Netherlands Environmental Assessment Agency

Determining future land use allocation with CLUE model

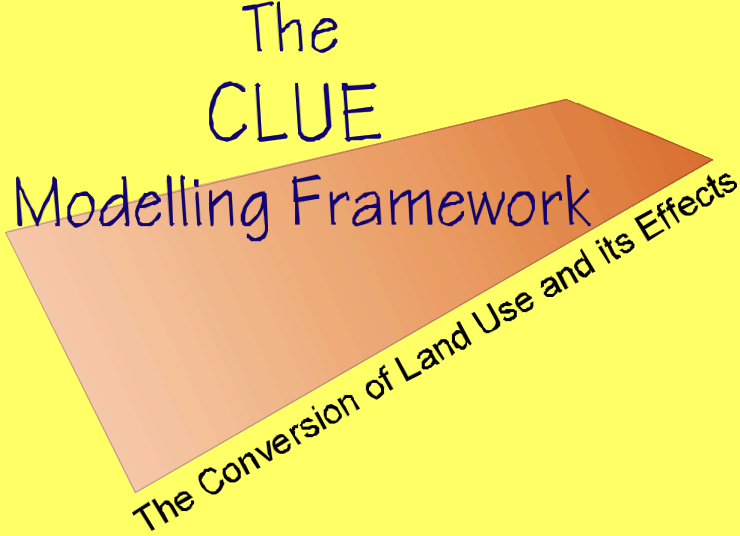
Presentation for the Modelling Planning Workshop

24-26 March 2009, Rio de Janeiro, Brazil

By Wilbert van Rooij

Netherlands Environmental Assessment Agency (PBL)

CLUE:
The Conversion of Land Use and its Effects
(http://www.cluemodel.nl)

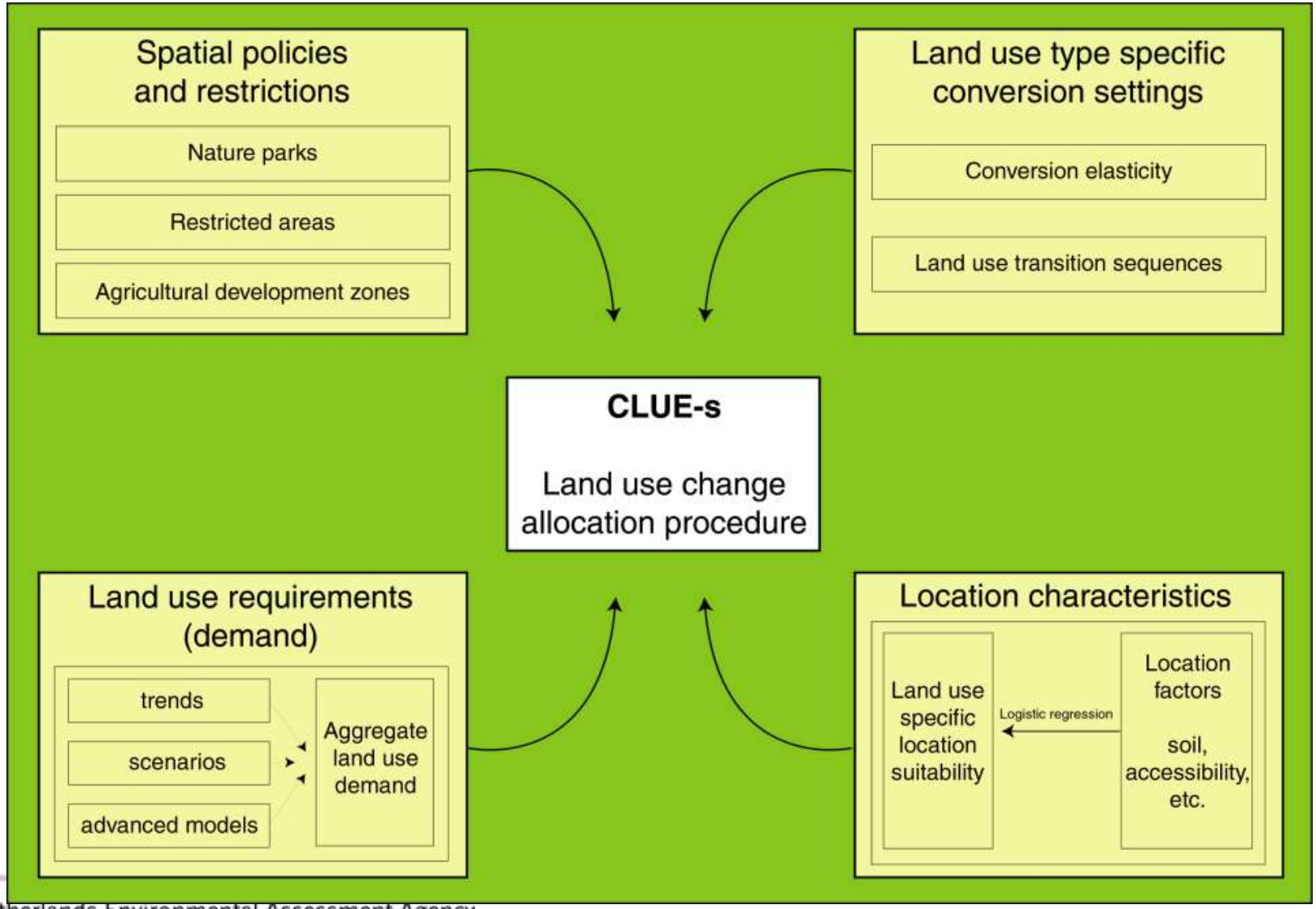


- Model for regional analysis of land use change
- First published in 1996
- Many new developments since first publication
- > 30 applications at varying scales

- Applications by the CLUE core-group
- Applications in close collaboration with counterparts
- Applications by other institutes

