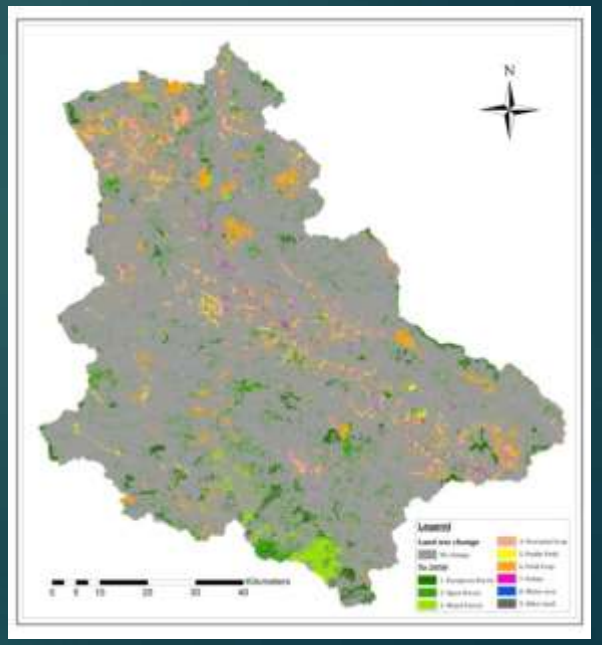
Grade of soil erosion	Soil loss (ton ha^{-1} yr^{-1})	Rating	Percent Area (%)			
			S1	*S2*	*S3*	*S4*
I	≤ 1	Nil	30.29	24.24	2.31	2.32
II	1 ÷ 5	Weak	46.38	36.41	29.87	24.05
III	5 ÷10	Moderate	8.18	12.57	27.20	22.27
IV	10 ÷ 50	High	13.15	21.02	38.14	44.62
V	≥ 50	Very high	2.00	5.76	2.47	6.73

Source: TCVN-5299-2009

Projected land use and climate scenarios

No.	Types of land use	Swat code	Area (km^2)		Changes	
			2015	2050	Area (km^2)	Percent
1	Evergreen Forest	FRSE	597.85	648.93	51.07	8.54
2	Open Forest	FRSD	3065.03	3039.54	-25.49	-0.83
3	Mixed Forest	FRST	286.44	240.57	-45.87	-16.01
4	Perennial crop	ORCD	100.84	197.07	96.23	95.42
5	Paddy Field	PDDY	52.15	130.05	77.90	149.38
6	Field crop	AGRR	2184.26	2084.49	-99.77	-4.57
7	Urban area	URBN	290.34	316.56	26.22	9.03
8	Water	WATR	91.76	30.95	-60.81	-66.27
9	Other land	BARR	19.48	0.00	-19.48	-100.00
	Total		6688.15	6688.15		

