Research Laboratory for INtelligent system in Agro-hydrological Monitoring and Management (INAMM)

Department of Irrigation Engineering, Faculty of Engineering at Kamphaeng Saen, Kasetsart University

Simulation of Runoff Changes based-on Land Use/Cover in Lam Pachi Basin by CA-Markov and SWAT Models

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Outlines

- **Introduction**
- **Study area: Lam Phachi Basin, western Thailand**
- **Methodology and Results**
  - Land use projection by CA-Markov model
  - Runoff simulation by SWAT model

Introduction

- **Surface runoff is a key component in hydrological cycle**
- **The quantification of runoff indicates water resources availabilities in a basin and provides important information for water management**
- **Land use/land cover are one of main factors affecting runoff processes**
- **This work is part of a research program**
  - Integrated Water Resource Management of Lam Pachi Basin
  - Land use change, runoff, water use, drought, flood, erosion

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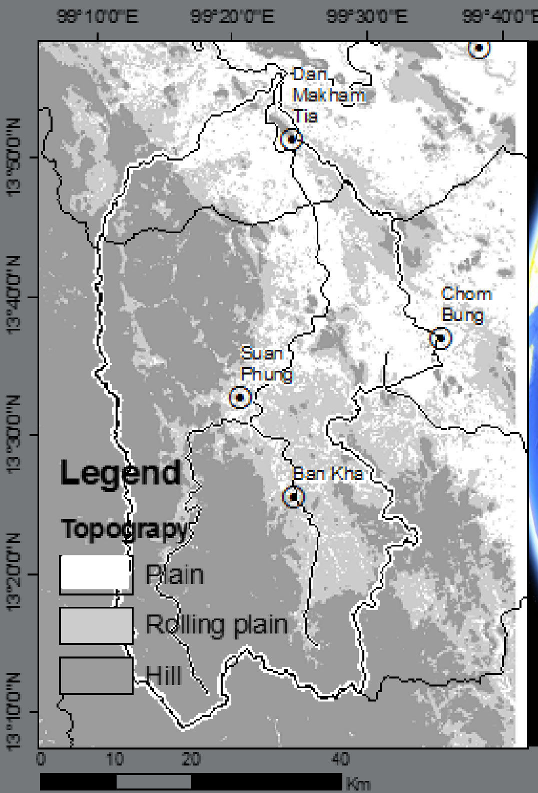
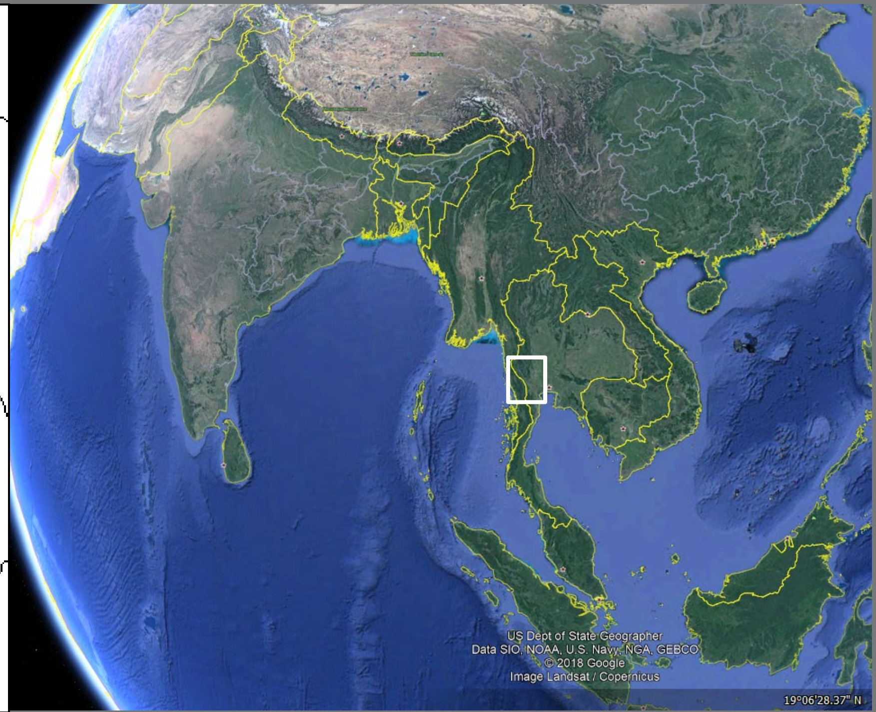
Objectives

- This work aimed to projecting the effects of land use/land cover change (LULCC) on runoff yield in Lam Pachi basin, Western Thailand

Study Area: Lam Phachi Basin





Lam Pachi Basin, Thailand

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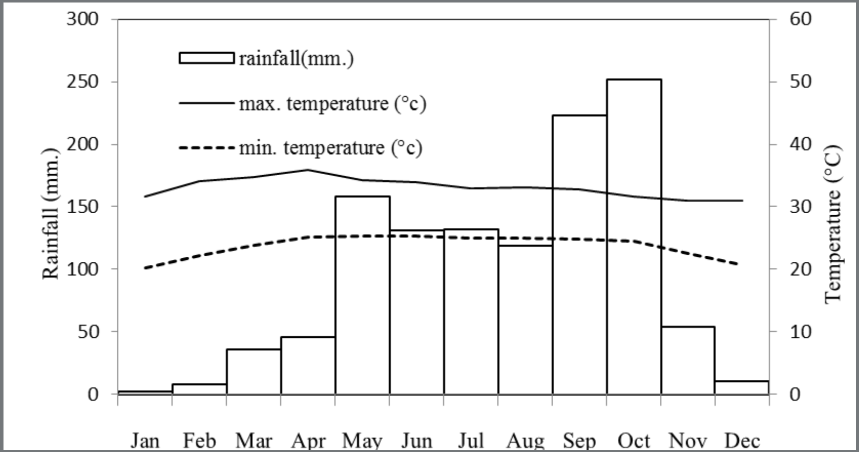
- **Watershed area 2543 km2**
- **Precipitation 1210 mm/yr (SW monsoon)**
- **Temperature 27.3°C (max-min: 35.9°C (Apr)- 19.8°C (Jan))**



Methodology and Result

Land use projection by CA-Markov model

Runoff simulation by SWAT model

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Methodology

- To develop CA-Markov model for spatially projection of future land use/land cover
- To develop SWAT-based hydrological model for evaluating the runoff response to the projected LULCC
- To simulate the impact of LULCC on runoff yield in the Lam Pachi basin by SWAT model.