- CLUE is methodology to model near-future changes in land use patterns
- CLUE is a hybrid methodology, combination of:
  - Statistical Analysis
  - Decision Rules
  - Cellular Automata
  - Markov Chains
- Specification depends on scale, land use processes, case study

Framework CLUE-s model (Conversion of Land Use & Its Effects)



Characterization of location suitability

- Land use is changed preferably at the location with the highest ‘suitability’
- ‘Suitability’ depends on the preferences of the decision maker
- ‘Suitability’ cannot be expressed in monetary value or solely by biophysical attributes

Land Use Type Specific Conversion Setting

Future LU

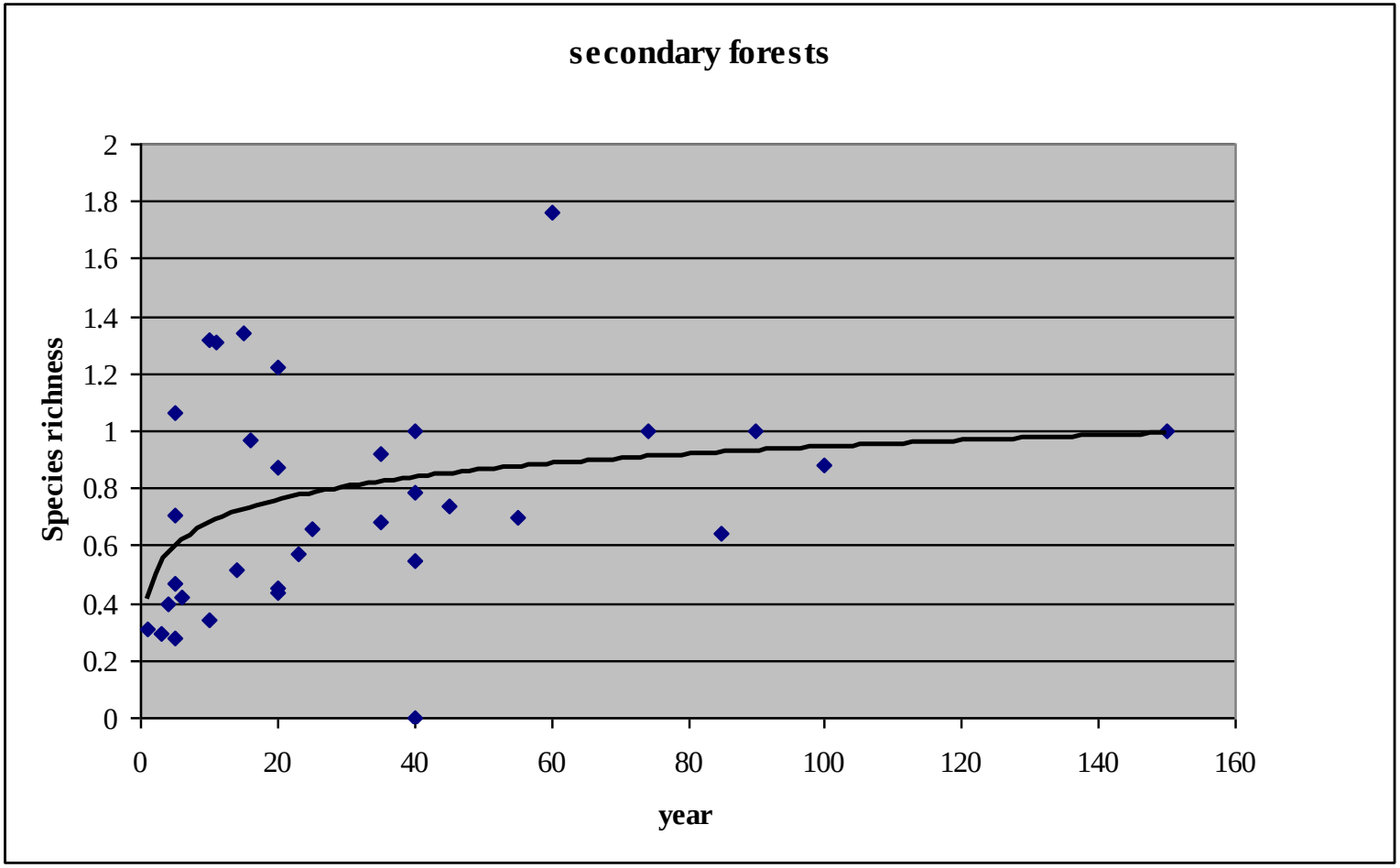
Land Use Conversion Matrix

Present LU

	Prim. For	Plant	Sec. For.	Ext. Agr.	Int. Agr.	Nature	Bare	Other
Prim. For	1	1	1	1	1	0	1	0
Plantation	0	1	110	1	0	0	1	0
Sec. For.	130	1	1	1	1	0	1	0
Ext. Agr.	0	1	1	1	1	0	1	0
Int. Agr.	0	0	0	1	1	0	1	0
Nature	0	0	0	0	0	1	0	0
Bare	0	1	110	1	1	0	1	0
Other	0	0	0	0	0	0	0	1

1 = Possible to change
0 = Not possible to change
130 = Remain at least 30 yrs

Regrowth after clearcut (secondary forest)



