Modeling Deforestation Baselines for REDD+ Projects: A Comparison of Modeling Approaches

Seminar Presentation:

Division of Spatial Information Science

University of Tsukuba (8 July, 2010)

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Presentation Outline

- **Background**
- **Part I. Land use/cover changes in the Pakxeng district.**
- **Part II. Modeling land use/cover changes in Pakxeng district.**
- **Summary and conclusions**

Background

- Deforestation is the second largest source of global greenhouse emissions after the energy sector, accounting for about 18% (IPCC, 2007; Stern, 2006).
- Thus, reducing deforestation and forest degradation is critical for mitigating climate change as well as enhancing sustainable development.
- Global climate policy initiatives (such as REDD+) are now being proposed to reward developing countries for reducing carbon emissions from deforestation and forest degradation.

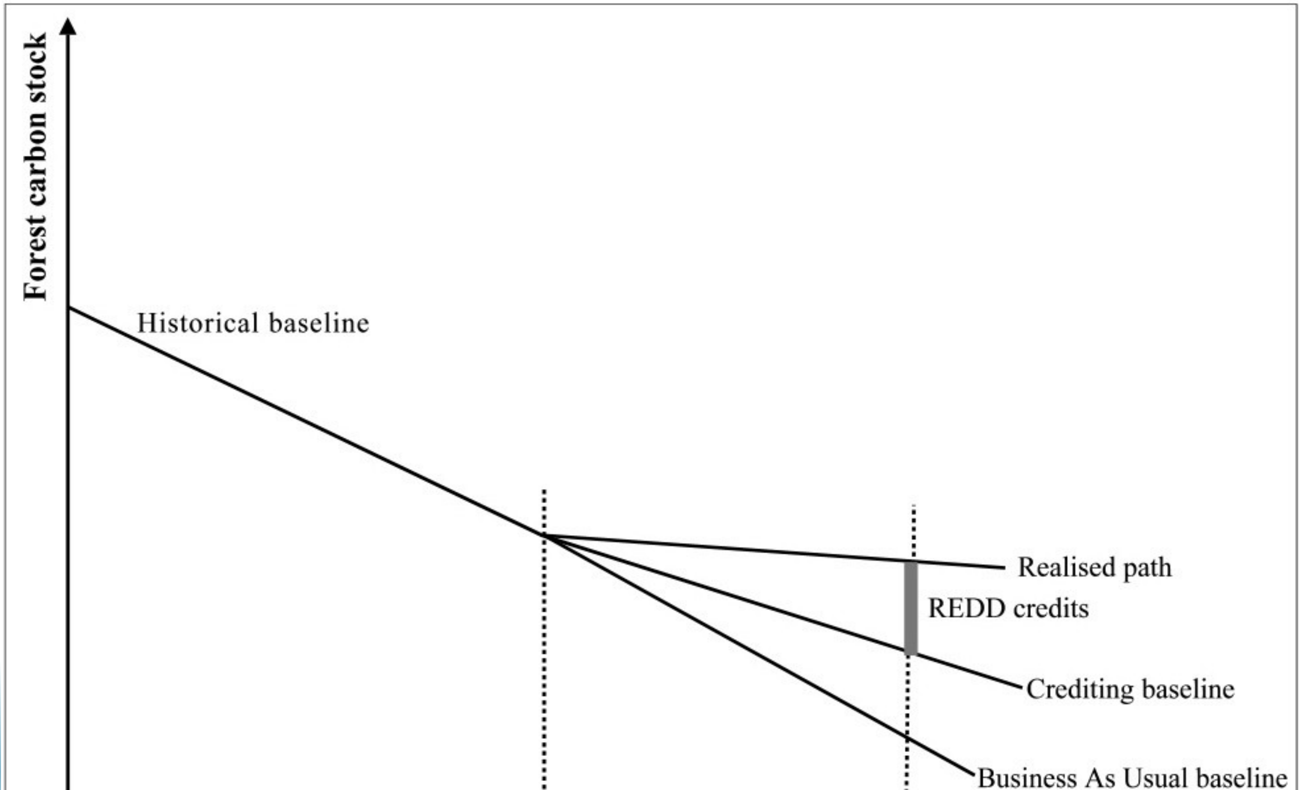
Projecting Future Deforestation

Step 1	**Task 1**. Definition of the proposed REDD project activity: saptial and temporal boundaries; carbon sinks and sources.
	Task 2: Analysis of historic land use/cover change in the *reference region*, *leakage belt* and *project area* (10-15 years from present).
	Task 3: Analysis of agents, drivers and underlying causes of deforestation, and sequencing of the typical chain of events leading to land use/cover changes.
Step 2	**Task 4**. Computing transition potential maps and projecting future deforestation in the *reference region, leakage belt* and *project area*.
	Task 5. Identification of *forest classes* in the areas that will be deforested under the *baseline scenario* and of the land use classes that will replace them.
	Task 6. Estimation of *baseline carbon stock* changes and, where forest fires are included in the *baseline* assessment of non CO2 emissions.
	Task 7. *Ex ante* estimation of actual *carbon stock* changes and non CO2 emissions under the *project scenario*.
	Task 8. *Ex ante* estimation of possible *leakage* due to GHG emissions associated to leakage prevention measures and displacement of baseline activities.
Step 3	**Task 9**. *Ex ante* calculation of net anthropogenic GHG emission reductions.

Modified from BioCarbon fund (2008) and Brown et al. (2007).

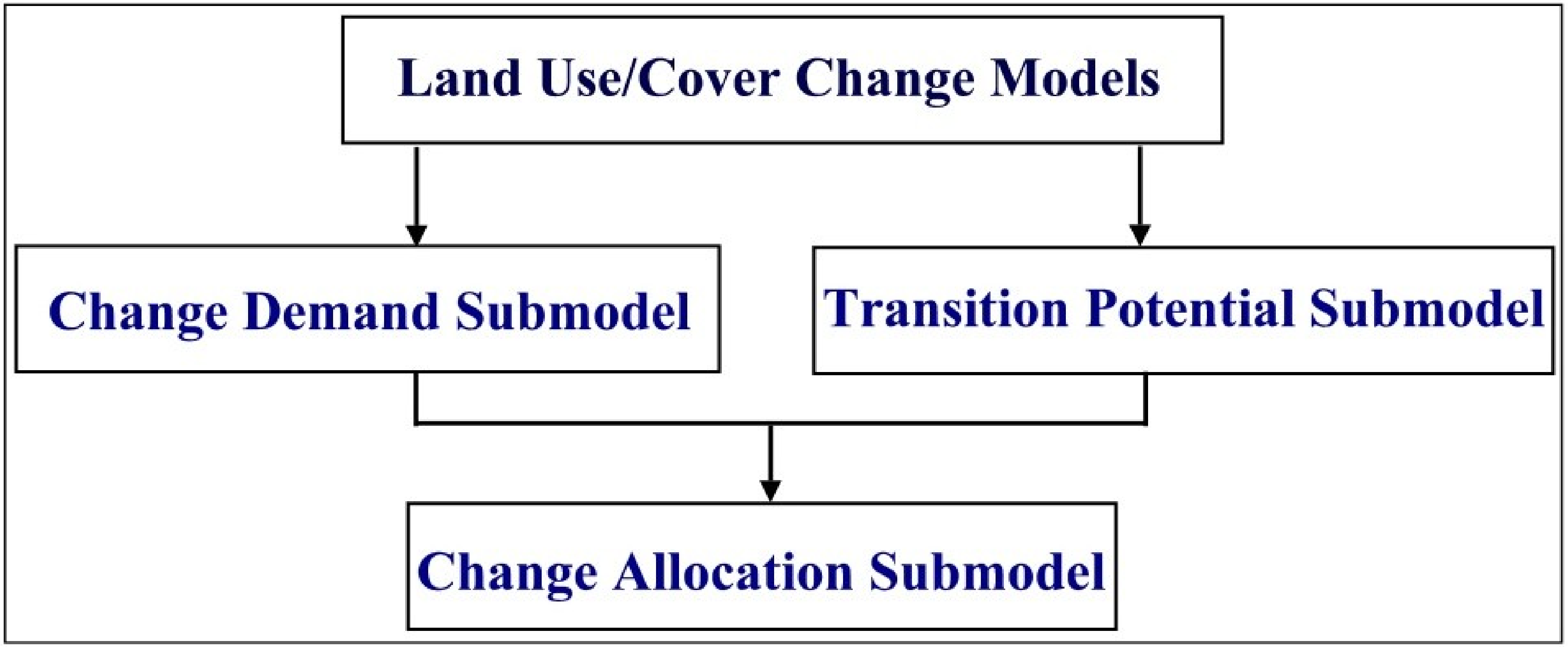
Background

- Setting the baselines or reference levels is critical for implementing REDD+ projects.
- Baselines provide a benchmark against which emissions reduction can be calculated.



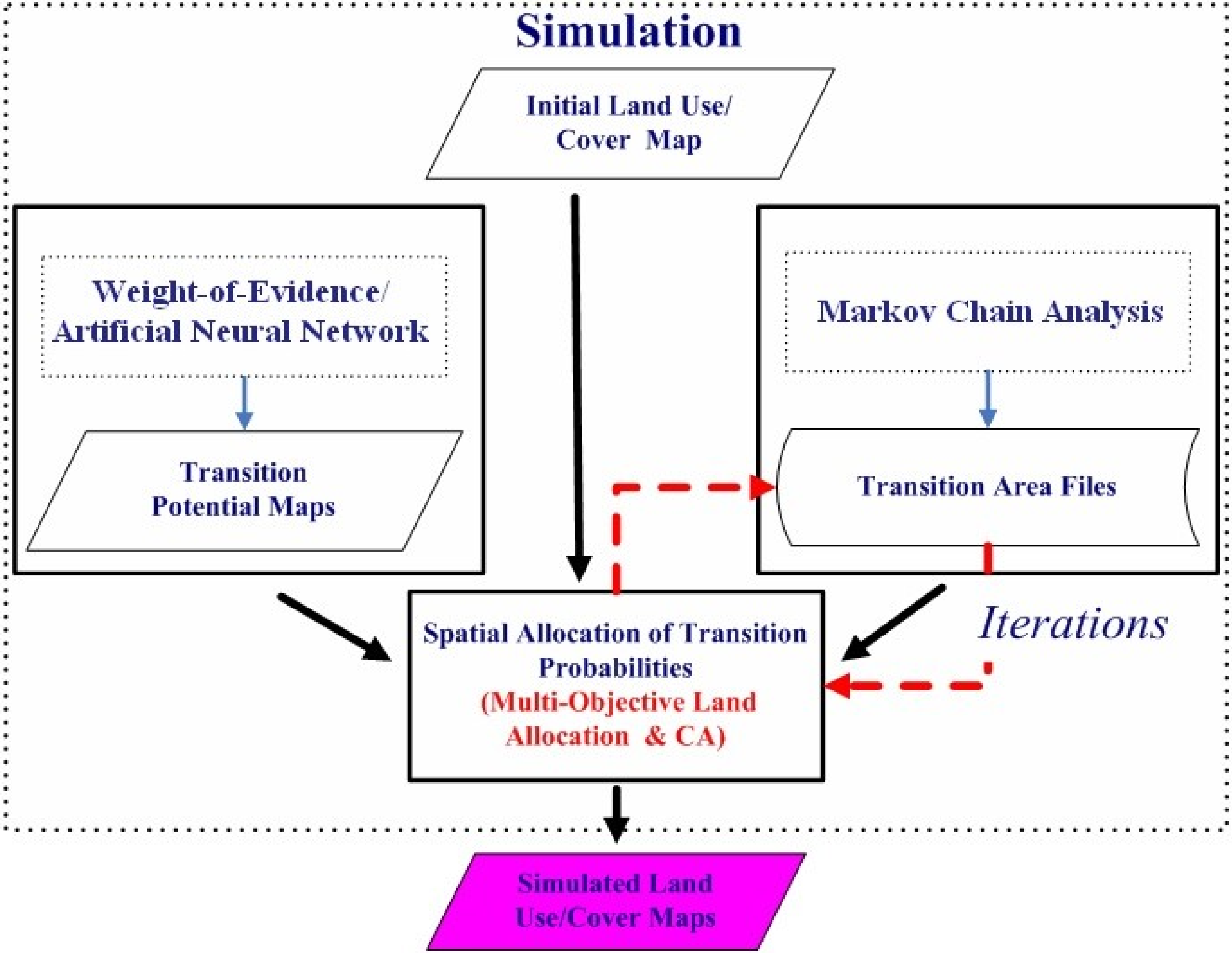
Source: Angelsen (2008).