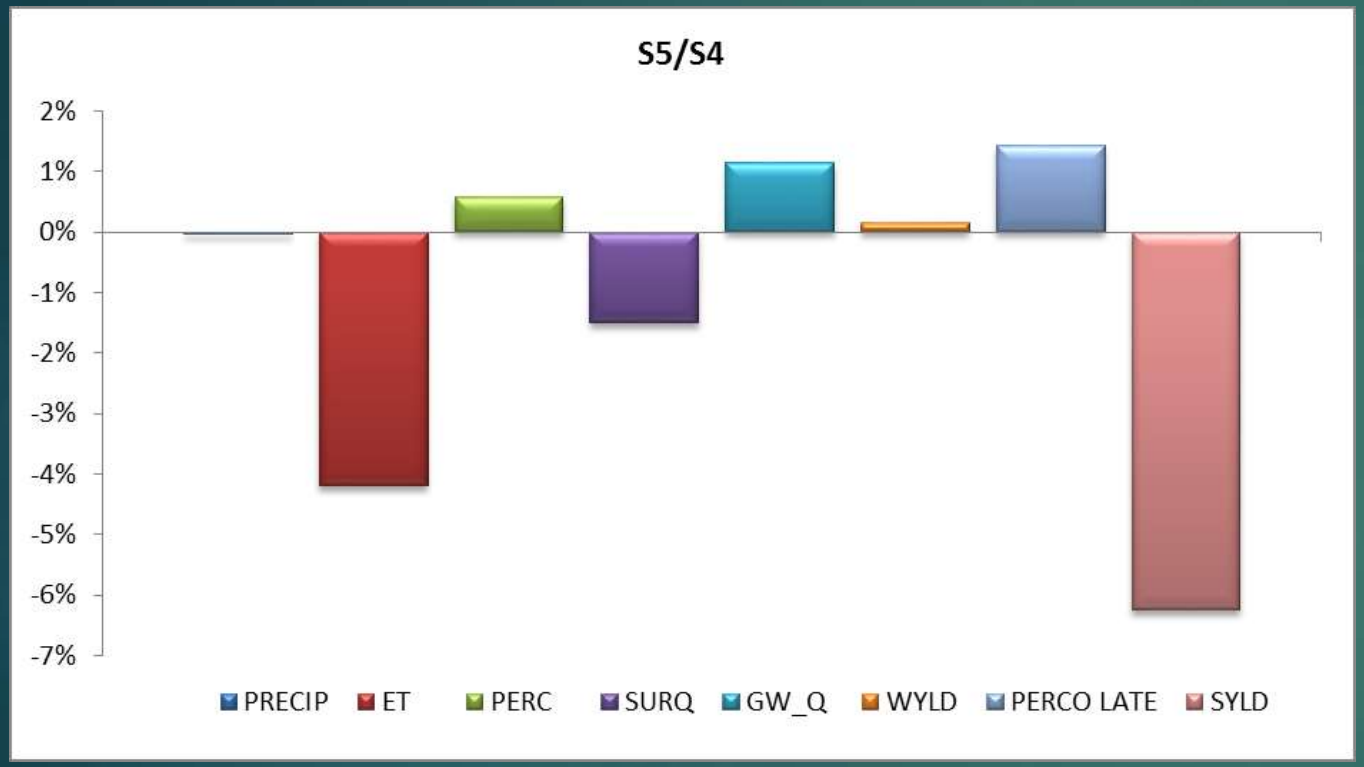




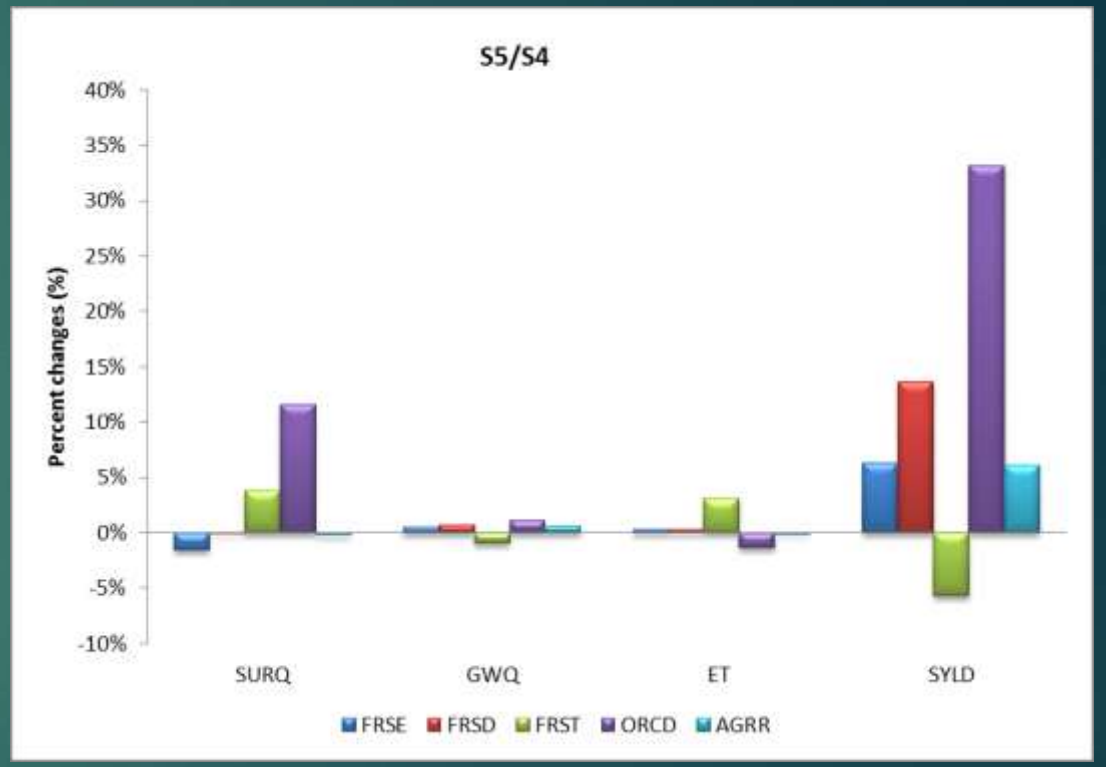
Seasons	The timeline of the 21st century								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
Winter (Dec to Feb)	1.5	2.2	3.1	3.9	4.8	5.5	6.3	6.9	7.5
Spring (Mar to May)	-0.5	-0.7	-1.0	-1.3	-1.6	-1.9	-2.1	-2.3	-2.5
Summer (Jun to Aug)	1.8	2.6	3.6	4.7	5.7	6.7	7.5	8.3	9.0
Autumn (Sep to Nov)	0.5	0.7	1.0	1.3	1.6	1.8	2.1	2.3	2.5

The change level of rainfall (%) compared to the 1980 - 1999 period, under the medium emissions scenario (B2) in Son La province

Impacts of Projected Land Use and Climate Change Scenarios on Hydrological Responses and Sediment Yield