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Land Use Projection by CA-Markov

- **Tool**
  - MOLUSCE: Modules for Land Use Change Evaluation
  - QGIS plug-in
- **Data**
  - Land use data (Department of Land Development, DLD)
  - Auxiliary data

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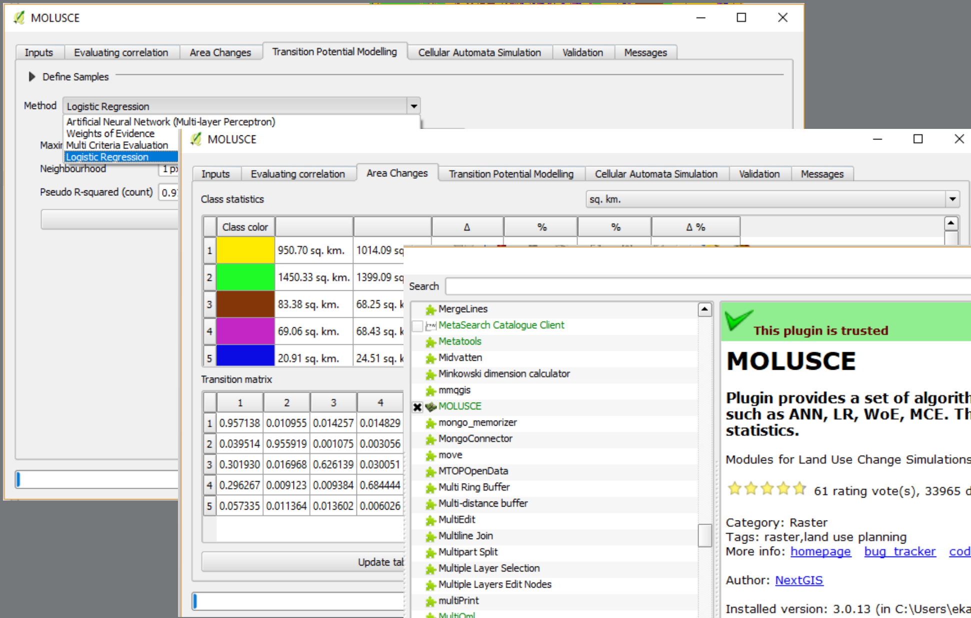
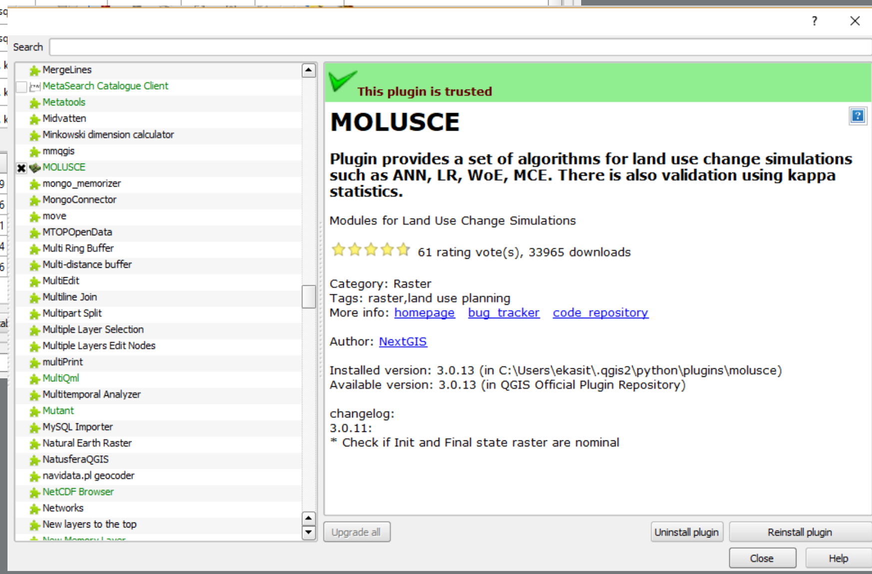