Major Components of LUCC Modeling



- Change demand - establishes how much change will take place over a specified time period.
- Transition potential - determines the likelihood that land would change from one cover to another based on driving factors.
- Change allocation - allocates specific areas that will change, given demand and potential surfaces.

Model



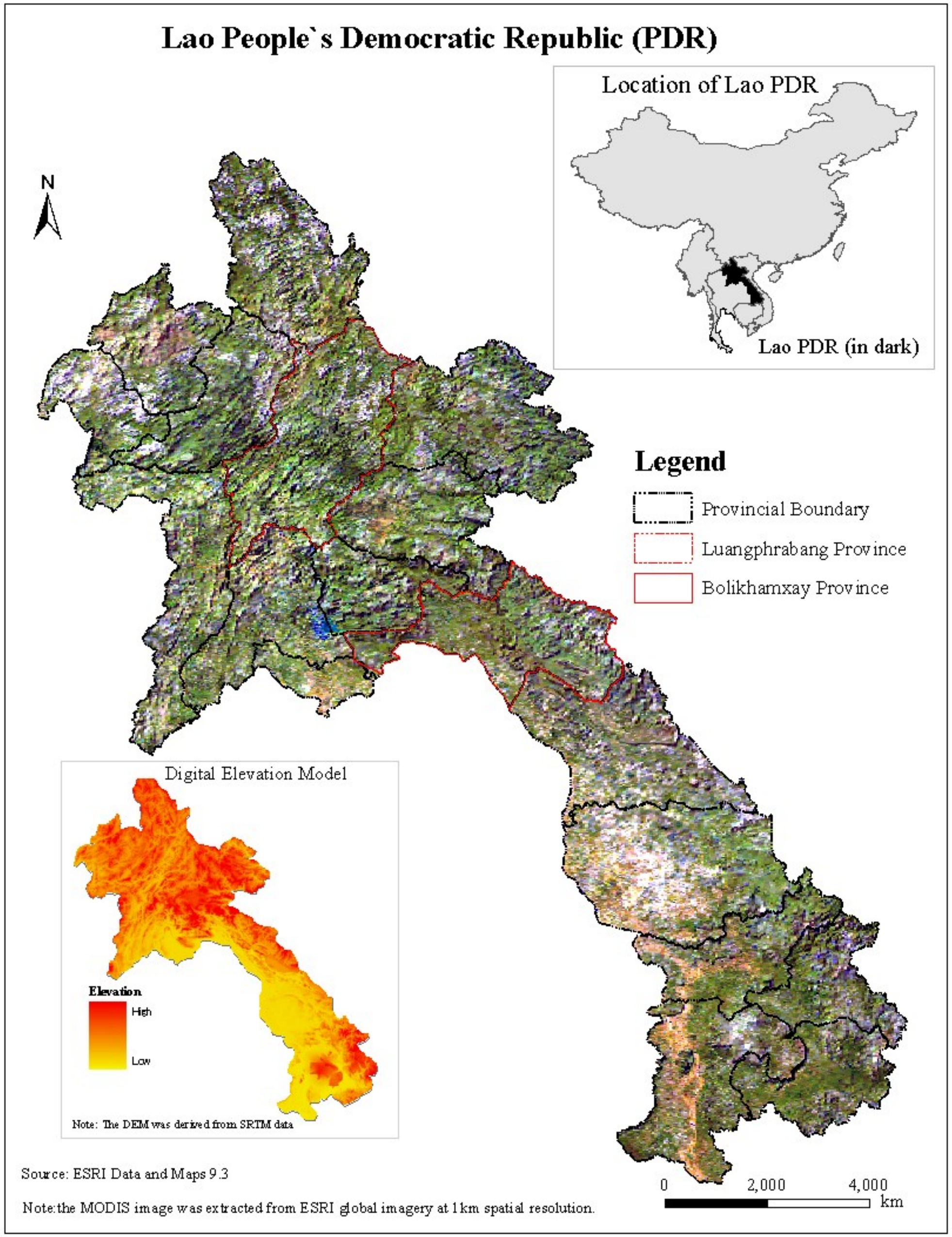
Simulation
Initial Land Use/
Cover Map
Weight-of-Evidence/
Artificial Neural Network
Transition
Potential Maps
Markov Chain Analysis
Transition Area Files
Spatial Allocation of Transition
Probabilities
(Multi-Objective Land
Allocation & CA)
Iterations
Simulated Land
Use/Cover Maps

Objectives

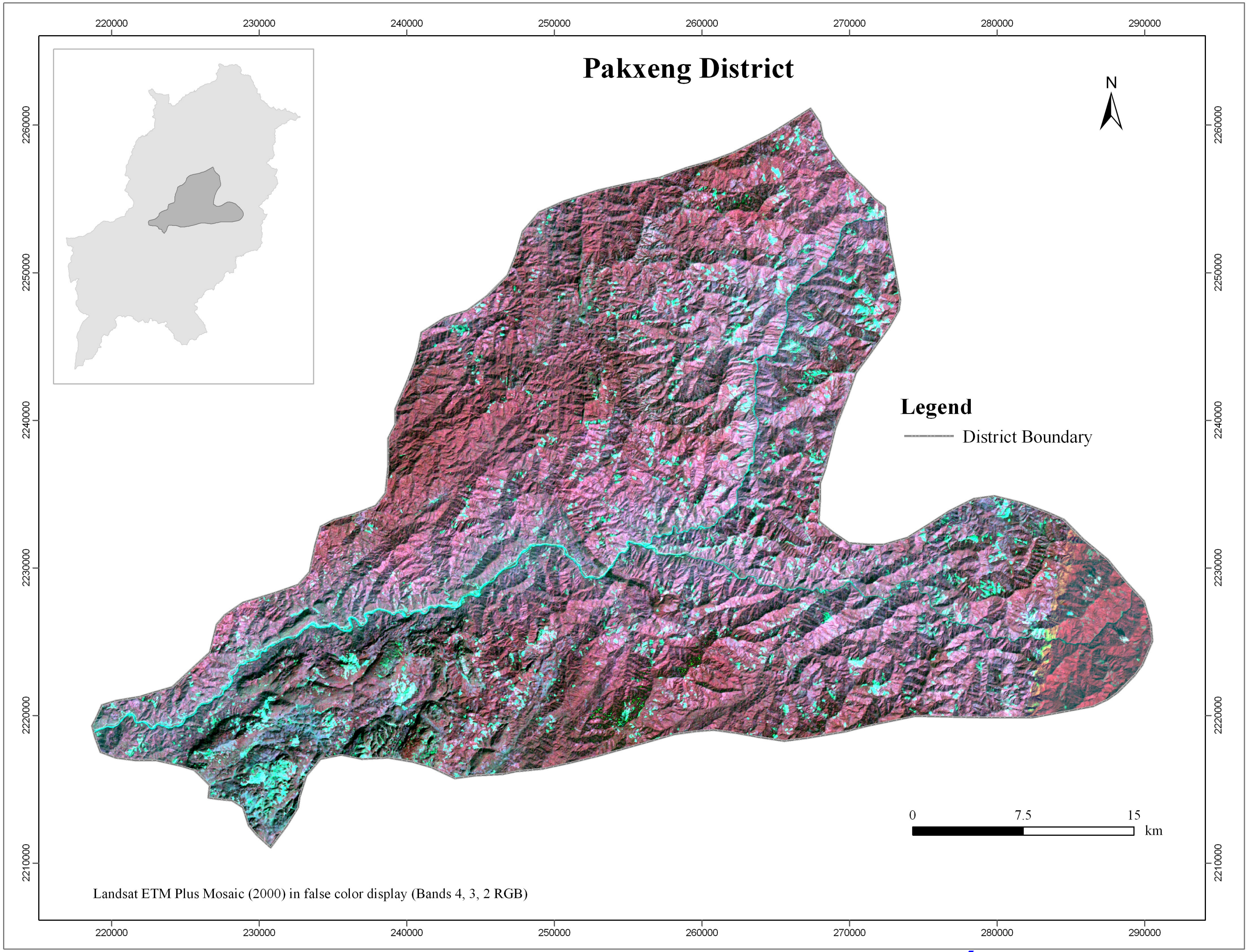
- To analyze land use/cover changes in Pakxeng district.

- To compare different land use/cover change modeling approaches: Land Change modeler (LCM) and Markov-CA (Dinamica).

Project Study Area



Study Area



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(Approx. 1,650 km^2)

Part I

Land use/cover change analysis

Land Use/Cover Classes

Land use/cover class	Description
Current Forest	Includes natural and plantation forest areas with crown density more than 20% & an area of 0.5 ha. Trees should reach a minimum height of 5 m.
Unstocked Forest	Previously forested areas in which crown density has been reduced to less than 20% due to disturbances (e.g., shifting cultivation or logging).
Ray	Area where the forest has been cut and burnt for temporary cultivation of rice and other crops (shifting cultivation areas).
Grassland	Unfertile or degraded land on which no trees or scrubs grow.
Cropland	Areas used for agricultural production e.g., rice paddy.
Others	Permanent settlement areas, roads, barren land/rock.
Water	Rivers, reservoirs.

