

Integrated land use modelling in an interdisciplinary project: The LUCIA framework

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Overview



1. Project framework
2. Model scope
3. Model framework
4. Technical information
5. Coupled and standalone version
6. Model environment
7. User interface

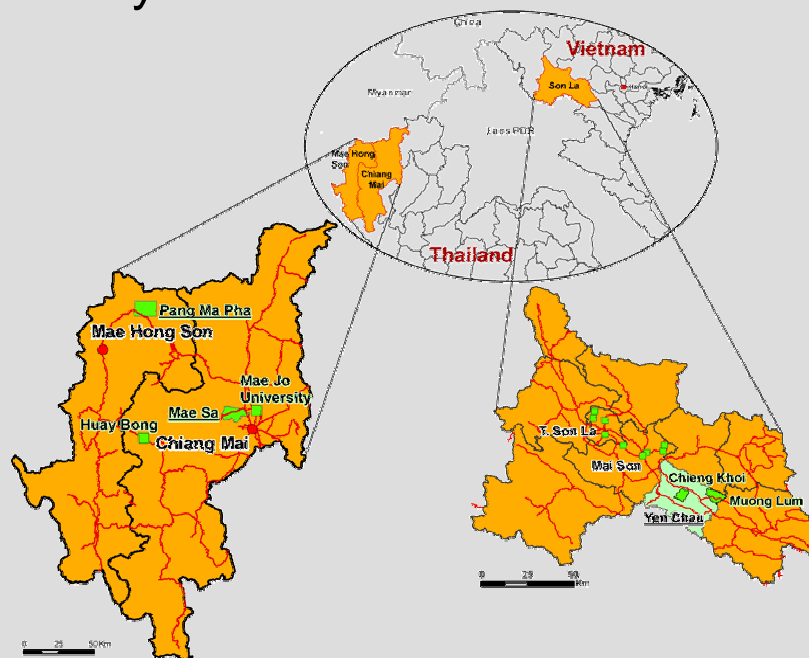
Project



Institutional framework:

- **University of Hohenheim**
- **Chiang Mai University**
- **Kasetsart University**
- **Mae Jo University**
- **Silpakorn University**
- **Thai Nguyen University of Agriculture and Forestry**
- **Hanoi University of Agriculture**
- **National Institute of Animal Husbandry**

Study sites



- **Developing and testing sustainable land use, production and processing systems;**
 - **Modelling approach**
- **Identifying *innovative approaches* for research of ecological systems considering *complex interactions* between ecosystems, ethnic diversity and institutional frameworks; *interdisciplinarity*;**
 - **Integration of biophysical and socio-economic models**
- **Elaborating concepts for rural institutions to solve problems of rural *poverty and food insecurity* in mountainous regions of Southeast Asia.**
 - **Stakeholder orientation**

Situation on site

Population pressure,
socio-economic change



Deforestation

Intensification:

Model scope:

Spatially and temporarily quantify interactions between upland and lowland ecosystems.

Project impacts of land use change on environmental functions and household decision-making (and vice versa).

Test alternative land use options

**Balanced swidden system: Upland export + regeneration
=> Massive erosion, top soil loss, declining soil fertility.
Siltation of lowlands.**