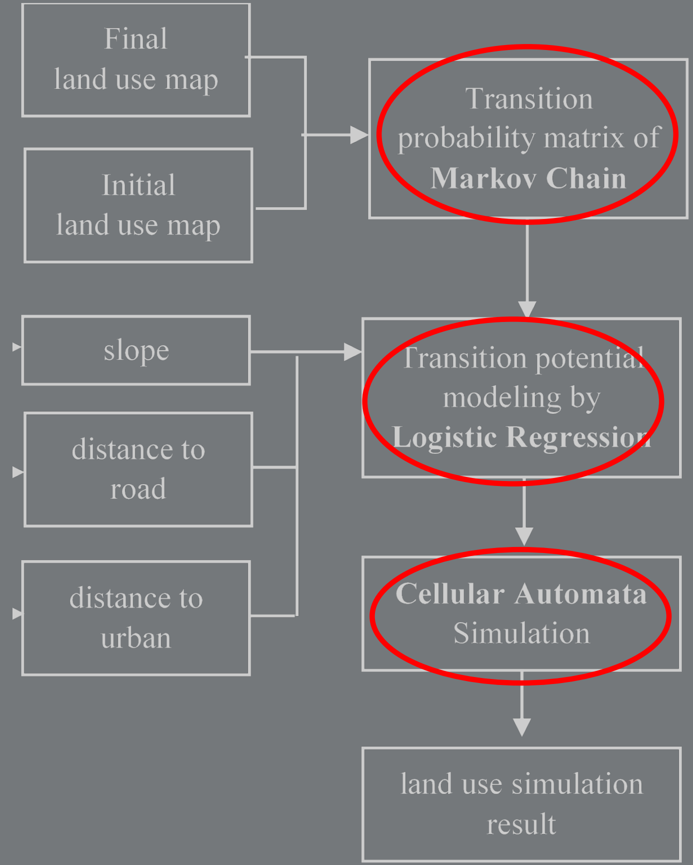


MOLUSCE

Modules for Land Use Change Evaluation

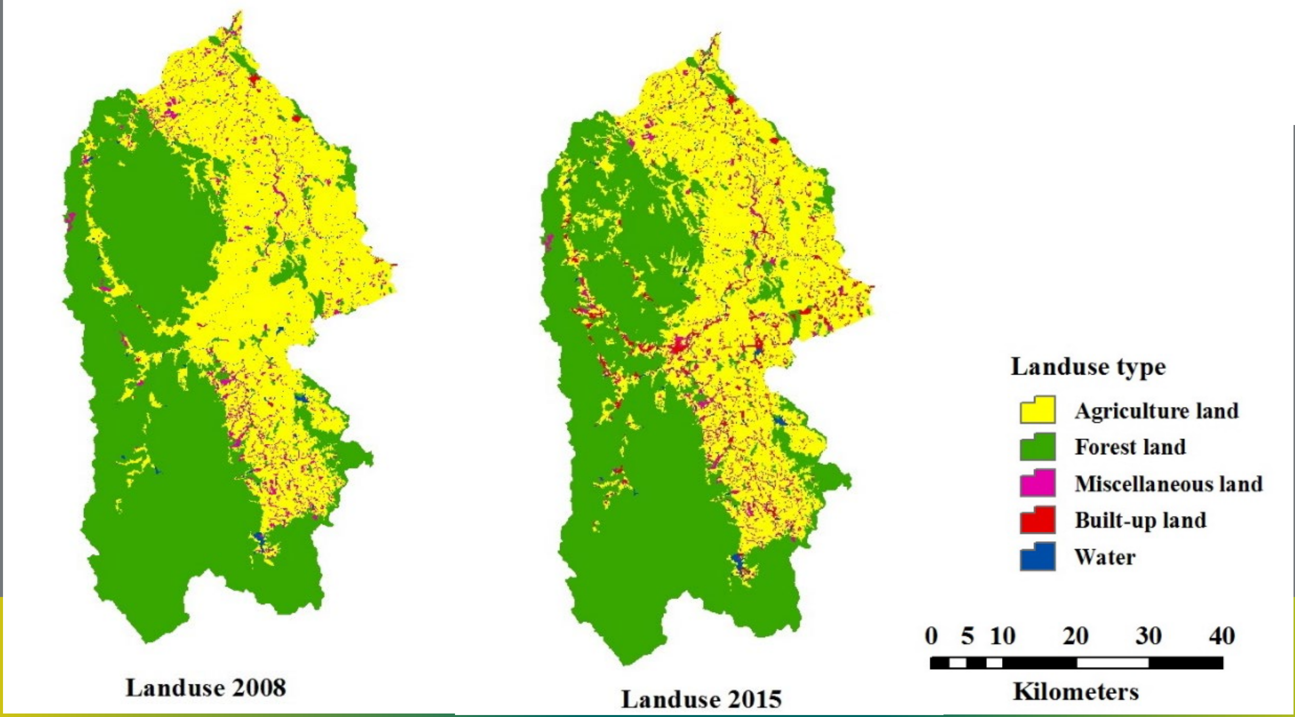
CA/Markov model

- **Convert vector land use data into raster format with grid size of 60 m**
- **Reclassify into 5 main group: agriculture, forest, built-up area, water, miscellaneous**
- **Driven forces: topography (slope), transportation (distance from road), neighbor (distance from existing built-up area)**
- **Transition probability matrix :**
  land 2008 vs land 2015 (step of 7 year)
- **Transitional potential modeling by logistic regression: 3 driven-force**
- **Future projection of land use change by Monte-Carlo Cellular Automata technique with 5 iterations:**
  2015, 2022, 2029, 2036, 2043, 2050