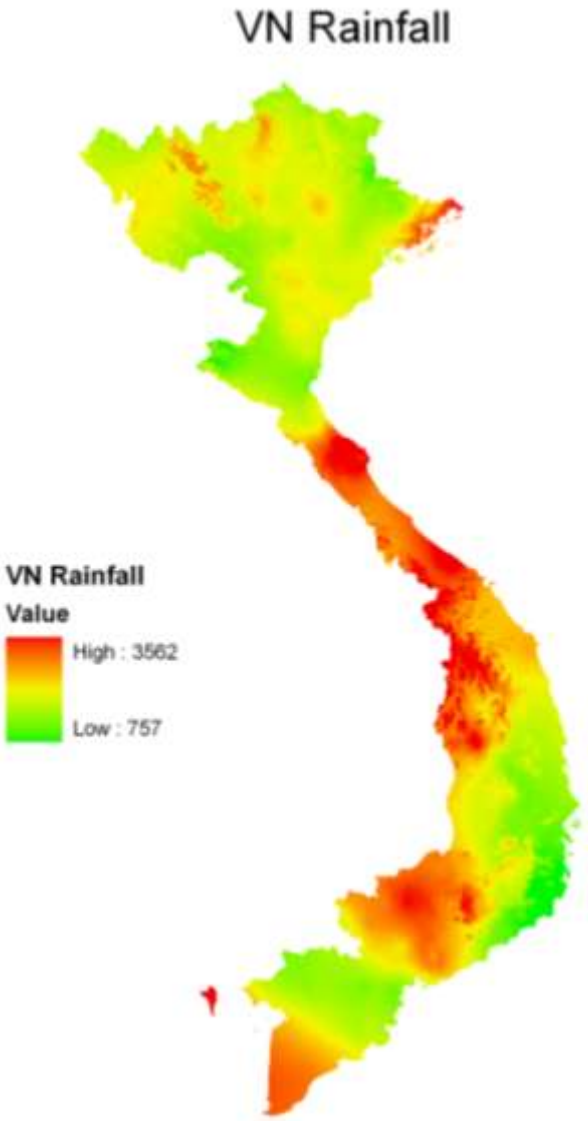
location factors

location factors	source	original resolution	description of 3 km resolution location factors
Local factors			
mean annual rainfall	GAEZ	10 km	
length of dry period	IIASA	0.5°	number of consecutive "dry" months
altitude	HYDRO1K	1 km	
slope	HYDRO1K	1 km	median of 1km resolution slopes
geology	SOTER Lac	1:5 million	metamorphic or igneous rock
soil depth	GAEZ	10 km	
soil drainage	GAEZ	10 km	
soil fertility	GAEZ	10 km	
protected area, or:	CIAT - UNEP-WCMC	various	
national/indigenous park	*idem*		
other park/reserve	*idem*		
population density	CIAT - UNEP - WRI	2.5'	
population growth	CIAT - UNEP - WRI	2.5'	1990-2000 extrapolated
Contextual factor			
topographical index	HYDRO1K	1 km	function of local gradient and contributive area
flat area size	HYDRO1K	1 km	surface of area with slope <3°
landscape fragmentation	GLC2000 / CCAD/WB	1 km	Euclidean distance to border of natural vegetation
cost of access from road	various	<1 km	cost distance from nearest paved road
cost of access to market	various	<1 km	cost distance to nearest city with over 100,000 inh.
proximity to fire	JRC	1 km	proximity to fire (15 and 45km neighbourhood)
population density			15 and 45km neighbourhood average
population growth			15 and 45km neighbourhood average

Input for CLUE-s model

- Allocation factors that have a spatial relation with the present and future land use classes

  For example:
  - rainfall distribution,
  - travel time to towns and markets,
  - elevation,
  - soil suitability (depth, texture, fertility)
  - slope
  - population density

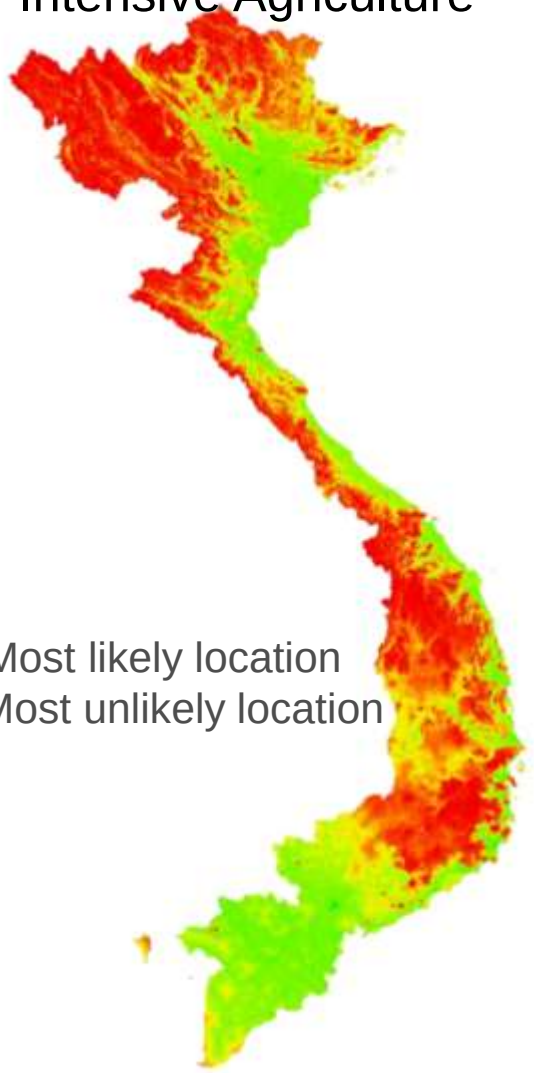


Intermediate output of CLUE-s model

- Probability / Suitability map for each land use type

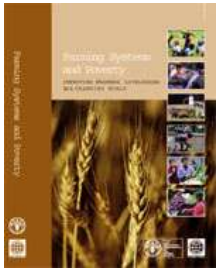
- Vietnam:
  Suitability based on following available location factors/maps:
  i). Precipitation (rainfall)
  ii). Travel time to town
  iii). DEM (Elevation)
  iv). Slope
  v). Population Density
  vi). Soil texture, fertility, depth

Probability / Suitablity map
Intensive Agriculture



Suitability maps based on region specific analysis

...for each country
and farming system



FAO/WB:
Dixon *et al.*, 2001

...for each land use class

...