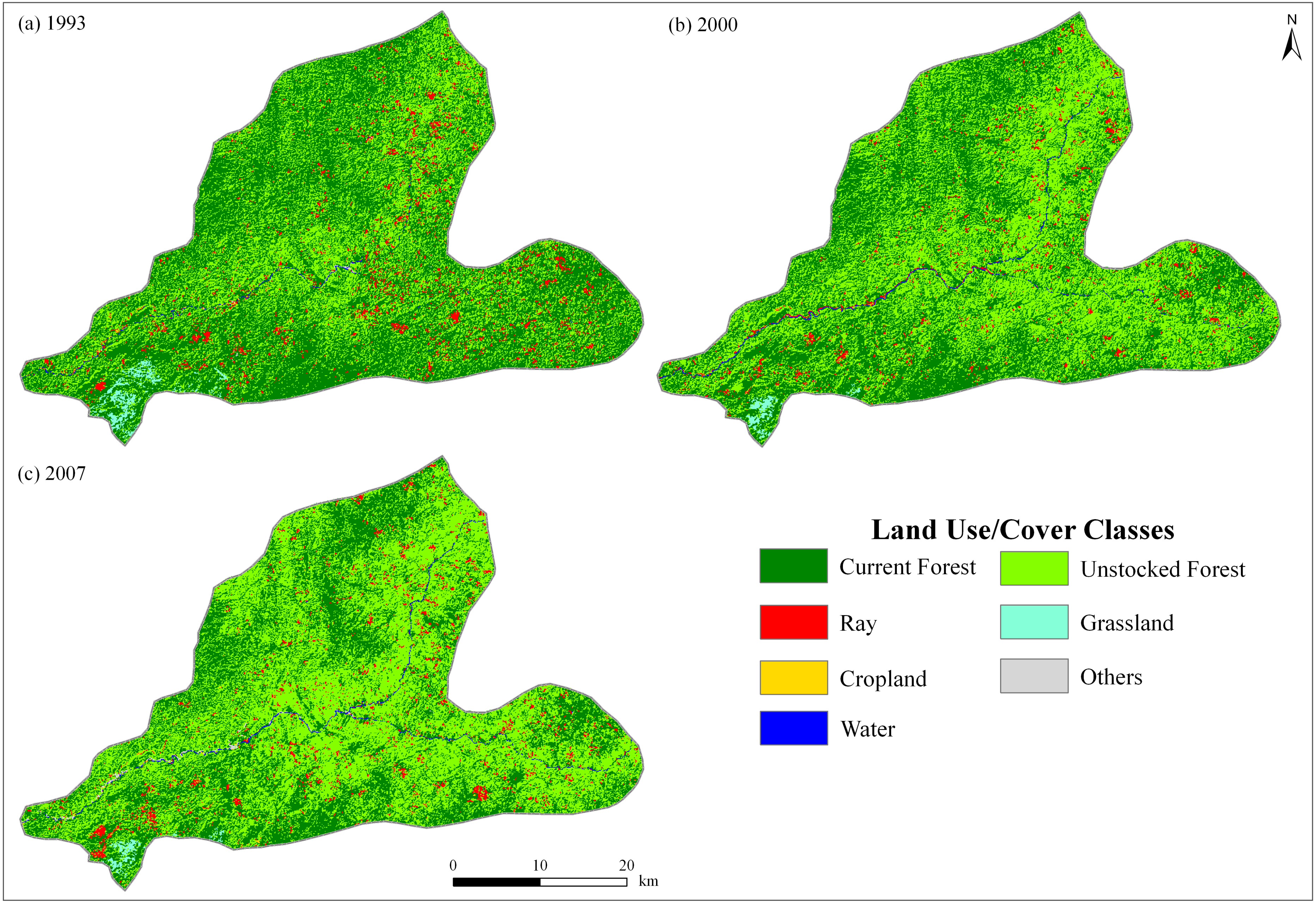
Examples of Land Use/Cover Classes

Current Forest

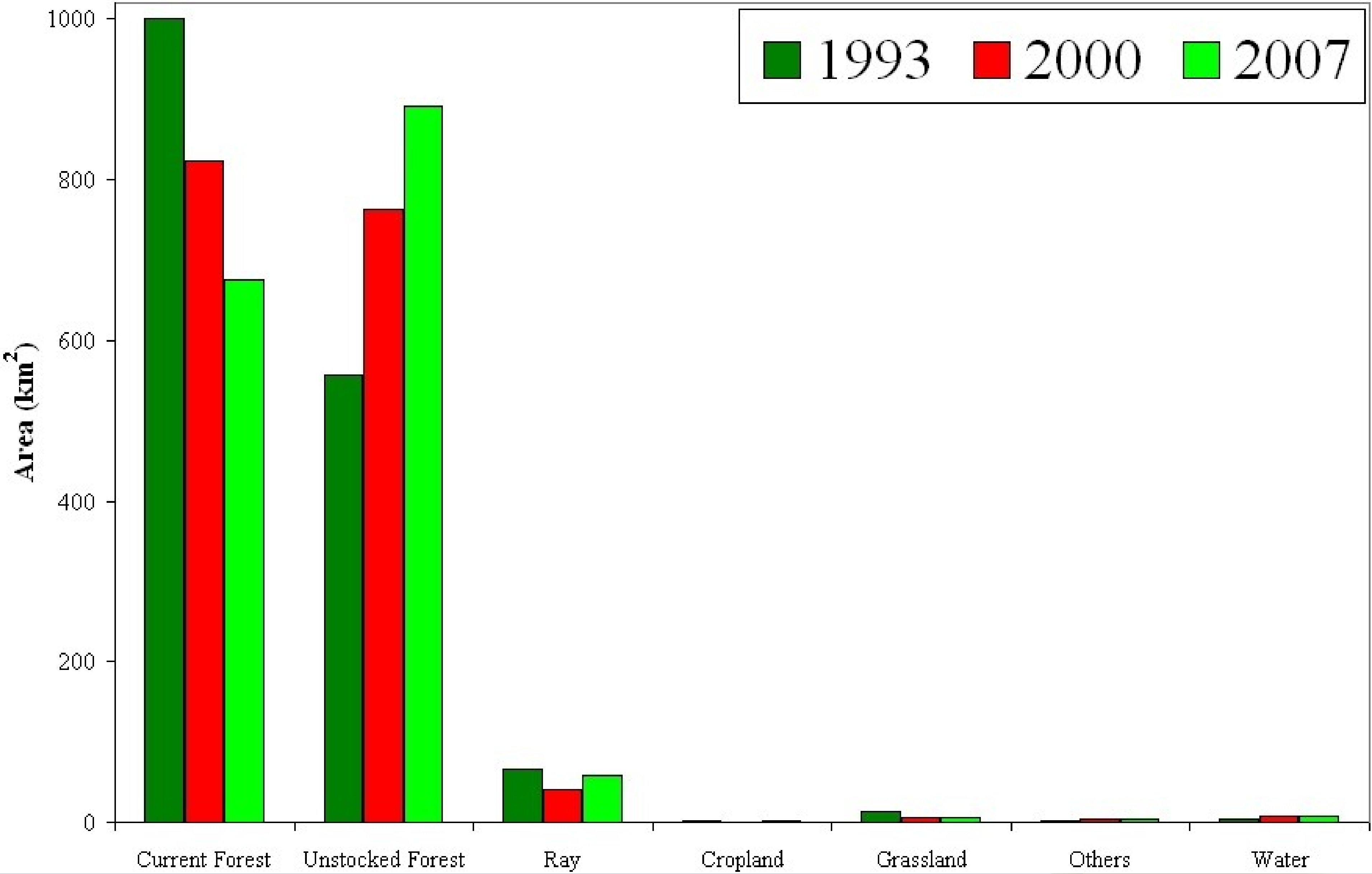
Ray

Unstocked forest

Land Use/Cover Classification



Land Use/Cover Statistics

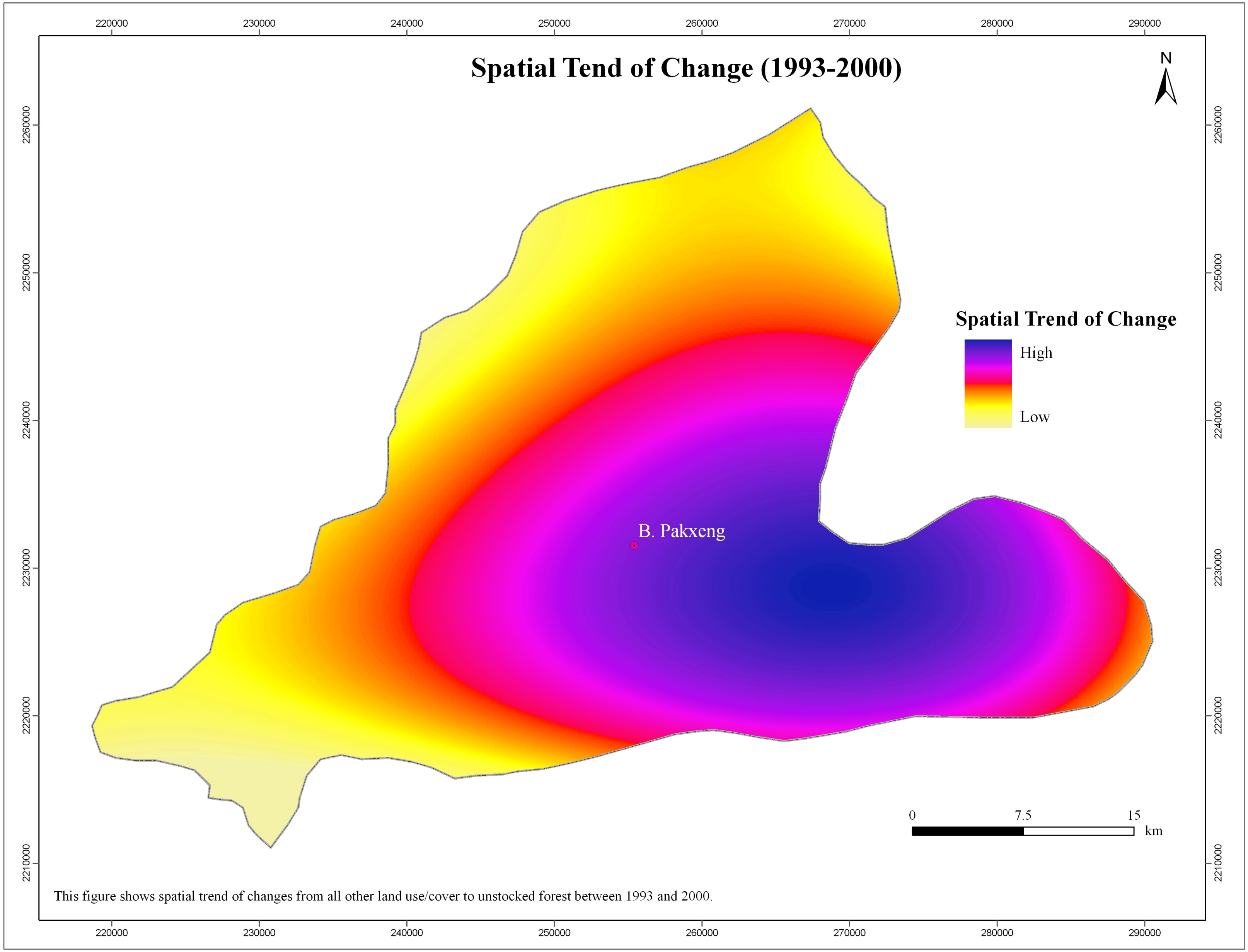


Major Land Use/Cover Transitions

Land Use/Cover Changes	1993-2000	2000-2007
Current forest to unstocked forest	164	215
Current forest to ray	19	18
Unstocked forest to current forest	5	86
Unstocked forest to ray	16	34
Ray to unstocked forest	61	35

(area in km^2)

Spatial Trend Analysis of Change



Summary

- Current forest areas declined, while unstocked forest areas increased, indicating deforestation.