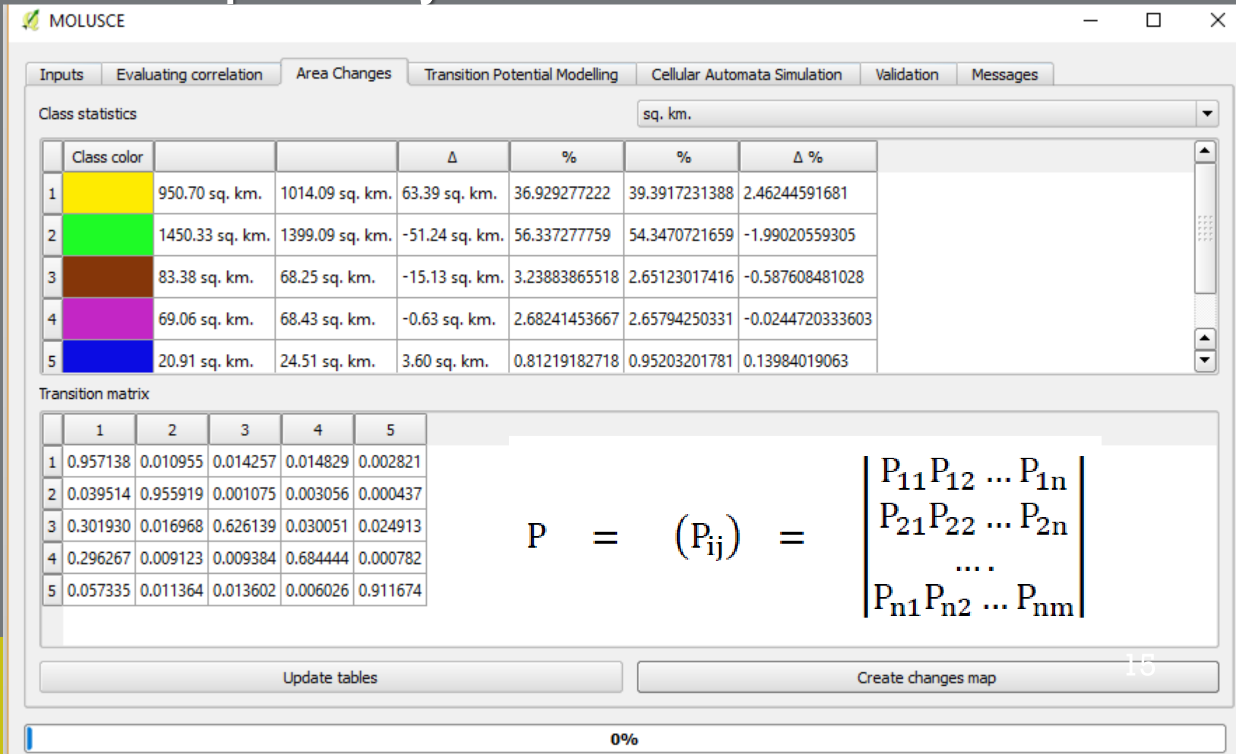
Land use map of Lam Phachi basin

- Reclassified into 5 main classes



Area Changes

- **Transition probability matrix or Markov matrix**



	Class color			Δ	%	%	Δ %
1		950.70 sq. km.	1014.09 sq. km.	63.39 sq. km.	36.929277222	39.3917231388	2.46244591681
2		1450.33 sq. km.	1399.09 sq. km.	-51.24 sq. km.	56.337277759	54.3470721659	-1.99020559305
3		83.38 sq. km.	68.25 sq. km.	-15.13 sq. km.	3.23883865518	2.65123017416	-0.587608481028
4		69.06 sq. km.	68.43 sq. km.	-0.63 sq. km.	2.68241453667	2.65794250331	-0.0244720333603
5		20.91 sq. km.	24.51 sq. km.	3.60 sq. km.	0.81219182718	0.95203201781	0.13984019063

Transition matrix

	1	2	3	4	5
1	0.957138	0.010955	0.014257	0.014829	0.002821
2	0.039514	0.955919	0.001075	0.003056	0.000437
3	0.301930	0.016968	0.626139	0.030051	0.024913
4	0.296267	0.009123	0.009384	0.684444	0.000782
5	0.057335	0.011364	0.013602	0.006026	0.911674

$$P = (P_{ij}) = \begin{vmatrix} P_{11} P_{12} \ldots P_{1n} \\ P_{21} P_{22} \ldots P_{2n} \\ \ldots . \\ P_{n1} P_{n2} \ldots P_{nm} \end{vmatrix}$$

Land Use Change 2008-2015

Land Use	2008 (km2)	2015 (km2)	Diff. (km2)	% Area 2008	% Area 2015	% Different
Agriculture	1092.51	1087.29	-5.22	39.04%	38.85%	-0.19%
Forest	1591.44	1536.75	-54.69	56.87%	54.91%	-1.95%
Misc.	74.57	73.75	-0.82	2.66%	2.64%	-0.03%
Built-up	18.34	75.52	57.18	0.66%	2.70%	2.04%
Water	21.75	25.31	3.56	0.78%	0.90%	0.13%

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Transition Matrix

		2015				
	Land use	Agriculture	Forest	Misc.	Built-up	Water
2008	Agriculture	91.50%	1.06%	2.19%	4.95%	0.31%
	Forest	3.82%	95.74%	0.11%	0.29%	0.04%
	Misc.	30.82%	1.66%	63.53%	1.98%	2.01%
	Built-up	14.39%	0.80%	1.79%	82.92%	0.10%
	Water	5.81%	1.09%	1.31%	0.76%	91.03%

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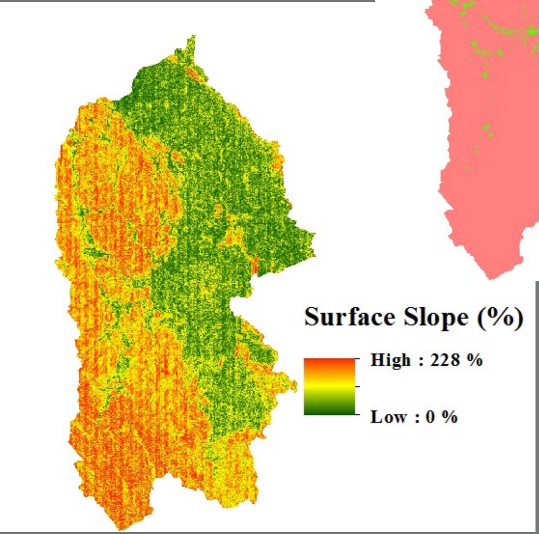