Location characteristics (spatial)

Land Suitability Factors and Accuracy

LU/ Factors	Elasticity	Precipitation	TravelTime	Distance to Road	DEM elevation	POP Density	Slope	ROC
Primary Forest	**0.9**	**X**	**X**	**-**	**X**	**X**	**X**	**0.729**
Plantation	**0.9**	**X**	**X**	**X**	**X**	**X**	**-**	**0.728**
Extensive Agriculture.	**0.6**	**X**	**X**	**X**	**-**	**-**	**-**	**0.586**
Intensive Agriculture.	**0.8**	**X**	**X**	**-**	**X**	**X**	**X**	**0.881**

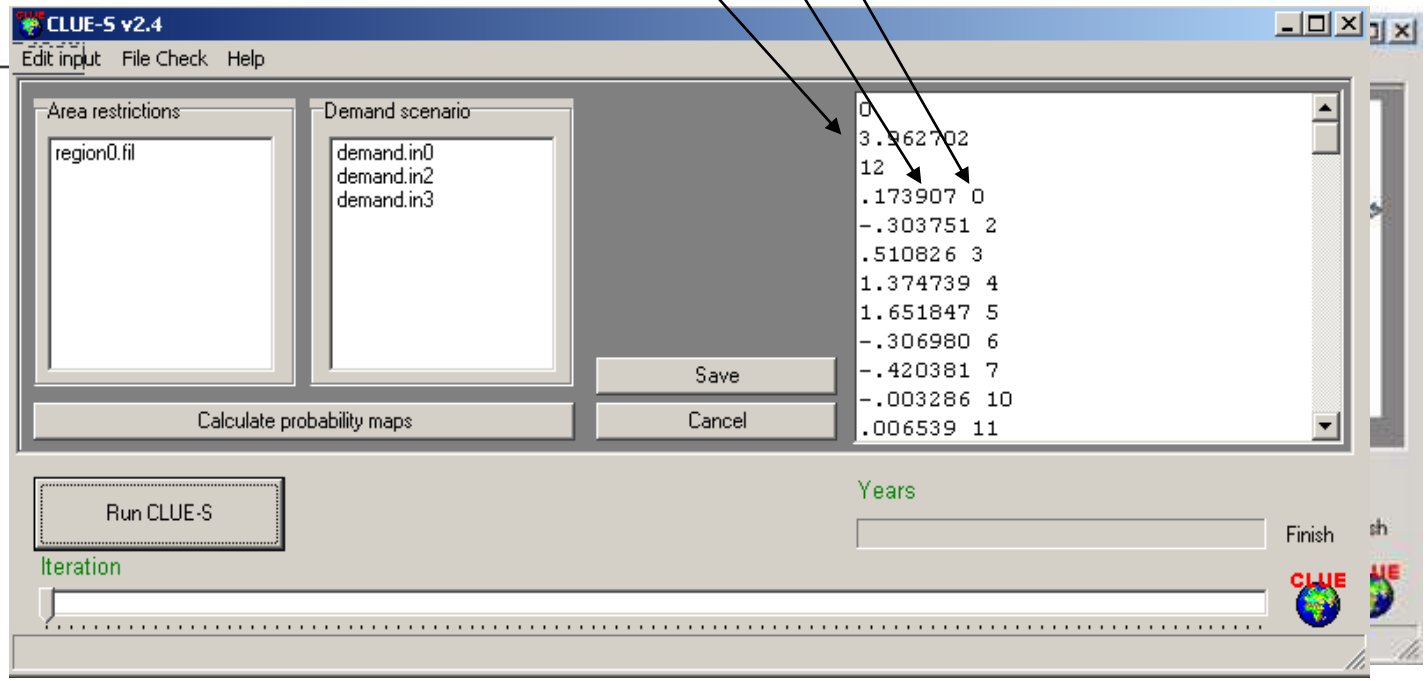
Elasticity
0 – easy conversion
1 – irreversible change

Probability/suitability calculations per land use type
based on regression equation between land use type and location factors