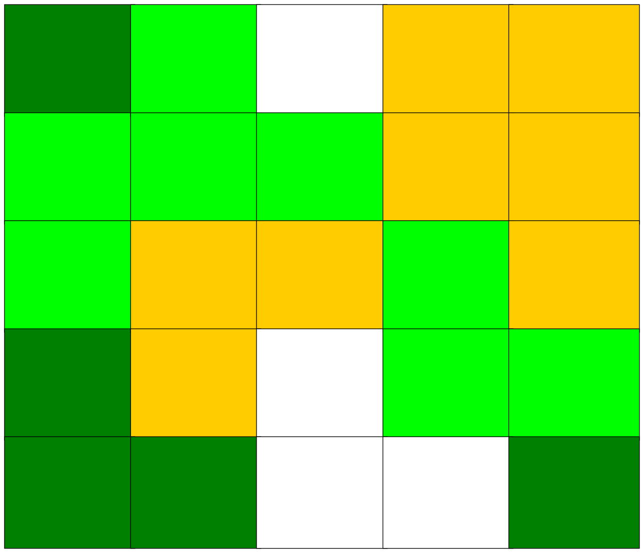
- The major land use/cover changes were from current forest to unstocked forest (both time periods) and unstocked forest to current forest (2000-2007).

Part II

Modeling Land Use/Cover Changes in Pakxeng District

Markov-Cellular Automata Model

(a) Cellular representation



A-Agriculture

W-Woodland

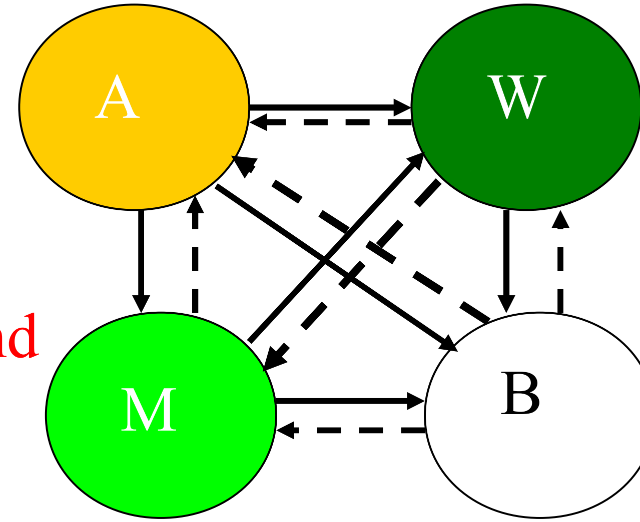
M-Mixed rangeland

B-Bareland

Source: Li and Reynolds, 1997

I. Spatial configuration

(b) Markov chain



II. State and transition model

- Spatial dynamics are controlled by local rules determined by the cellular automata
- Markov chain analysis controls temporal dynamics among the land use/cover classes

Markov-Cellular Automata Model

- The Markov chain can be expressed as:

$$\mathbf{v}_{t2} = \mathbf{M} \times \mathbf{v}_{t1}$$

where:

$\boldsymbol{v}_{t2}$ = *output land use/cover proportion column vector;*

$\boldsymbol{M}$ = *m* x *m transition matrix for the time interval* $\Delta t = t_2 - t_1$; and

$\boldsymbol{v}_{t1}$ = *input land use/cover proportion column vector*

- The cellular automata (CA) model can be expressed as:

$$\mathbf{St+1= f\ (St,\ Nt\ ,TP)}$$

where:

St+1 is cell's state in time t+1;

St is the cell's state in time t;

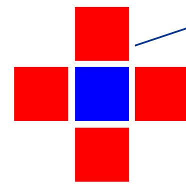
Nt is the cell's neighbourhood situation in time t; and

TP denote the transition rules of the CA

Markov-Cellular Automata

- Markov-cellular automata (Li and Reynolds, 1997) is expressed as:

$$\mathbf{C}\,(i, j) = m \rightarrow k, \textbf{ if } \; R > P_{m,k} \cdot N_k / 4 \;\; \textbf{else } \textit{No change}$$



Four neighbors

where:

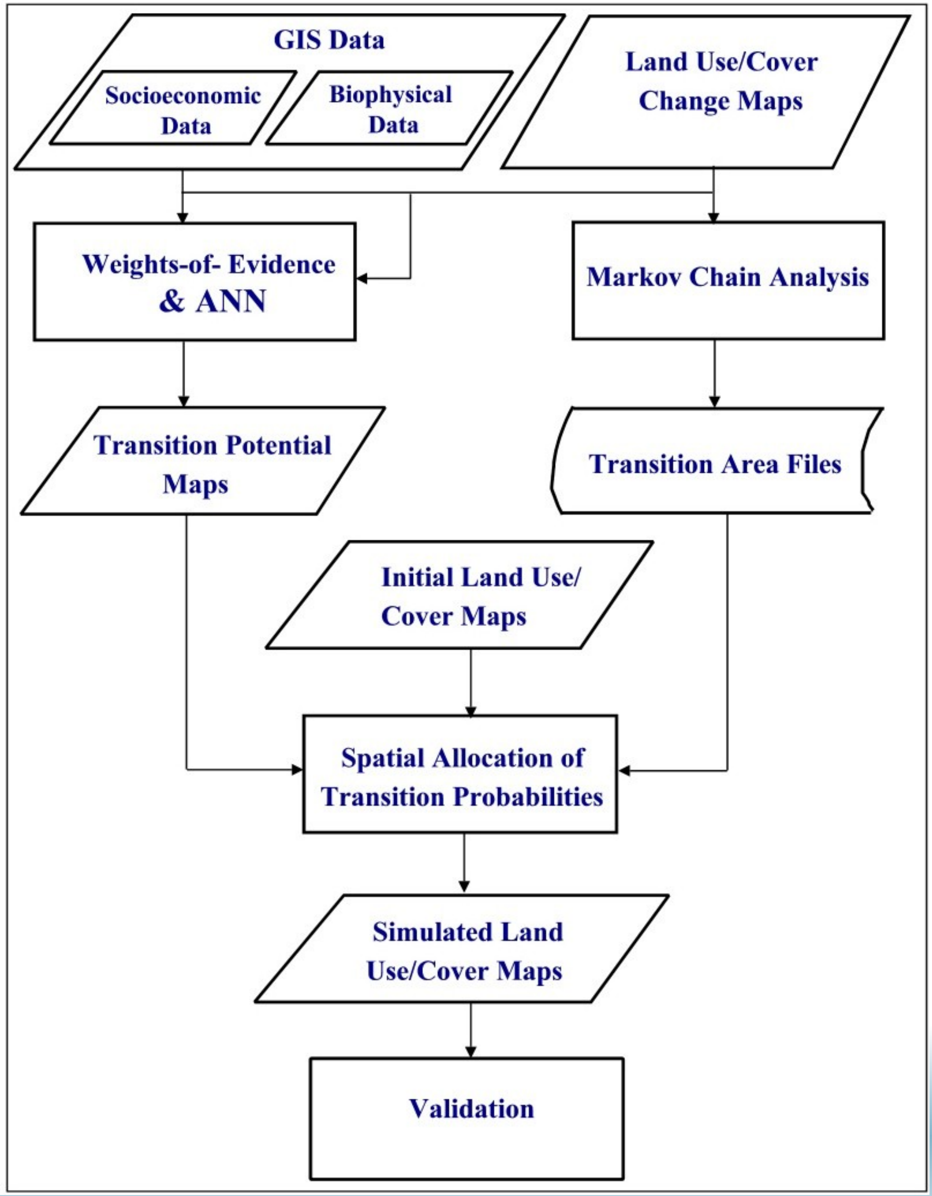
C (i, j): the land use/cover class of cell (i, j);

R : random number with a uniform distribution;

$\boldsymbol{P}_{m,k}$: transition probability from one land use/cover class m to k;

$\boldsymbol{N}_k$: number of neighbouring cells of land use/cover k, which includes the evaluation score of land use/cover transition potential at location i, j