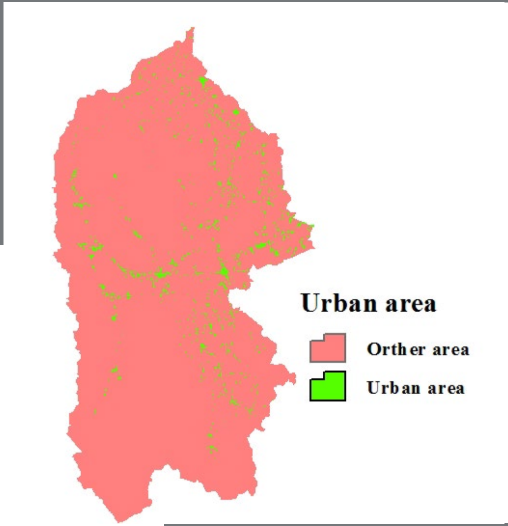

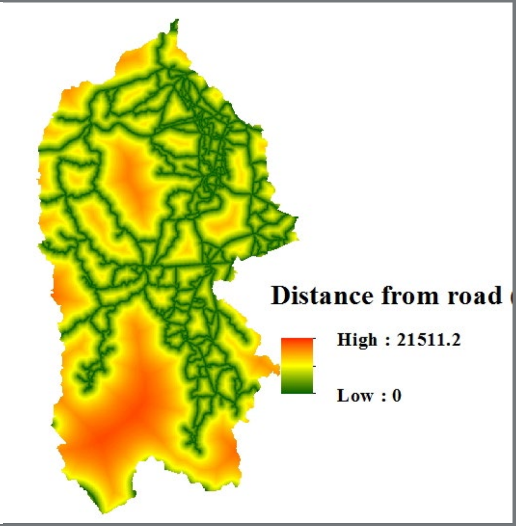

Driving factor data

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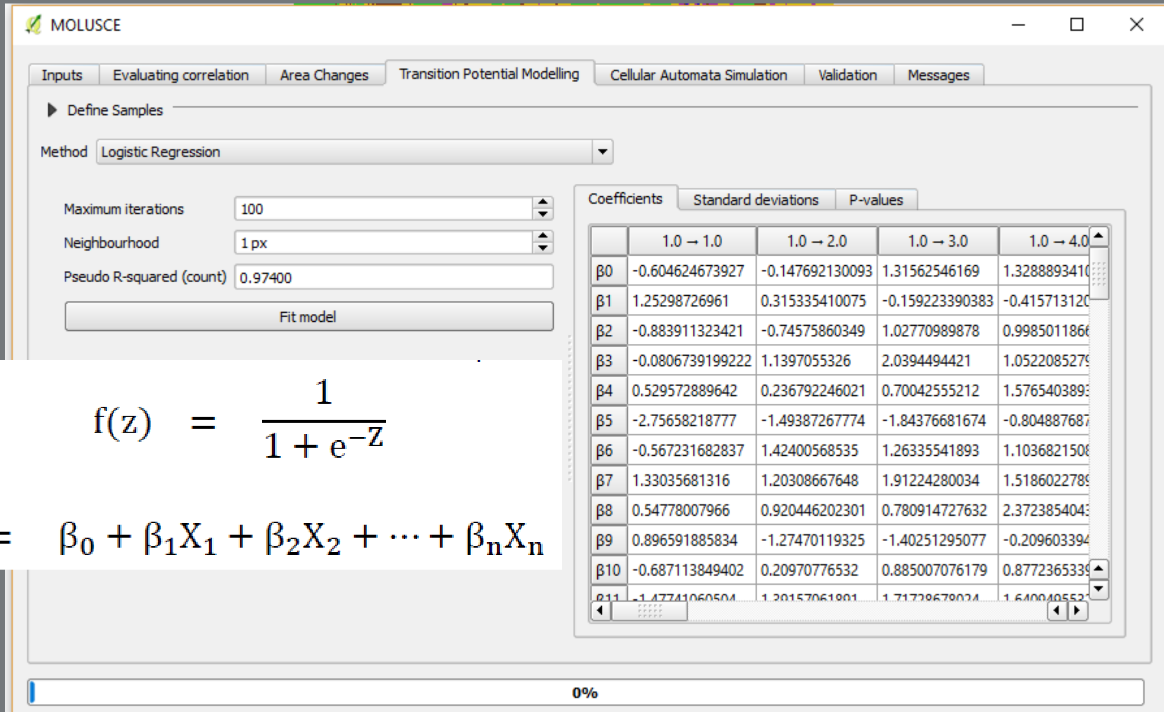

	1.0 → 1.0	1.0 → 2.0	1.0 → 3.0	1.0 → 4.0
β0	-0.604624673927	-0.147692130093	1.31562546169	1.328889341
β1	1.25298726961	0.315335410075	-0.159223390383	-0.41571312
β2	-0.883911323421	-0.74575860349	1.02770989878	0.99850118
β3	-0.0806739199222	1.1397055326	2.0394494421	1.05220852
β4	0.529572889642	0.236792246021	0.70042555212	1.57654038
β5	-2.75658218777	-1.49387267774	-1.84376681674	-0.80488768
β6	-0.567231682837	1.42400568535	1.26335541893	1.10368215
β7	1.33035681316	1.20308667648	1.91224280034	1.51860227
β8	0.54778007966	0.920446202301	0.780914727632	2.37238540
β9	0.896591885834	-1.27470119325	-1.40251295077	-0.20960339
β10	-0.687113849402	0.20970776532	0.885007076179	0.87723653

$$f(z) = \frac{1}{1 + e^{-z}}$$

$$z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n$$

Transitional Potential Modeling
Logistic regression

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CA : Cellular Automata

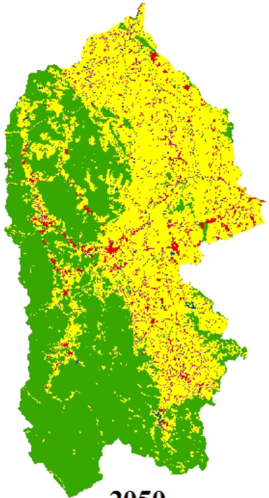
- **Monte-Carlo Cellular Automata simulation**

	F	F	W	
	A	?	A	
	U	A	A	

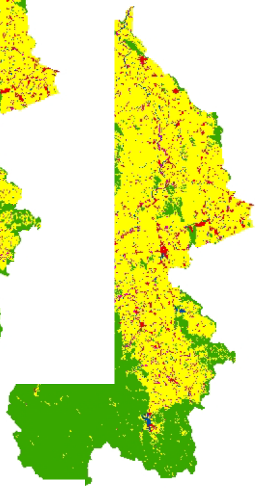
	F	F	W	
	A	A	A	
	U	A	A	

Projected Land Use Maps

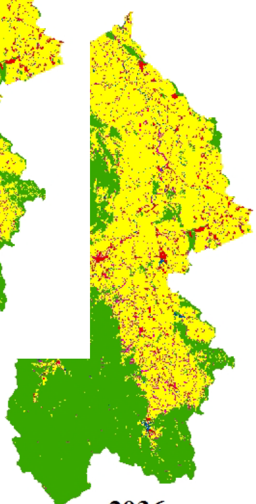
- 5 iterations from Land2015



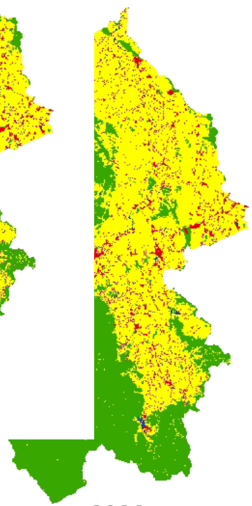
2050



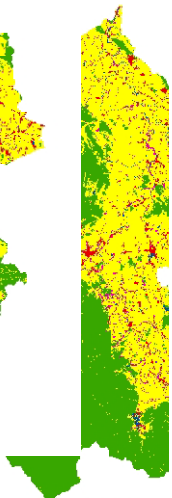
2043



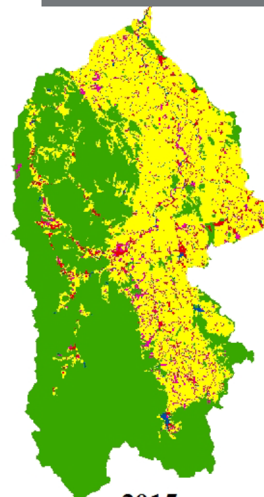
2036



2029



2022



2015

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Projected Land Use (%)

Year	Land use				
	Agriculture	Forest	Misc.	Built-up	Water
2008	39.75%	56.34%	2.68%	0.42%	0.81%
2015	39.39%	54.35%	2.65%	2.66%	0.95%
2022	41.79%	52.78%	1.91%	2.73%	0.80%
2029	42.99%	51.87%	1.90%	2.75%	0.49%
2036	43.55%	50.84%	1.83%	2.69%	1.09%
2043	42.04%	51.27%	3.17%	2.69%	0.83%
2050	47.03%	46.74%	2.35%	2.79%	1.08%
2015-2050	+7.64%	-7.60%	-0.30%	+0.13%	+0.13%

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Projected Land Use

- **The result revealed that more than half of the Lam Pachi Basin covered by forest area.**
- **The CA-Markov model projected the future land use in the next 45 years.**
  - Forest area would decrease about 7.6%
  - Agricultural area would increase at the similar rate.