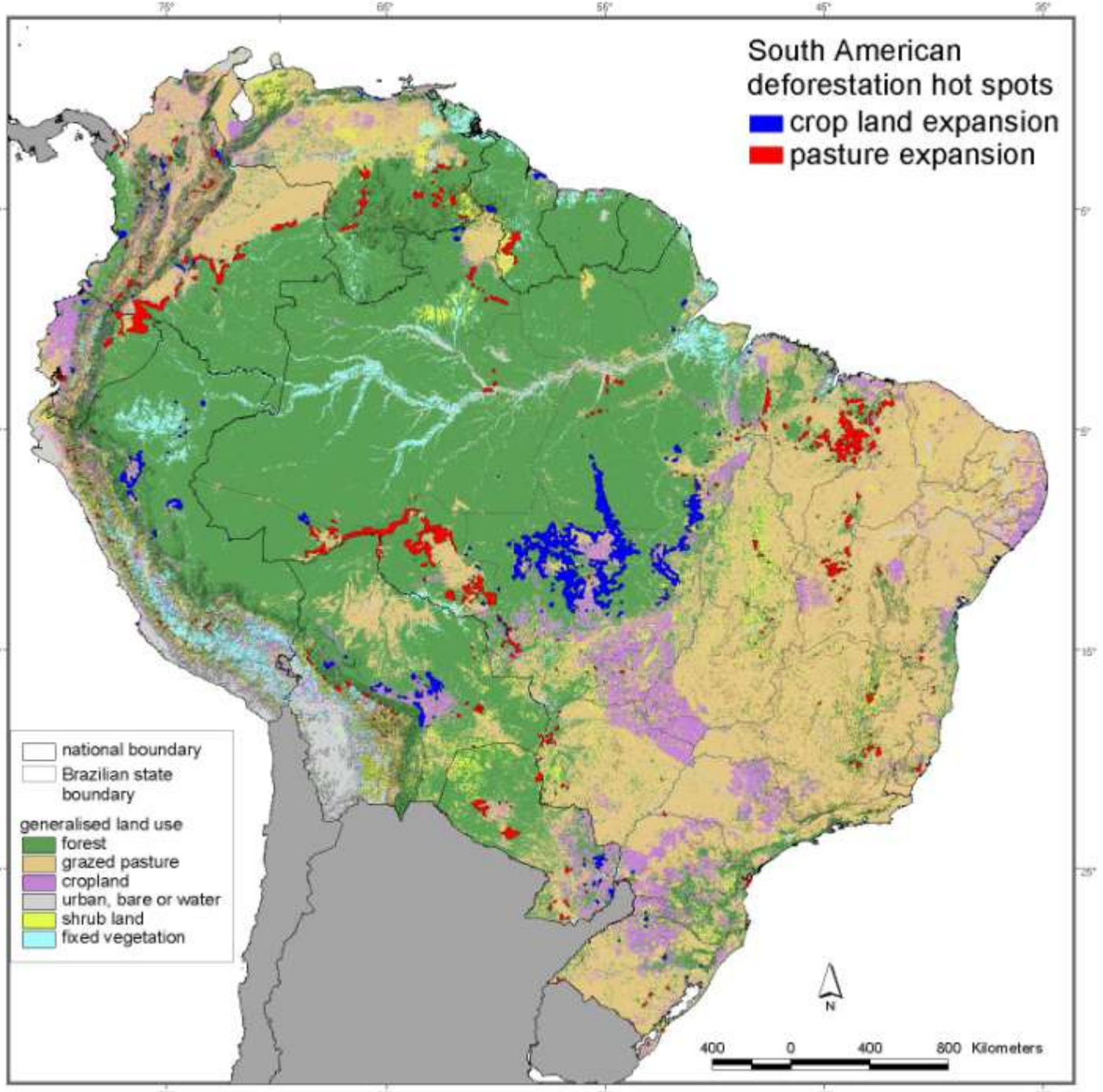
$$Log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 X_{1,i} + \beta_2 X_{2,i} \ldots\ldots + \beta_n X_{n,i}$$

Main parameters
Regression results
Change matrix
Neighborhood settings
Neighborhood results

Edit the regression equations (file: alloc1.reg)
Edit land use conversion matrix (file: allow.txt)
Edit neighborhood settings (file: neighmat.txt)
Edit neighborhood results (file: alloc2.reg)



Map of predicted agricultural expansion into forest

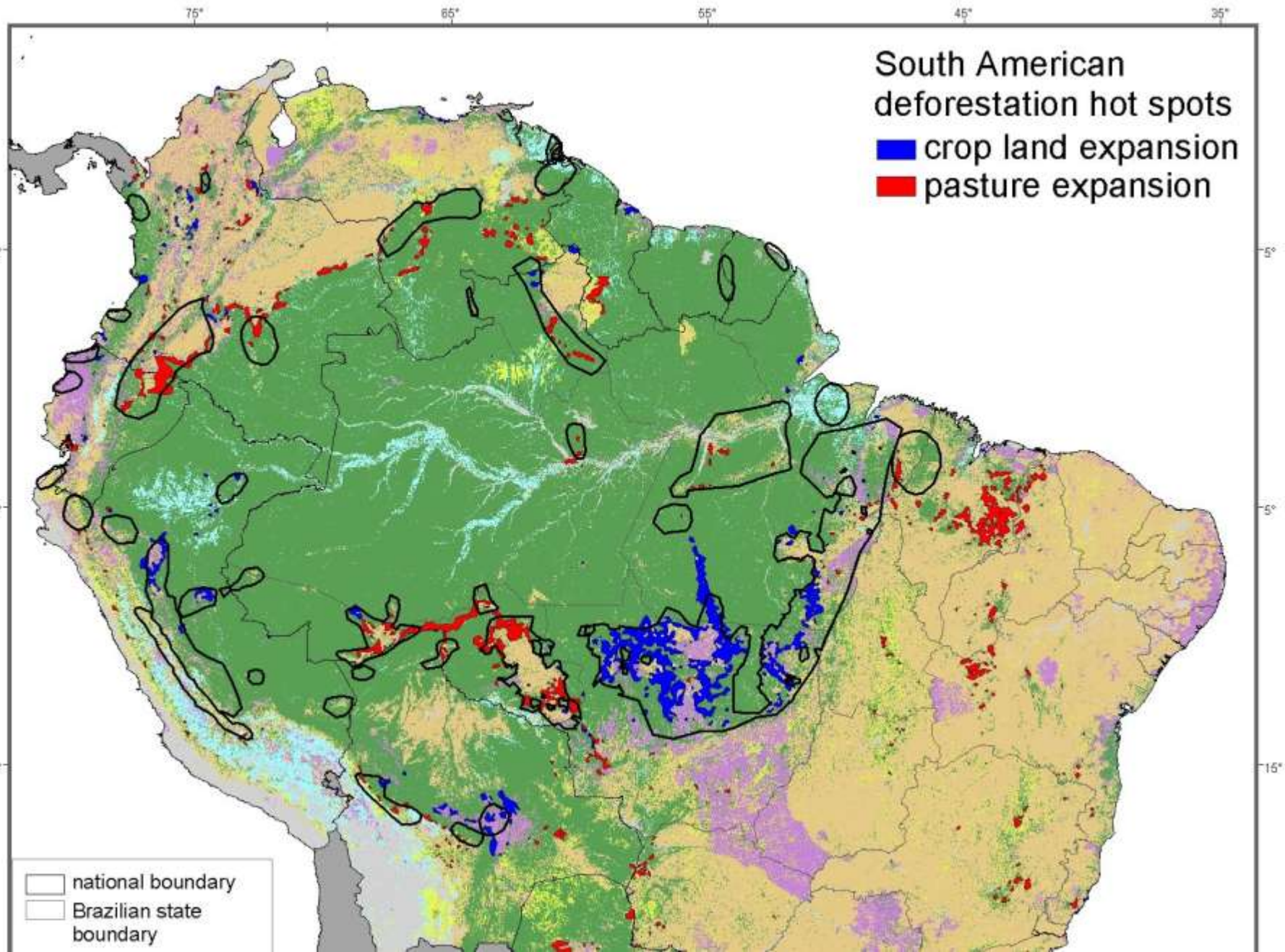


Netherlands

oij, March 2009

Validation (?)