Methodology



ANN: Artificial Neural Network

Data Inputs for Computing Transition Potential Maps

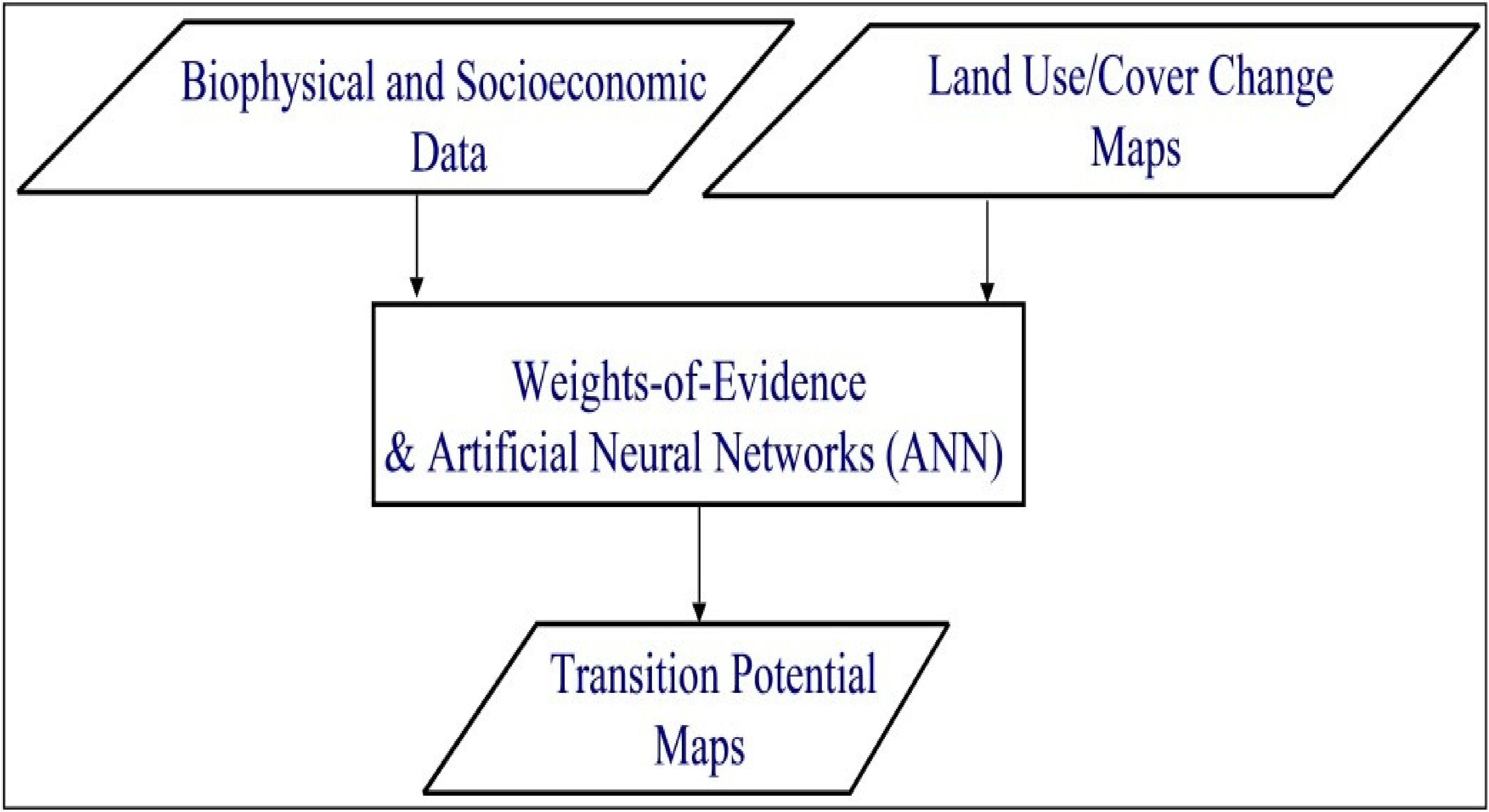
Biophysical data

- Land use/cover changes (1993-2000)
- DEM (slope)
- Distance measures

Socioeconomic data

- Number of households

Methodology For Computing Transition Potential Maps



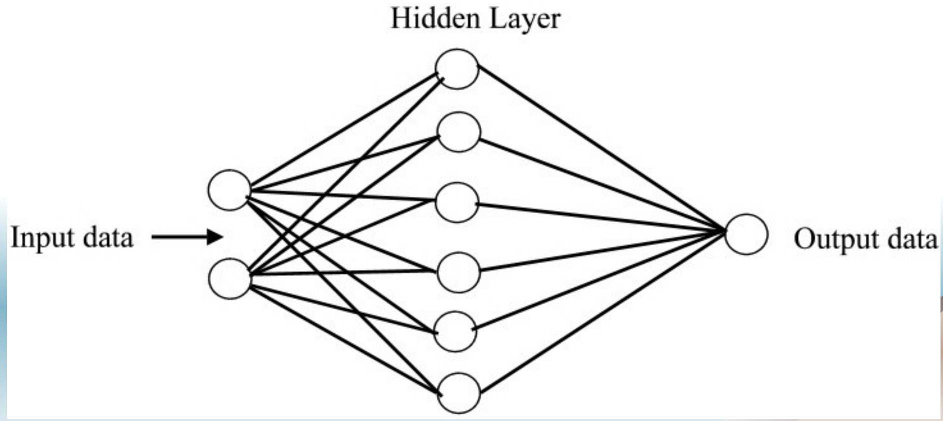
Weights-of-Evidence/Bayesian Aggregation

- The weights-of-evidence (Bonham-Carter et al., 1989) is expressed as follows:

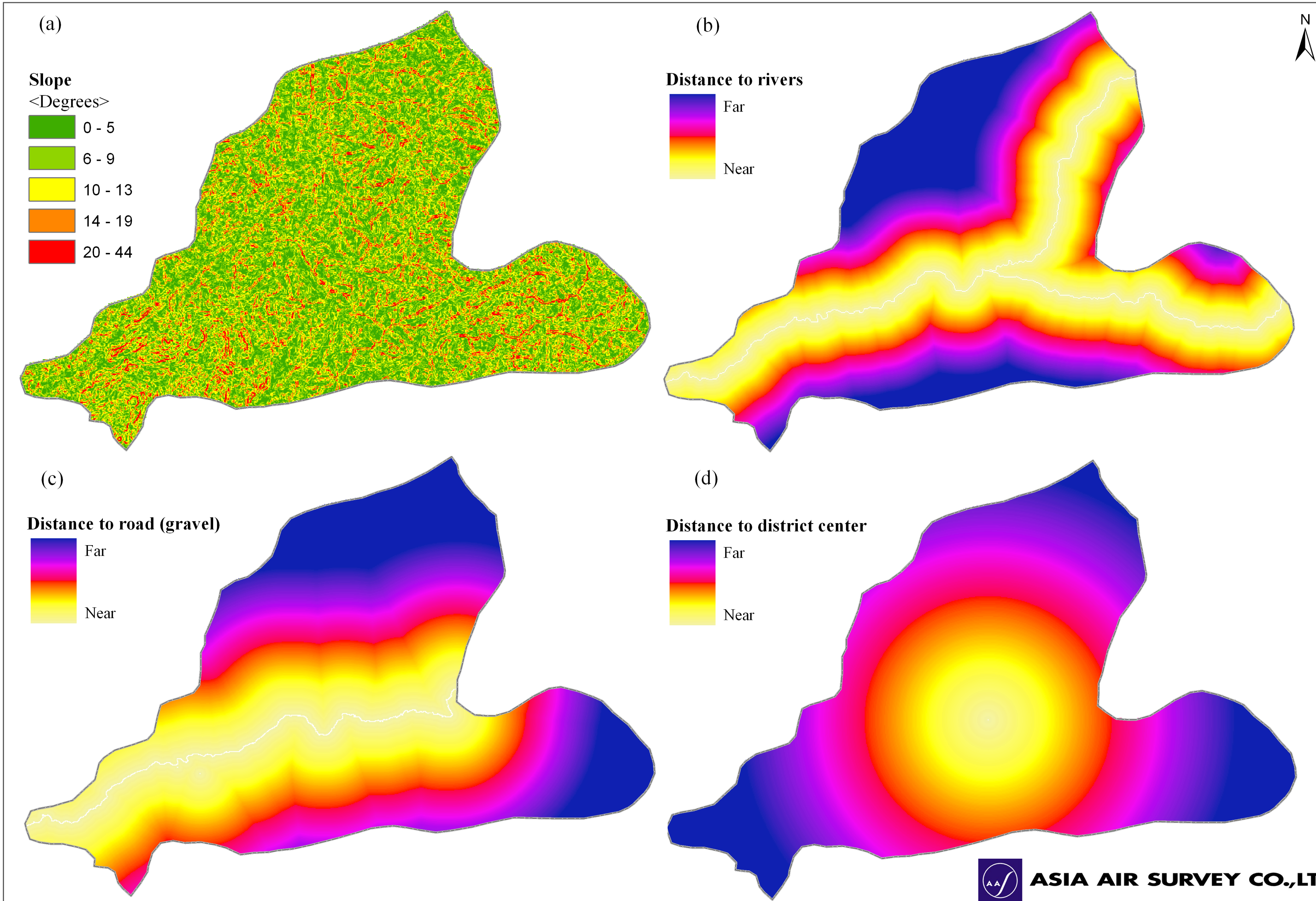
$$p(\text{change}|X_1 \cap X_2) = \frac{p(\text{change}) * p(X_1|\text{change})p(X_2|\text{change})}{p(X_1)p(X_2)}$$

Artificial Neural Network (ANN)

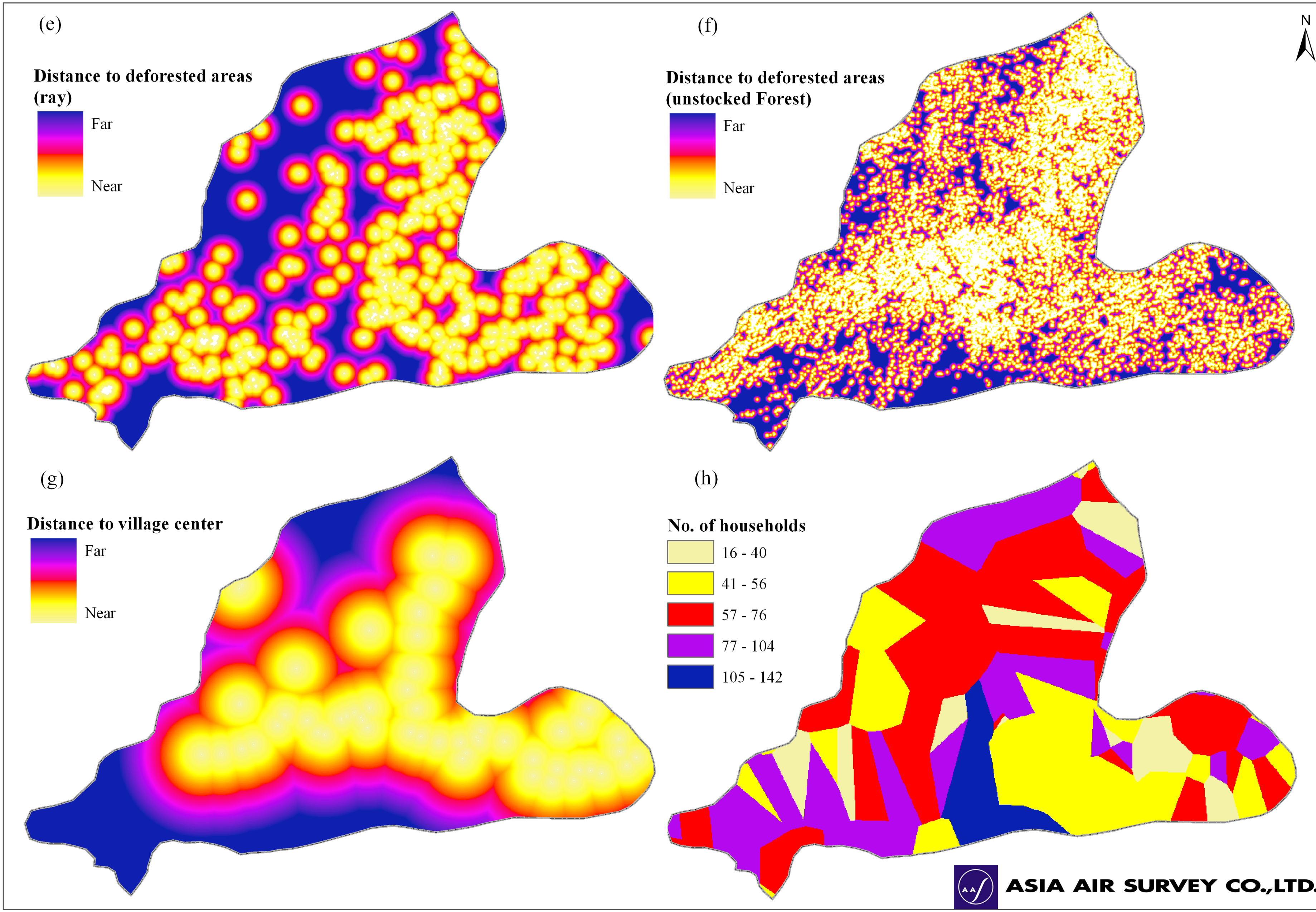
- ANN is a mathematical model that mimics the functionality of the human brain for knowledge acquisition, recall, synthesis and problem solving.