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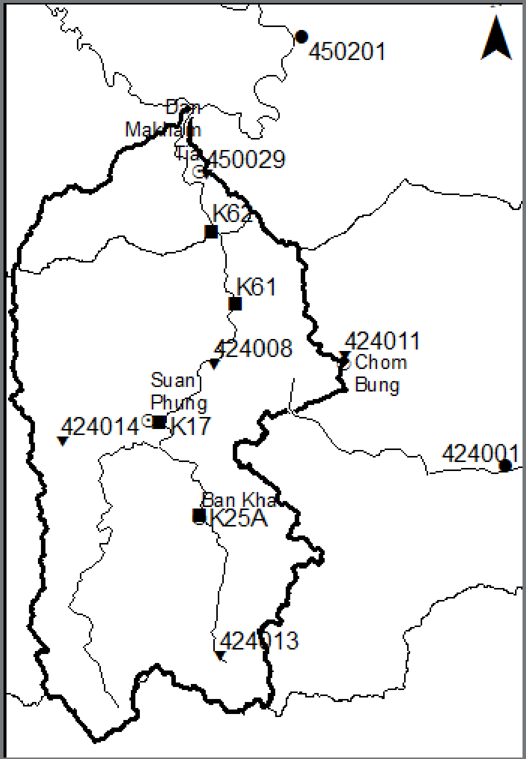
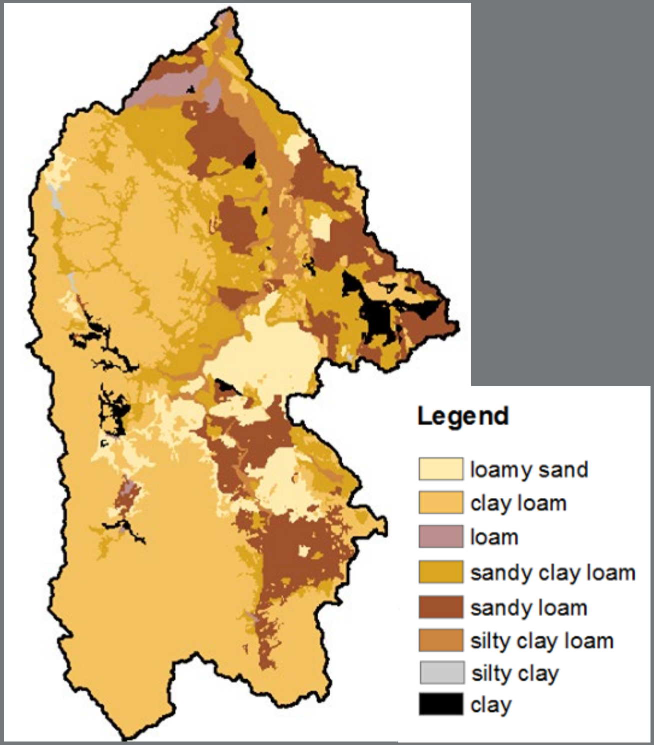
Runoff Simulation by SWAT model

- **Tool**
  - SWAT model
- **Data**
  - Land use – Department of Land Development (DLD)
  - + projected land use maps
  - Soil – Department of Land Development (DLD)
  - DEM – CGIAR-CSI SRTM 90m Digital Elevation Data
    - http://srtm.csi.cgiar.org/
  - Climate – Thai Meteorological Department (TMD)
  - Streamflow – Royal Irrigation Department (RID)



Observation stations



Soil texture

Model calibration and validation

- **Calibration : monthly streamflow, 2010-2015**
- **Validation : 2005-2009**

Parameter	Unit	Method	Initial Value	Range	Fitted Value
1. CN2.mgt	-	Relative	varied	-10% … +10%	-9.55%
2. GWQMN.gw	mm	Absolute	1000	+0 … +4000	+3582
3. SOL_AWC.sol	mm_{H2O}/mm_{soil}	Absolute	varied	+0 … +0.4	+0.1455

Note:

1. CN2.mgt = Initial SCS runoff curve number for moisture condition II
2. GWQMN.gw = Threshold water level in shallow aquifer for base flow
3. SOL_AWC.sol = Available water capacity of the soil layer