Interesting coincidences and differences with JRC's TREES hot spots .



Scenarios Vietnam

(Based on National socio-economic development plan)

1: Baseline scenario:

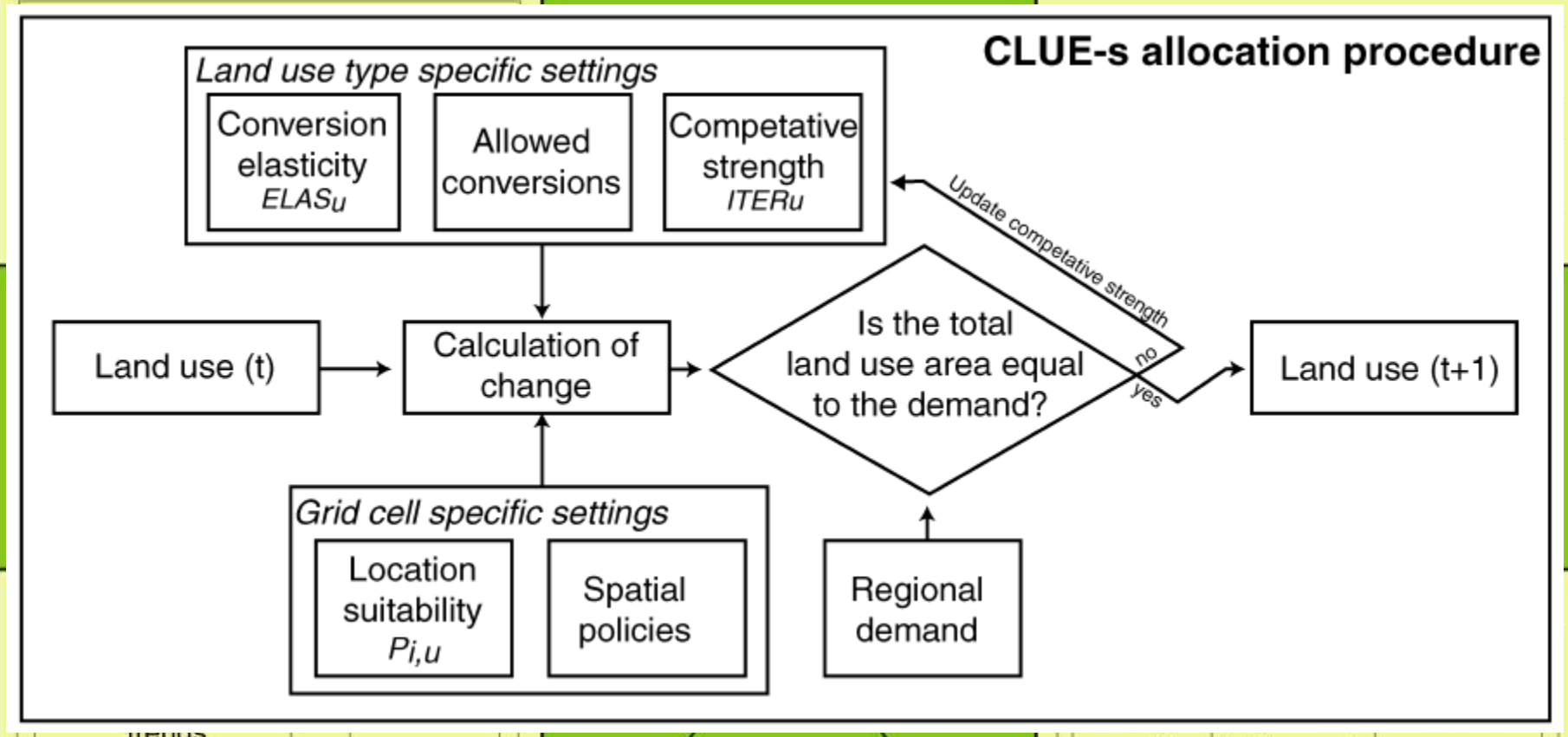
- Cropland demand: IMAGE OECD baseline scenario + 25% for 2030
  - Cropland diversification: extensive (80%) and intensive (20%)
- Plantation demand: increment of 500 km^2/year.
- Primary forest assumed to remain constant

2: Biodiversity conservation scenario (policy option):

- Primary forest: total forest cover (plantation + primary class) in 2030 will reach 40% of country land area
- **Protected areas (PAs)** increase from 7% to 10% of the land:
  - existing parks and primary forests above 1000 m
- Strict law enforcement (no LUC inside PAs)