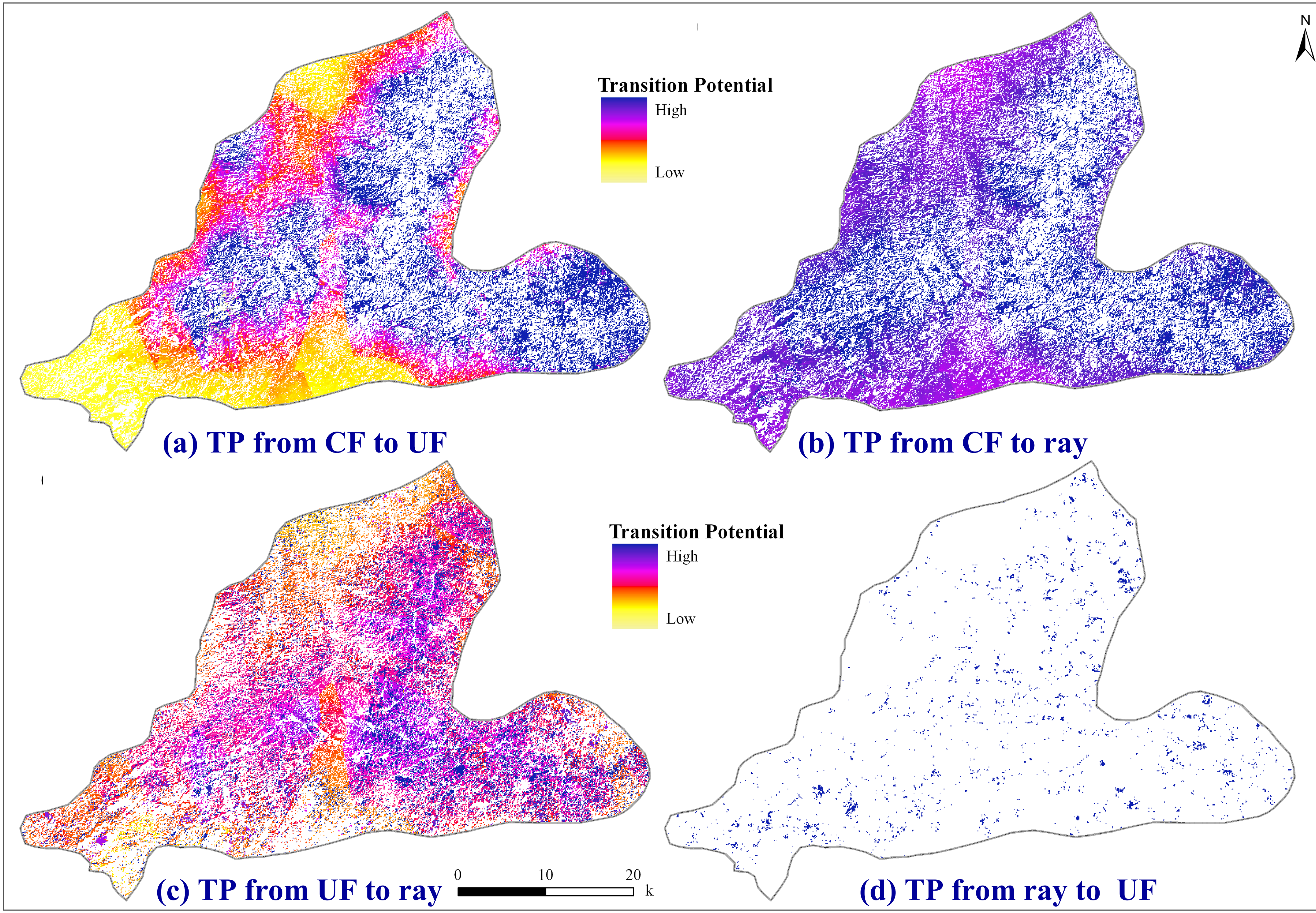
Computation of Transition Potential Maps



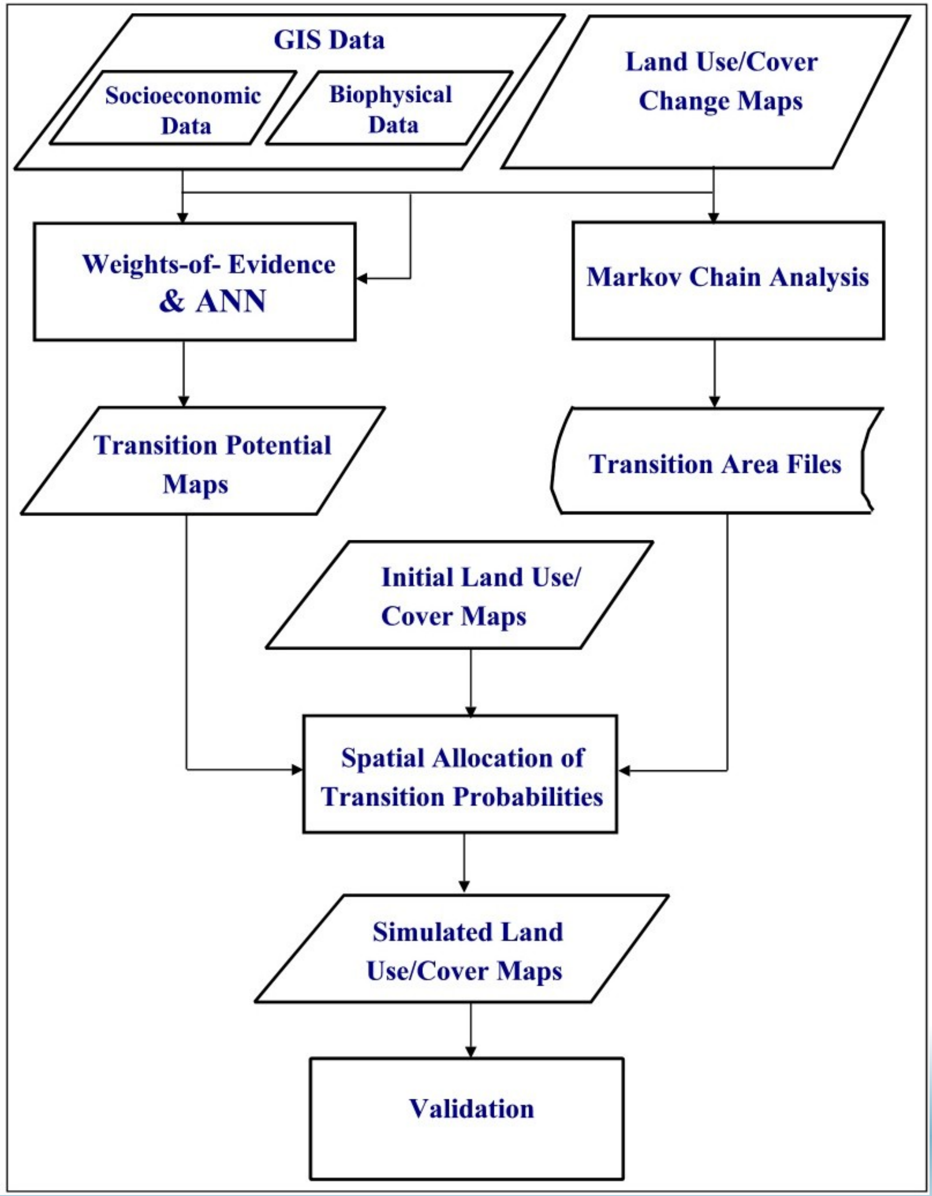
Computation of Transition Potential Maps



Transition Potential Maps

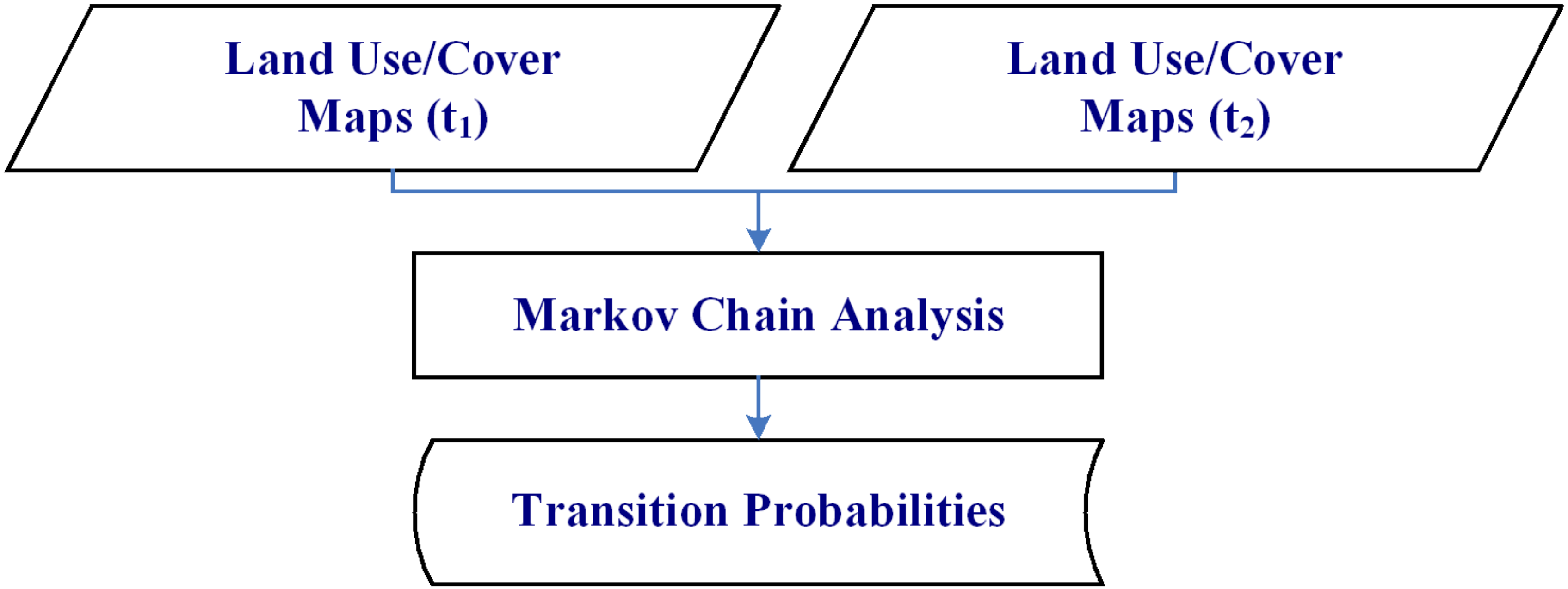


Methodology



ANN: Artificial Neural Network

Methodology For computing Markov Transition Probabilities



Land Use/Cover Transition Probabilities (1993-2000)