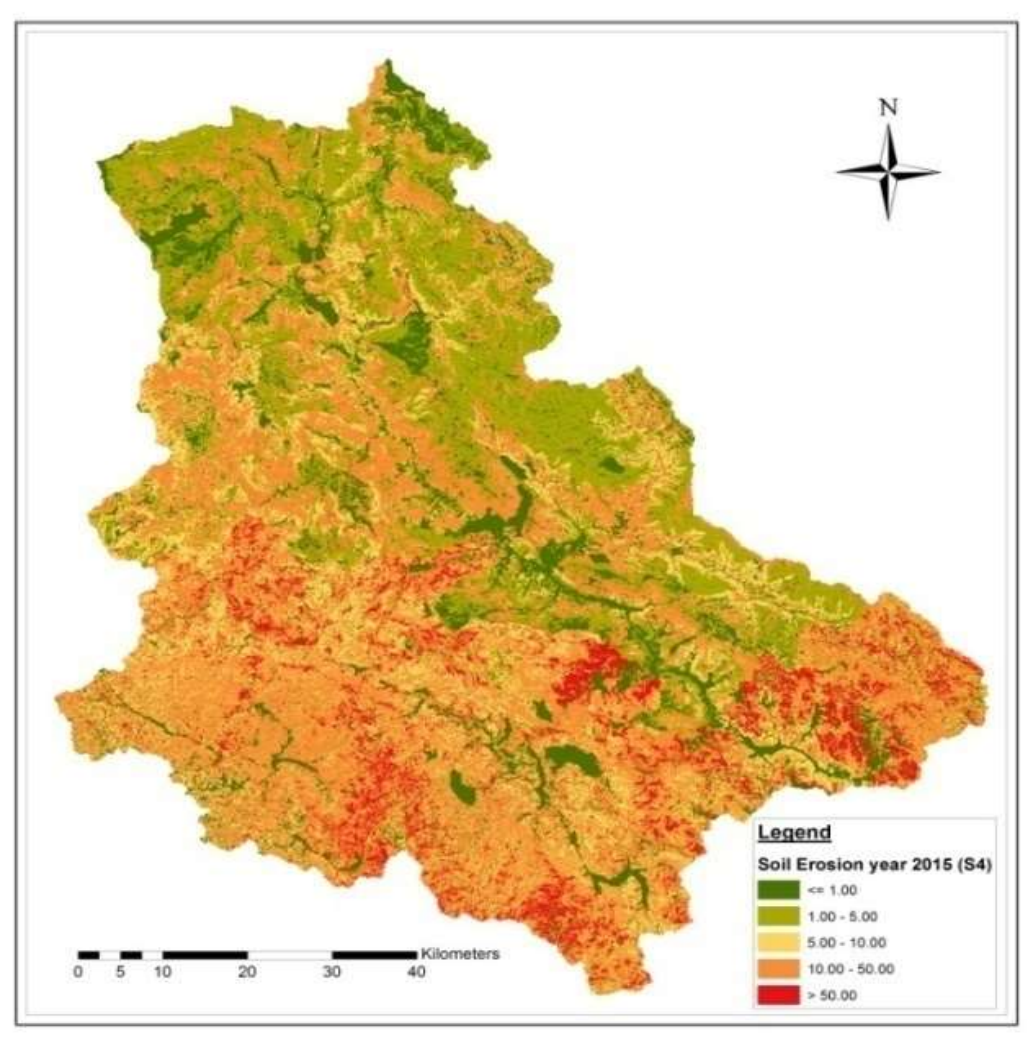


Annual changes of hydrological components and sediment under Projected Land Use and Climate Change Scenarios