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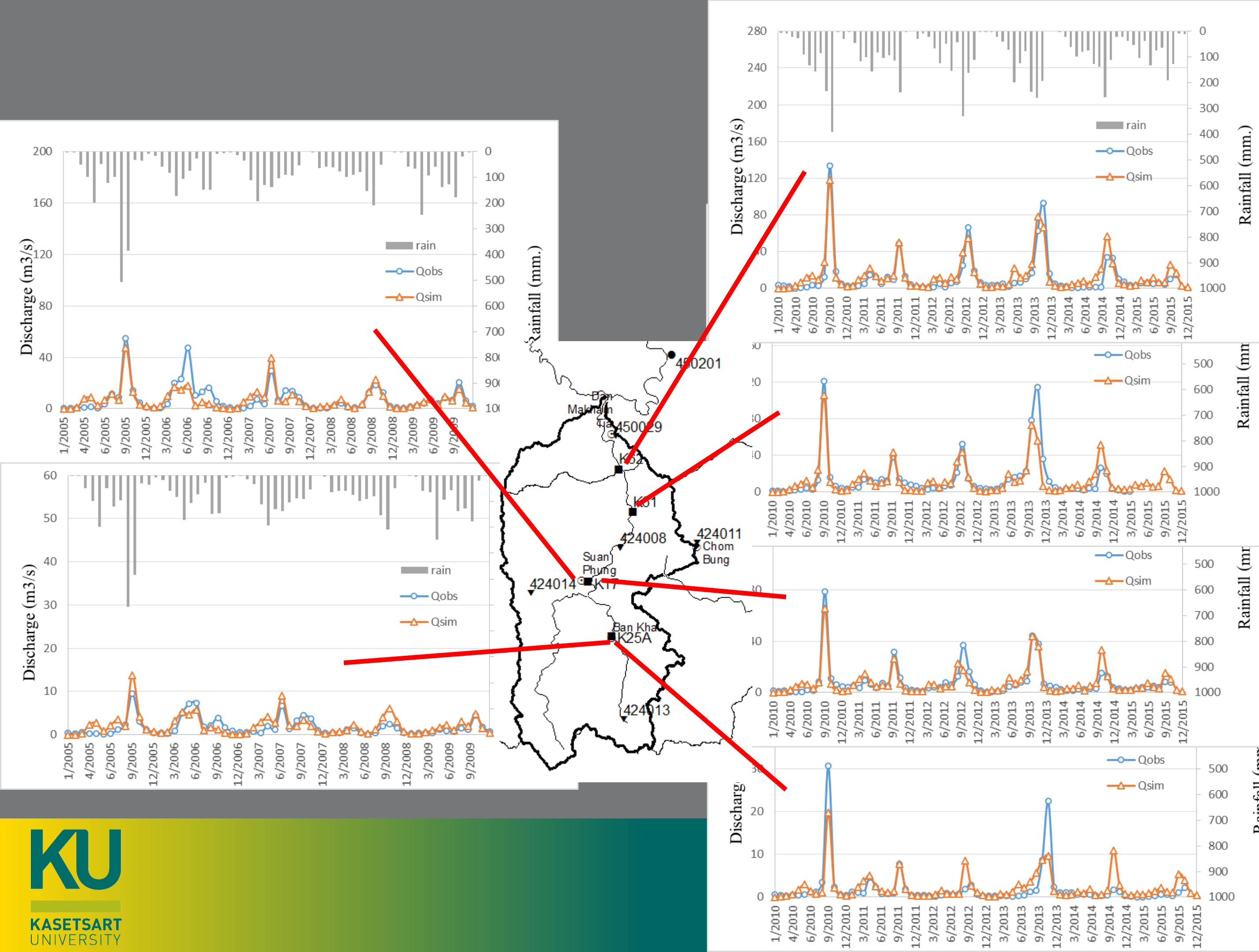

Discharge (m3/s)
Rainfall (mm.)
rain
Qobs
Qsim
450201
Ban Mak Hin Tia
450029
K52
K51
424008
424011
Chom Bung
Suan Phung
424014
K17
Ban Kha
K25A
424013
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Hydrometric Station	Calibration (2010-2015)		Validation (2005-2009)	
	R2	NSE	R2	NSE
K25A	0.818	0.647	0.821	0.504
K17	0.880	0.772	0.846	0.711
K61	0.894	0.792	N/A	N/A
K62	0.936	0.863	N/A	N/A

Note: N/A = Observed data not available

Model performance indicators

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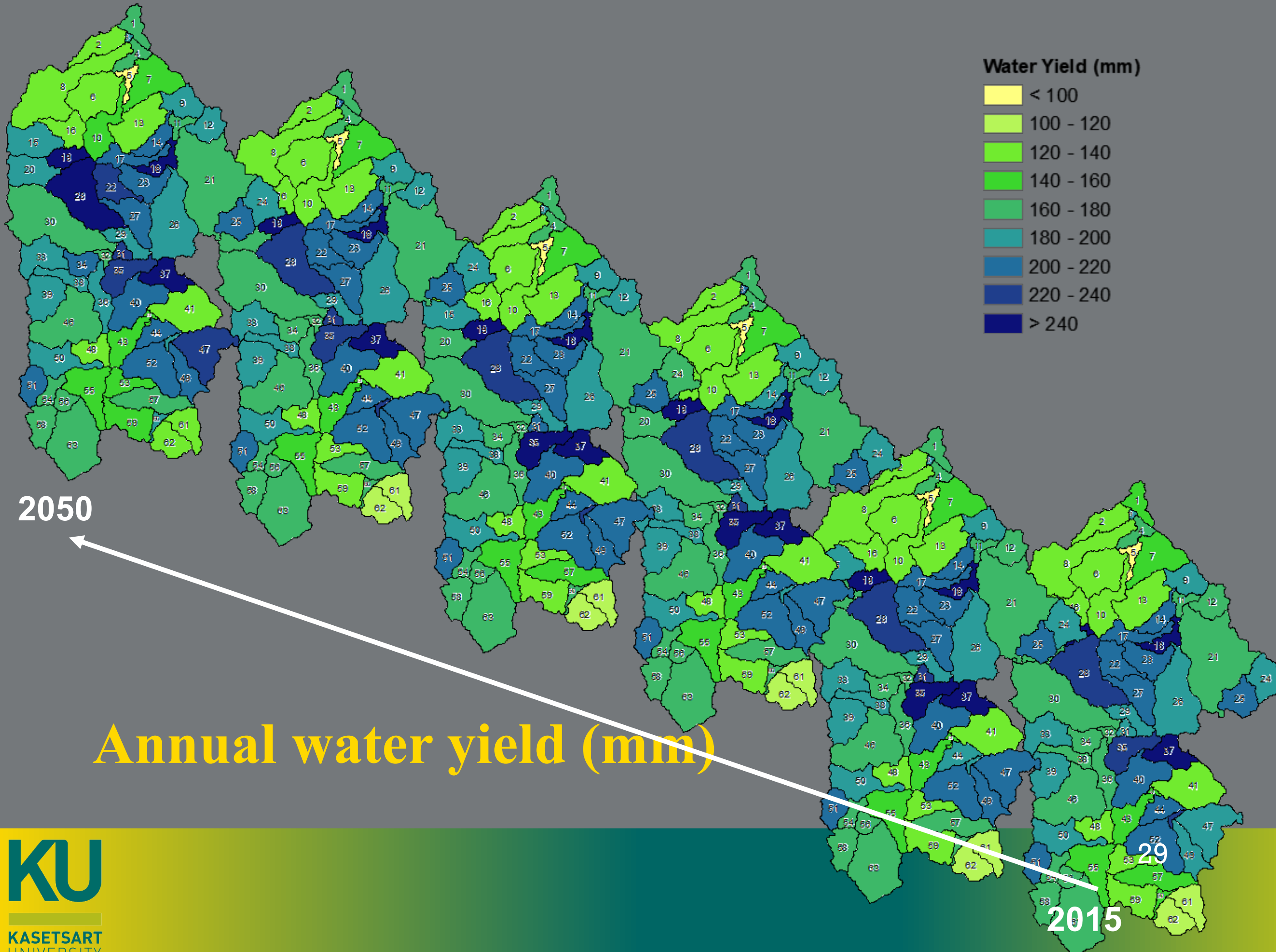