		2000						
		CF	UF	RA	GL	CL	OT	WT
1993	CF	*0.81*	0.16	0.02	0.00	0.00	0.00	0.00
	UF	0.01	*0.96*	0.03	0.00	0.00	0.00	0.00
	RA	0.01	0.91	*0.07*	0.27	0.00	0.00	0.01
	GL	0.00	0.00	0.12	*0.01*	0.00	0.24	0.37
	CL	0.20	0.35	0.05	0.00	*0.27*	0.00	0.00
	OT	0.10	0.20	0.08	0.00	0.00	*0.52*	0.03
	WT	0.20	0.04	0.01	0.00	0.00	0.01	*0.76*

Note: CF – Current forest; UF – Unstocked forest; RA-Ray; GL-Grassland; CL-Cropland; O - Others; and W - Water

Simulation Data Inputs

For simulating the 2007 land use/cover map

- Transition potential maps (computed from the 2000 data)
- Transition probabilities between 1993 and 2000
- Validation (actual land use/cover map 2007 versus simulated land use/cover map 2007)

Land Use/Cover Change Modelling Results

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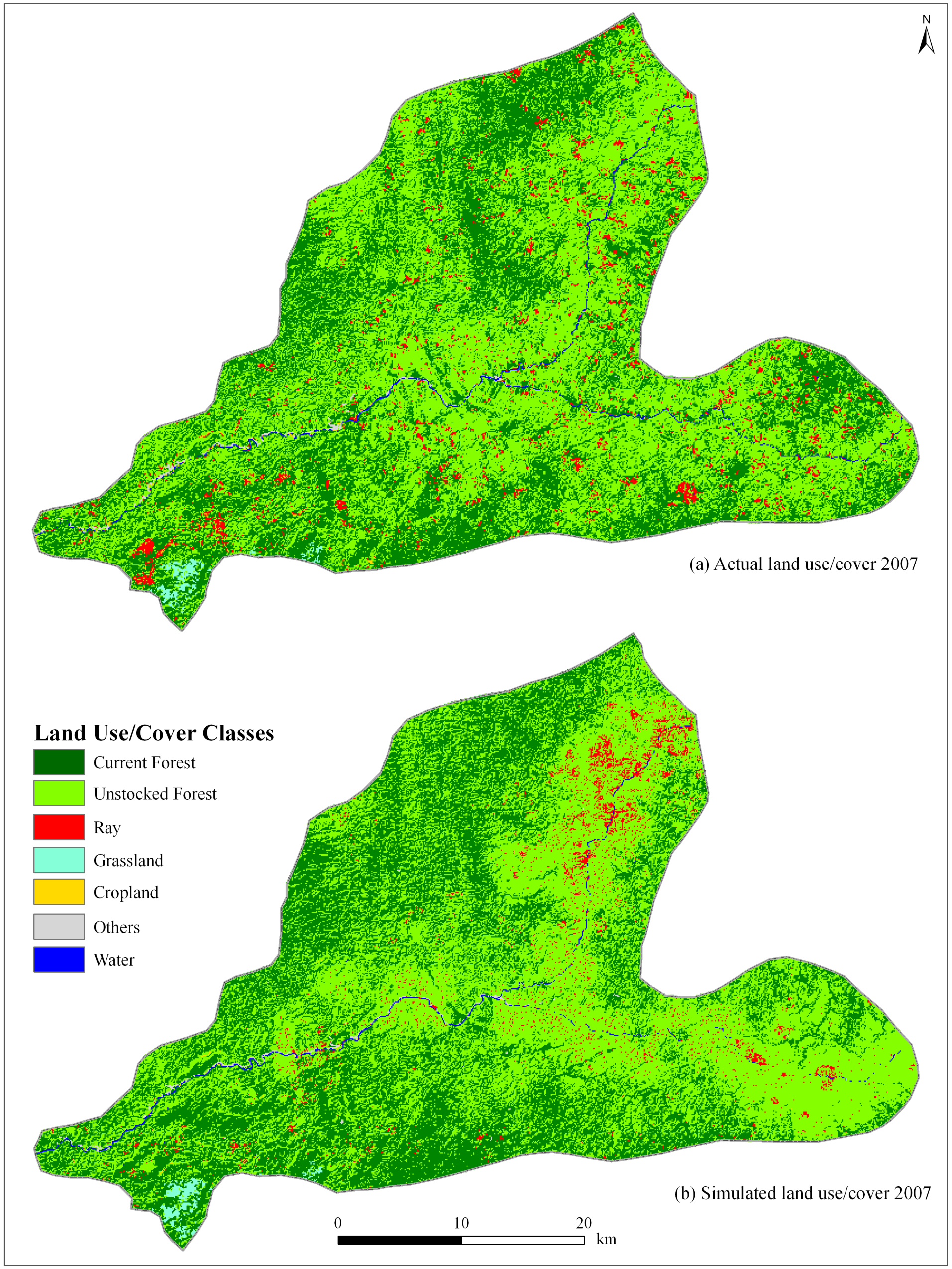
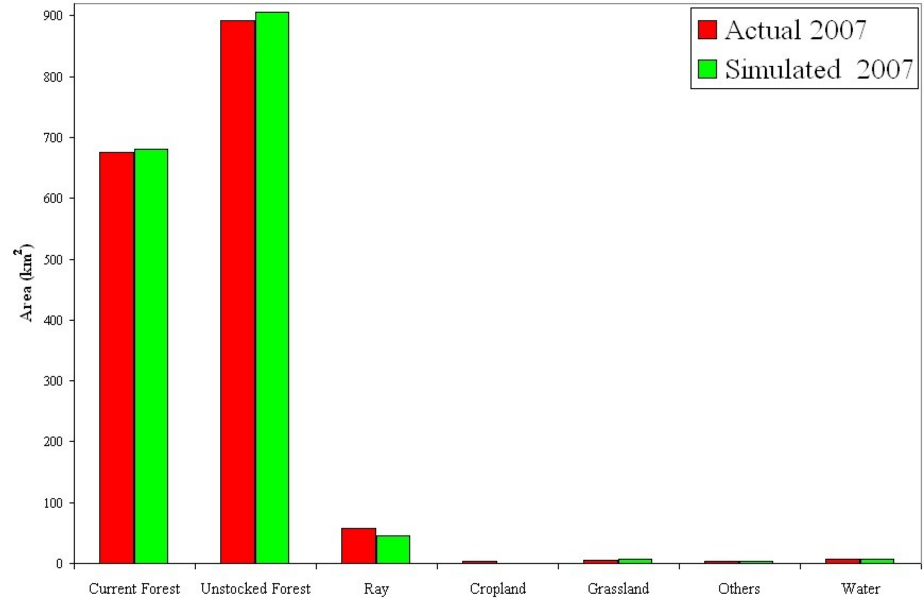
Actual versus Simulated Land Use/Cover (2007)