Spatial policies and restrictions

Land use type specific conversion settings



trends

scenarios

advanced models

Aggregate land use demand

specific location suitability

Logistic regression

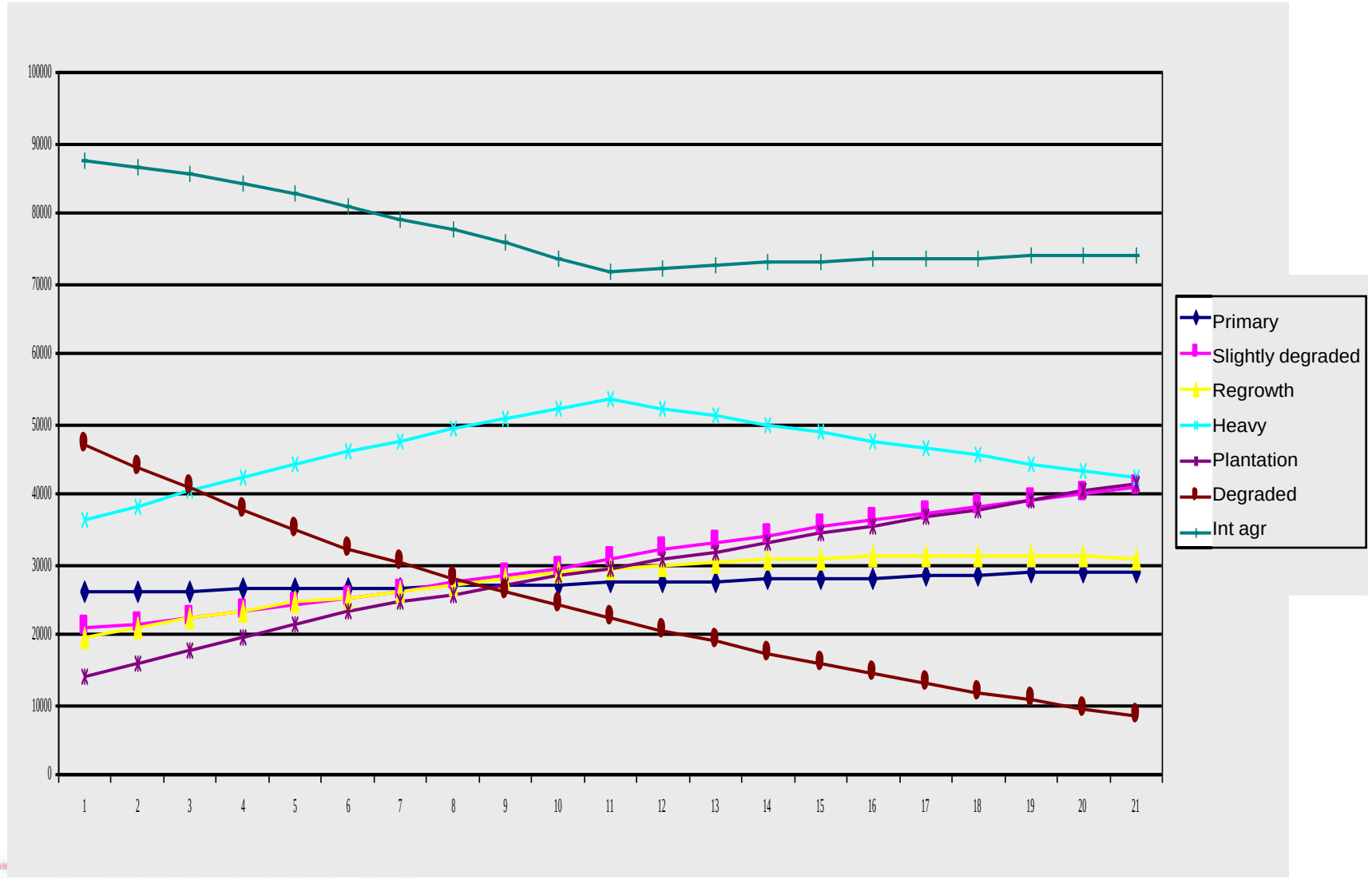
soil, accessibility, etc.

Forest scenario Vietnam used in Clue

Year		Primary forest	Slightly disturbed forest	Heavily disturbed forest	Regrowth shrub and bushes	Plantation	Shifting cultivation (ext.agr)	Degraded lands	Intensive agriculture	Residential and urban land	Nature	Others	Area
2000	0	26020	20763	36142	19691	13963	17846	47162	87488	11634	18229	28525	32,7463
2001	1	26124	21563	38226	21115	15830	15704	43870	86619	11657	18229	28525	32,7463
2002	2	26232	22411	40257	22375	17698	13820	40743	85493	11681	18229	28525	32,7463
2003	3	26344	23305	42238	23479	19565	12162	37772	84141	11704	18229	28525	32,7463
2004	4	26460	24244	44169	24434	21433	10702	34950	82590	11727	18229	28525	32,7463
2005	5	26581	25227	46052	25247	23300	9418	32269	80863	11751	18229	28525	32,7463
2006	6	26708	26253	47617	26254	24513	8288	30049	79254	11774	18229	28525	32,7463
2007	7	26839	27312	49143	27150	25727	7293	27939	77508	11798	18229	28525	32,7463
2008	8	26975	28404	50631	27940	26940	6418	25936	75644	11821	18229	28525	32,7463
2009	9	27117	29527	52081	28630	28153	5648	24032	73674	11845	18229	28525	32,7463
2010	10	27265	30682	53495	29225	29367	4970	22224	71612	11869	18229	28525	32,7463
2011	11	27418	31866	52255	29730	30580	4374	20506	72088	11893	18229	28525	32,7463
2012	12	27578	33013	51045	30148	31793	3849	18874	72492	11916	18229	28525	32,7463
2013	13	27743	34124	49865	30485	33007	3387	17324	72834	11940	18229	28525	32,7463
2014	14	27913	35200	48715	30745	34220	2981	15851	73120	11964	18229	28525	32,7463
2015	15	28089	36242	47594	30931	35433	2623	14452	73357	11988	18229	28525	32,7463
2016	16	28271	37250	46501	31047	36647	2308	13123	73551	12012	18229	28525	32,7463
2017	17	28457	38227	45435	31096	37860	2031	11860	73708	12036	18229	28525	32,7463
2018	18	28648	39171	44395	31083	39073	1787	10660	73831	12060	18229	28525	32,7463
2019	19	28844	40085	43382	31009	40287	1573	9520	73924	12084	18229	28525	32,7463
2020	20	29044	40970	42394	30878	41500	1384	8438	73993	12108	18229	28525	32,7463