Annual water yield (mm)

Projected Basin Water Yield (mm)

	LU2015	LU2022	LU2029	LU2036	LU2043	LU2050
January	34.74	34.42	34.3	34.19	34.37	33.81
February	21.71	21.5	21.42	21.34	21.45	21.07
March	20.94	20.96	20.99	20.94	20.98	21.08
April	29.57	30.21	30.48	30.45	30.38	31.53
May	34.02	34.28	34.52	34.27	34.54	35.21
June	40.65	40.91	41.16	40.91	41.26	41.99
July	44.09	44.13	44.23	43.96	44.3	44.59
August	46.19	46.35	46.56	46.29	46.54	46.98
September	183.59	186.29	187.85	187.99	186.91	193.35
October	368.92	373.42	375.81	376.14	373.73	383.94
November	162.17	163.3	164.08	163.93	163.79	166.53
December	59.64	59.16	59.11	58.85	59.27	58.64
Annual	1046.23	1054.93	1060.51	1059.26	1057.52	1078.72

Surface Runoff

- **Minor changes in term of water yield at the basin scale.**
- **More changes could be observed at subbasin level.**
  - 1. Agricultural land yielded more water than forest in high land
  - 2. Land conversion from forest to agriculture
    in sloped high-land resulted in increase of water yield
  - 3. Whereas the same conversion
    in flat low-land resulted in reduction of yield

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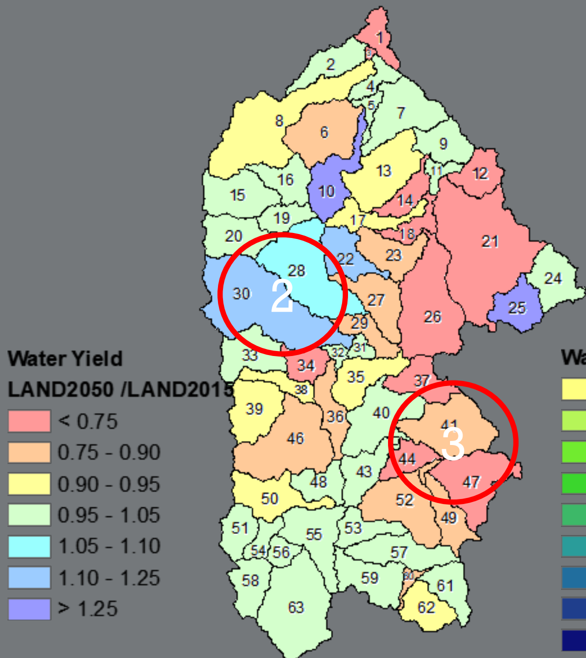
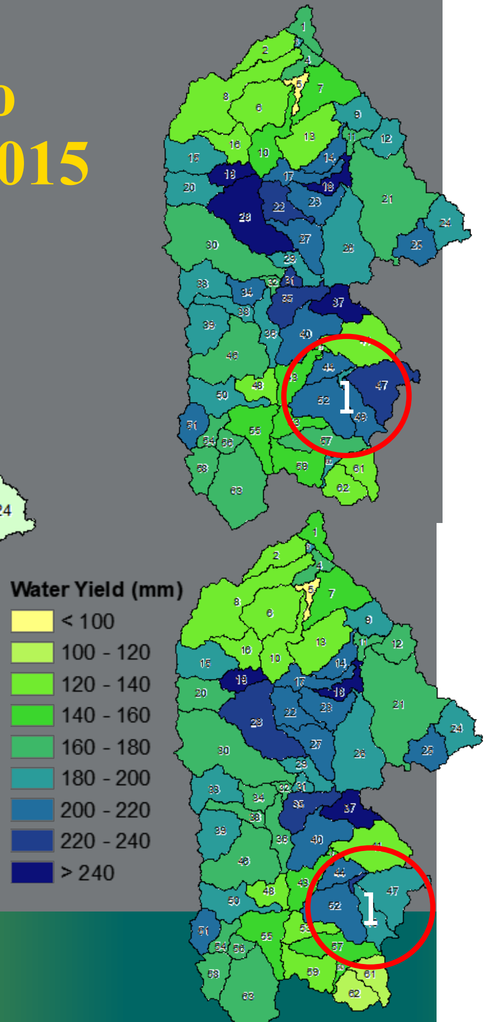
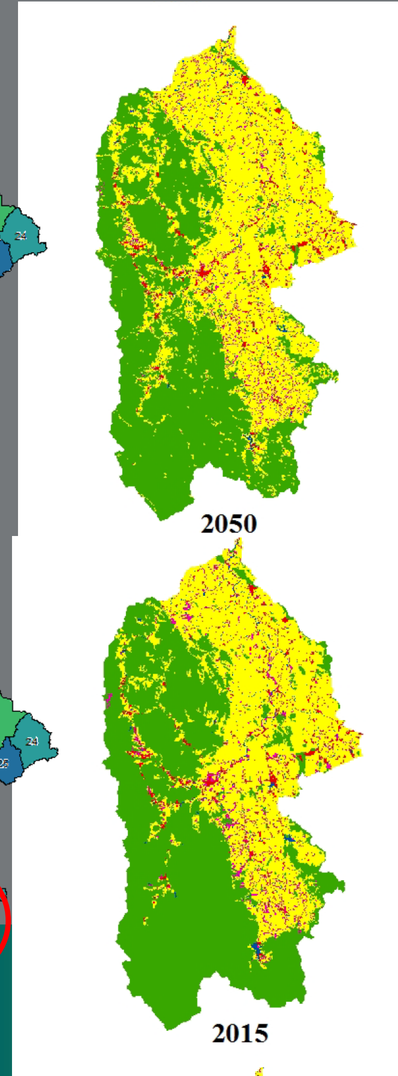
Water Yield Ratio Land2050/Land2015







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Thank you