Kno - 0.85

Kappa for location - 0.80

Overall kappa - 0.80

LCM - IDRISI

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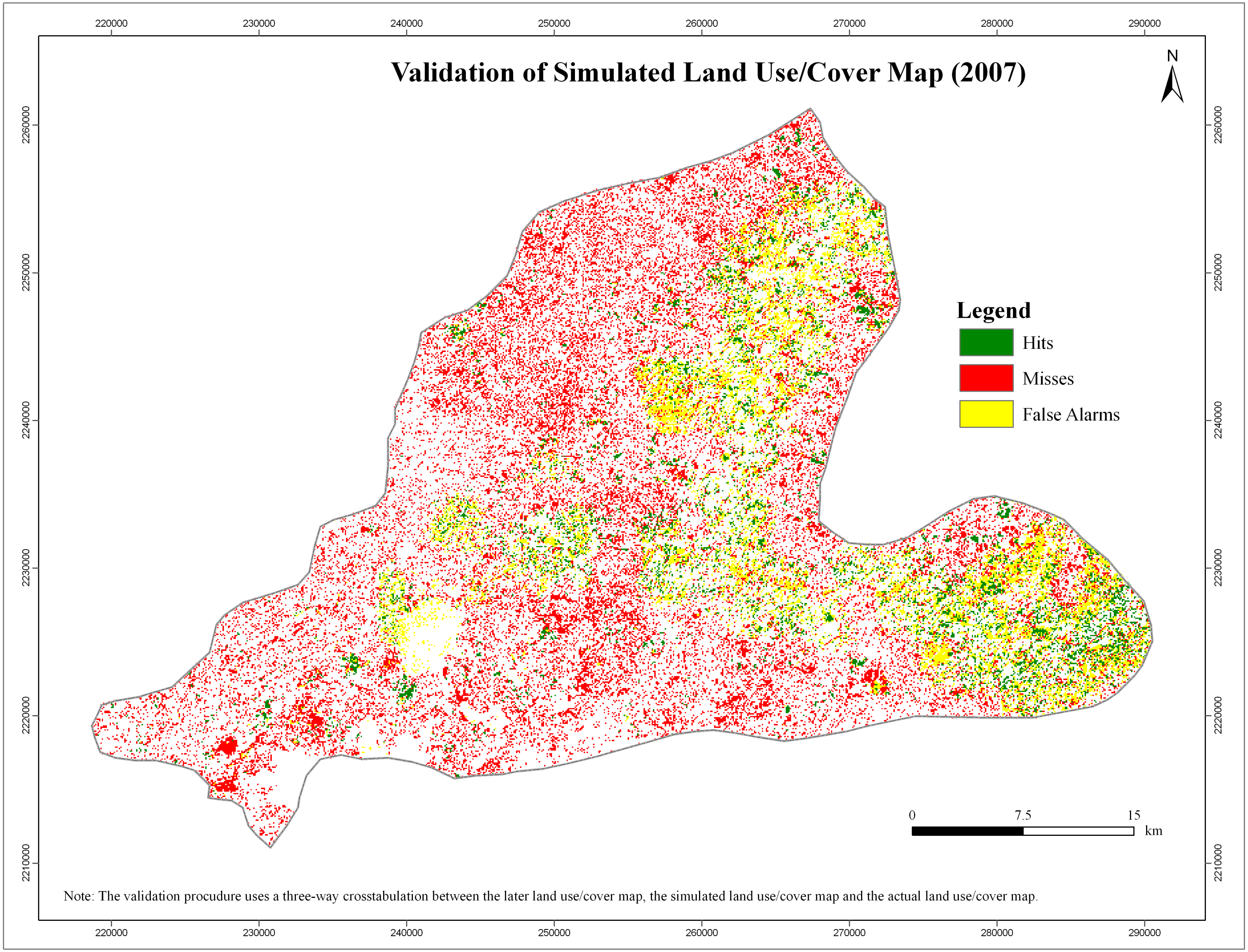
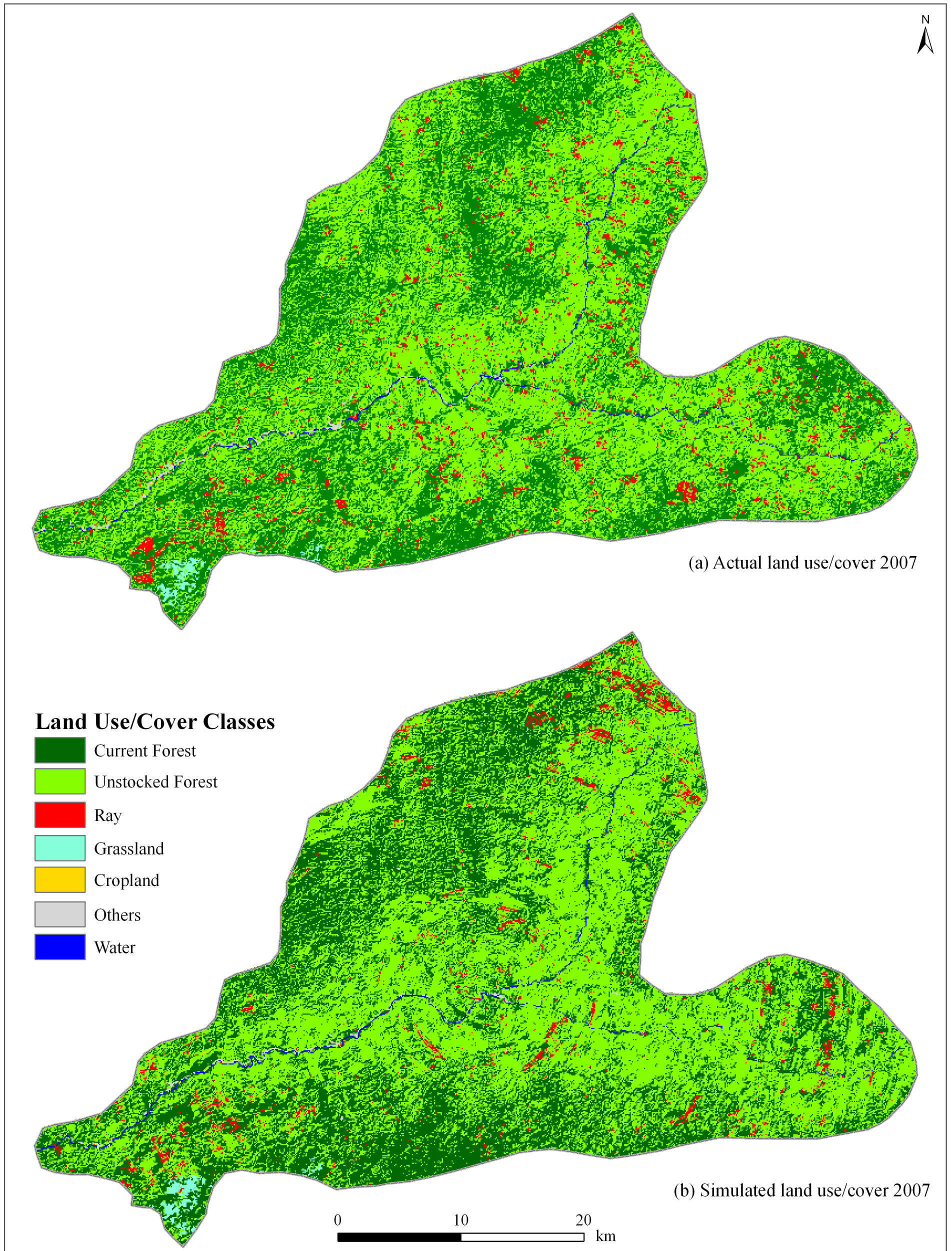
Validation of Simulated LUCC (2007)-LCM

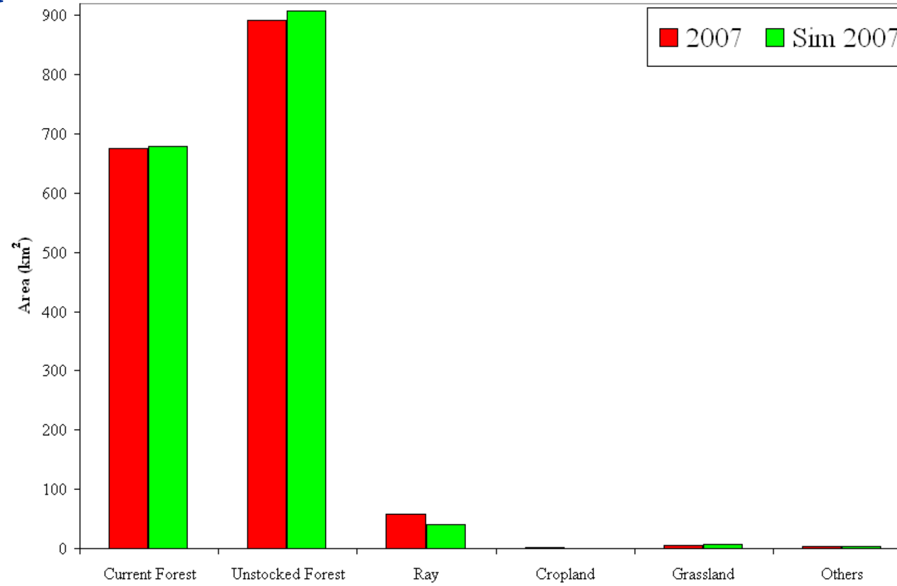


Actual versus Simulated Land Use/Cover (2007)



(a) Actual land use/cover 2007

(b) Simulated land use/cover 2007



Kno - 0.85

Kappa for location - 0.80

Overall kappa - 0.79

Dinamica EGO

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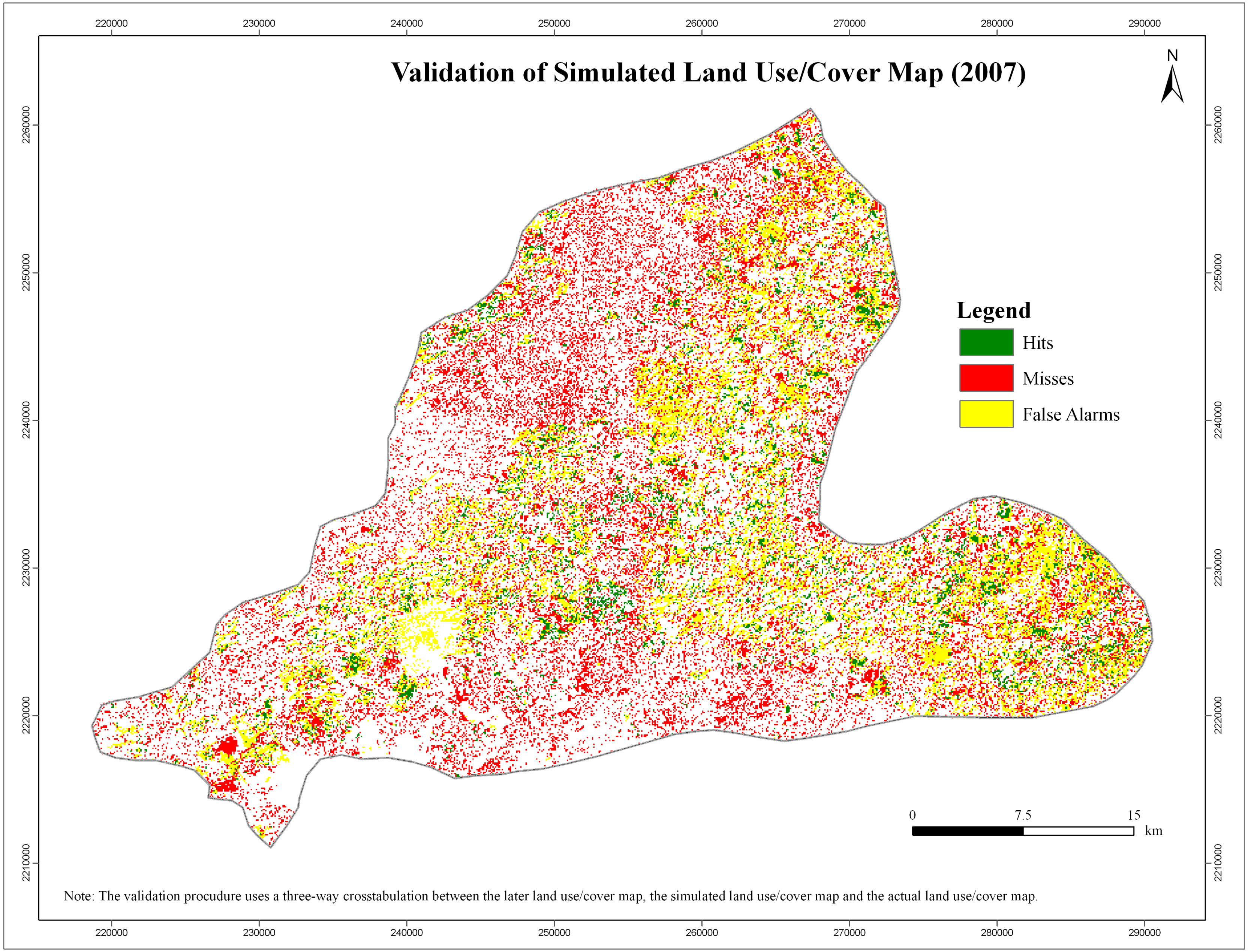
Validation of Simulated LUCC (2007) - DINAMICA



Summary and Conclusions

- The overall kappa statistic indicates accuracy of the entire maps not specific LUCC transitions.
- The LCM and Dinamica models do not reveal significant differences in terms of simulating quantity (Change Demand component).
- However, Dinamica is better than LCM in simulating location because the former uses CA neighborhood configuration.
- The "three way" map comparison reveals lot of misses and false alarms – for the actual LUCC transitions that occurred.

Thank you for your attention.