2000 is the baseline derived from the current land use map. The rest are projections from a scenario

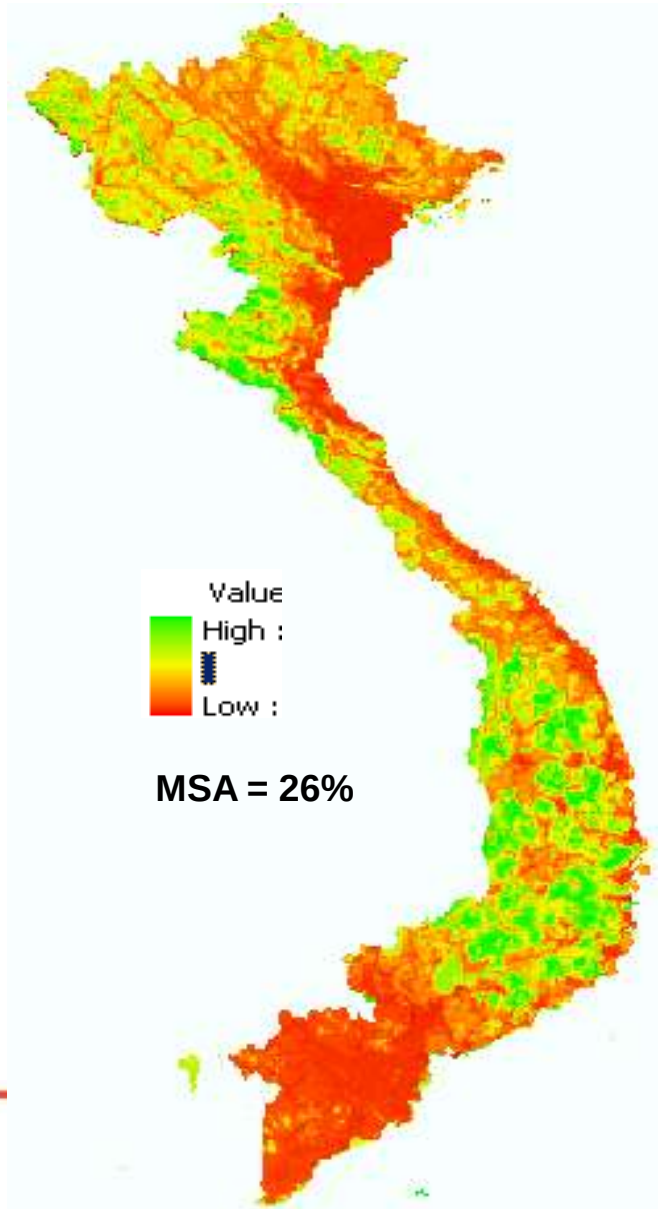
Forest scenario Vietnam used in Clue



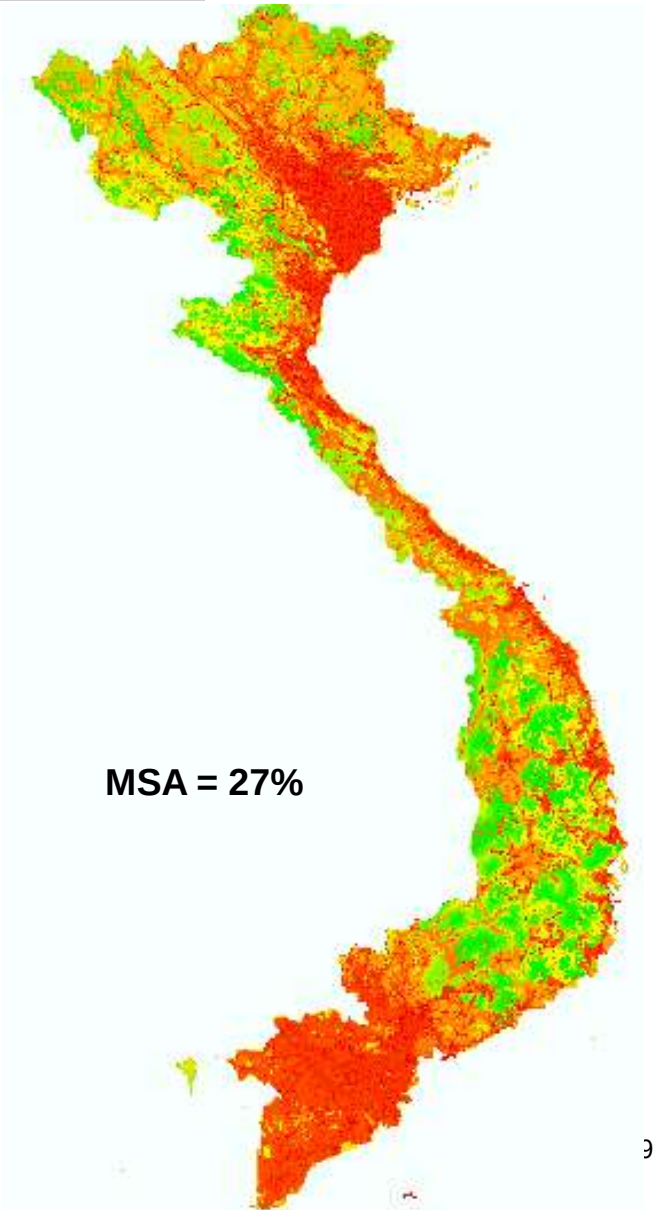
MSA trend Vietnam

2000

2030



MSA = 26%



MSA = 27%