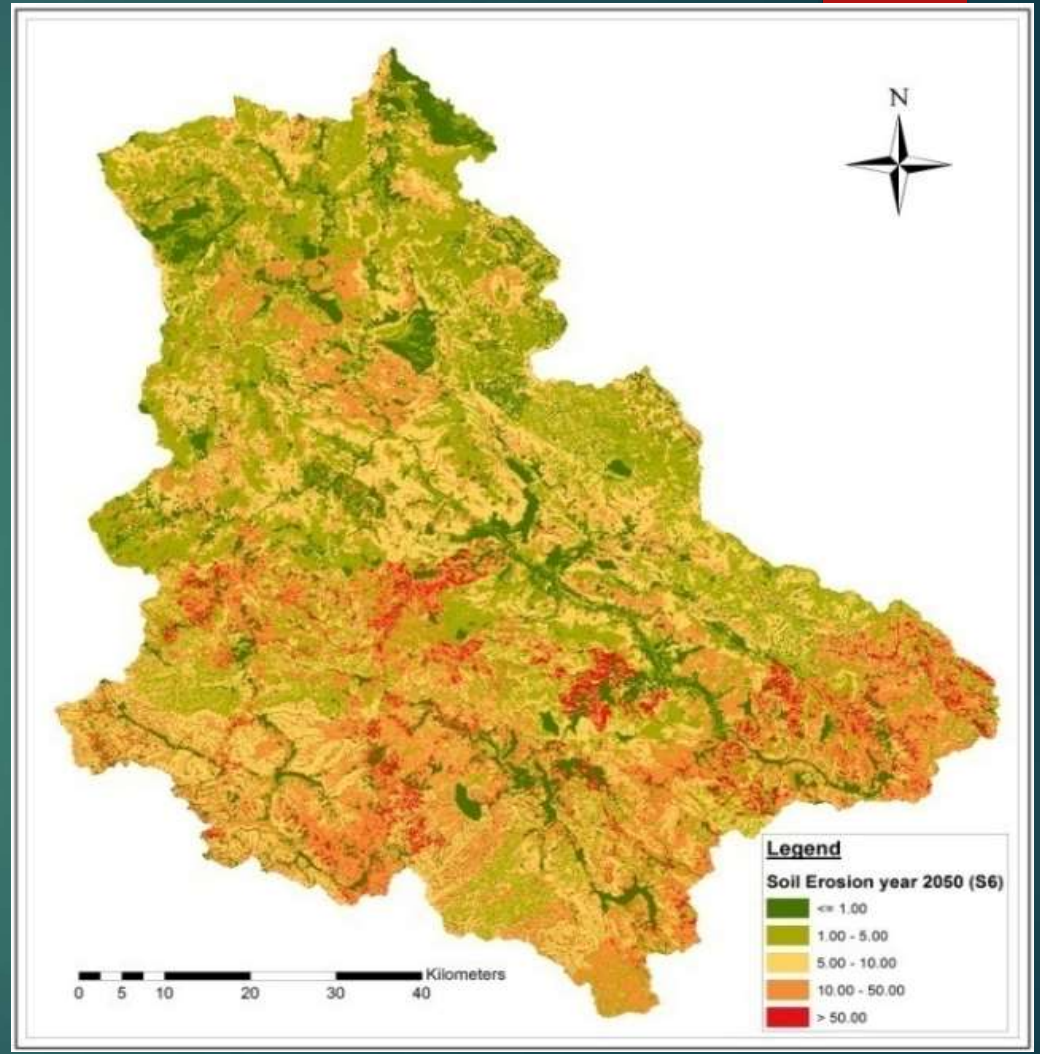


Annual changes of hydrological components and sediment under different land use types in the future

Potential Soil Loss in 2050



2015



2050

Area of soil loss classes in year 2050

Grade of soil erosion	Soil loss (ton ha^{-1} yr^{-1})	Rating	2015 (%)	2050 (%)
I	≤ 1	Nil	2.32	1.54
II	1 ÷ 5	Weak	24.05	24.87
III	5 ÷10	Moderate	22.27	31.43
IV	10 ÷ 50	High	44.62	36.61
V	≥ 50	Very high	6.73	5.56

Conclusions

- SWAT model was **applied successfully** to simulate stream flow and sediment yield in the upper Ma River Basin
- **Rapid land use** change occurred from 1994 to 2015, especially dramatically decreased forest from 77.91% to 59.05% and increased field crop from 14.73% to 32.66%.
- Land use change in the study area **increased** surface runoff, ET, water yield, and sediment load considerably while **decreased** percolation, and ground water
- Climate change in the period 1994-2004 and 2005-2015 led to **significant increase** of all hydrological components, however, decrease sediment load
- **combination of land use and climate changes impacts** caused increase significantly ET, surface runoff and sediment yield.
- changes in land use affected hydrological components and sediment yield **more significantly and strongly** than the changes in climate

Recommendations

- establishment of **spatial strategies** should be implemented to allocate the different land use types (Regional Level)
- contribute ideas about **local development frameworks** in term of the possibility of land utilization and change for regional land use planning (Local level)
- **knowledge** about the **negative environmental impacts** and **importance of soil and water conservation** should be aware to farmers
- enhance the **diversifications of existing land management practices** and ensure continuous **governments support** in implementation of soil and water conservation.
- government policies should implement to **longer land use rights with supporting financial aids**

Limitations

- Model data requirements proved to be the main issue for the study
- huge amount of data requires skills in GIS (ArcGIS, DEM, dbf, etc.), in programming, in hydrology and soil science (to assess reliability of data), etc.
- dealing with changes in time of land use and infrastructures have impacts on monitored flow and sediment load data.

Future Research

- Developing website to disseminate study research to the public
- Developing land use modelling and stakeholders analysis.
- develop a number of resource management scenarios, ranging from unsustainable to sustainable, and assess the socio-economics associated with such scenarios









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Thank you for your attention

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