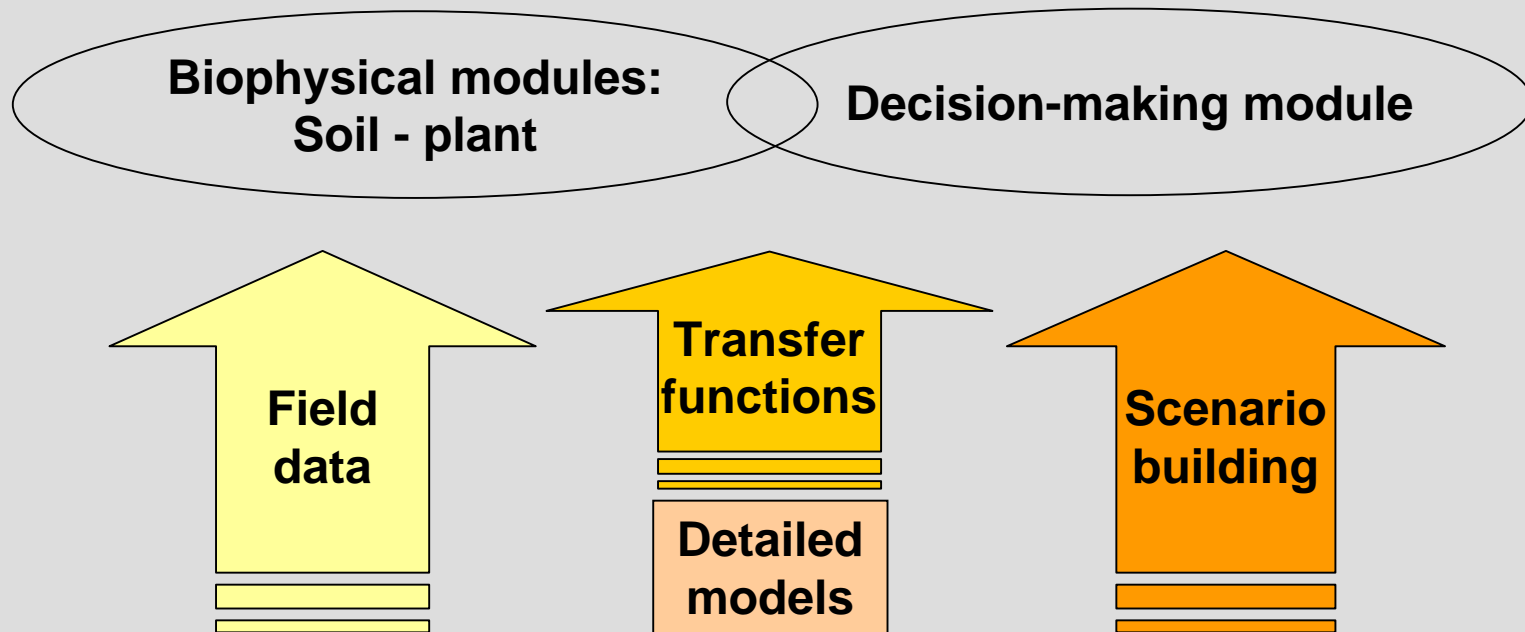
Potential scenarios



Different catchments along a gradient of agricultural intensification

	Pang Ma Pha (TH)	Muong Lum (VN)	Chieng Khoi (VN)	Mai Son (VN)	Son La (VN)	Mae Sa up (TH)	Mae Sa mid (TH)
Indicator crops	Upland rice, maize	Maize, cassava	Paddy rice, maize	Sugarcane, maize	Vegetable	Litchi, cabbage	Sweet pepper
Indicator animals	Local pigs, buffaloes	Local pigs, cattle	Improved pigs, fish, cattle	Pigs	Exotic pigs	-	-
Market integration							
Challenges f. sustainable land use	Forest loss, erosion		Erosion, floods, water contamination, limited feed resources			Water & soil quality, agrochemical residues	
Options, innovations	Soil and water conservation, fruit-based agroforestry, improvement of aquaculture			Improved breeding & feeding schemes, high-value agricultural markets		Value-adding by certified production, processing & marketing	

Subproject linkages



The data base:

Land cover, topo, soil, discharge, erosion, pesticides, farmers' preferences, household economy, innovations

The framework



Land Use Change Impact Assessment tool

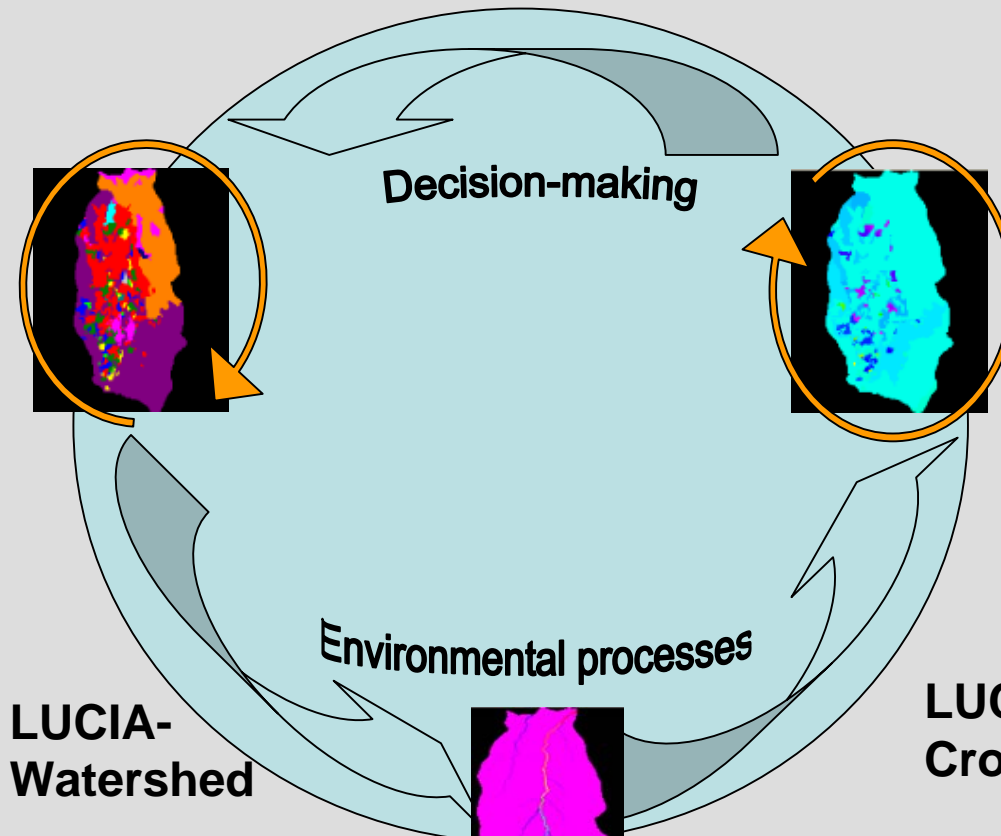
Outputs:

LUCIA-Choice

Decision-making

Growth limitations
Crop yield
Forest development
C sequestration

Economic outputs
Land use change



LUCIA-Crop

Water, soil resources
for plant growth

Erosion / deposition,
reservoir siltation

LUCIA-Watershed

Technical data

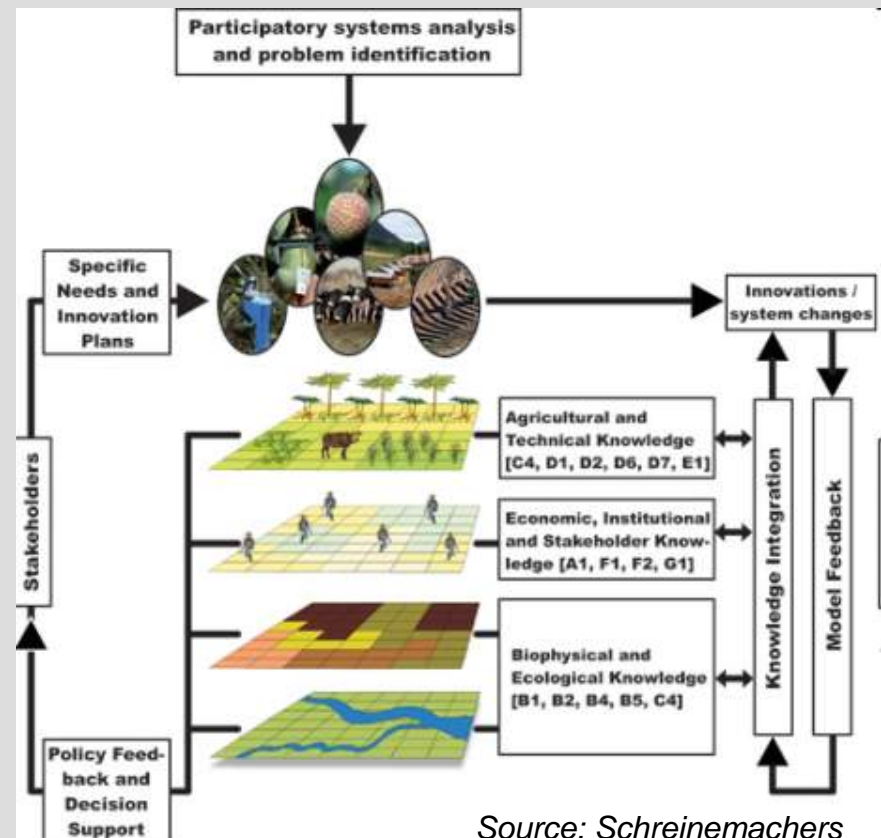


Software requirements for the biophysical core model:

- **Spatially explicit dynamic model environment to integrate different data layers and time steps**
- **Easy to program**
- **Compatibility to other software**

PCRaster (v. *Deurssen* 1995):

- **GIS**
- **Modelling language**
- **Aguila visualisation**
- **Gstat (geostatistics)**
- **Python framework (*Schmitz et al.* 2009)**



Source: Schreinemachers

Biophysical core modules



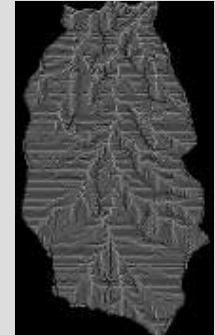
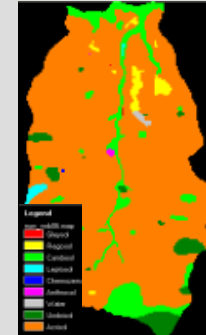
Soil & Water

Concepts: GenRiver (v. Noordwijk et al. 2003), KINEROS2 (Woolhiser et al. 1990)

Inputs: Soil map, SOC, $N_{T/min}$, P_{Bray} , K, BD, texture

Pedotransfer functions: Ksat (Saxton & Rawls 2006)

Routing algorithms: PCRaster (DEM, LDD, accu)

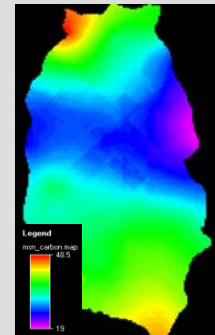


SOM

Metabolic and structural litter, active, slow and passive SOM

Concept: CENTURY (Parton et al. 1988) + K

Inputs: C:N, C:P ratios, k_f rates, initial stocks



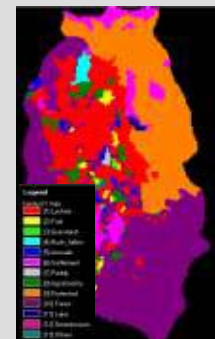
Land cover

Type: Stand level, single cropping

Concepts: WOFOST-CGMS (Supit 2003), including trees

Hierarchical model: Assimilation, N, P, K, water limitation

Inputs: LU map, plant physiology, development stages, management

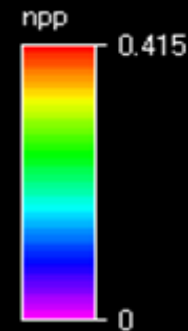
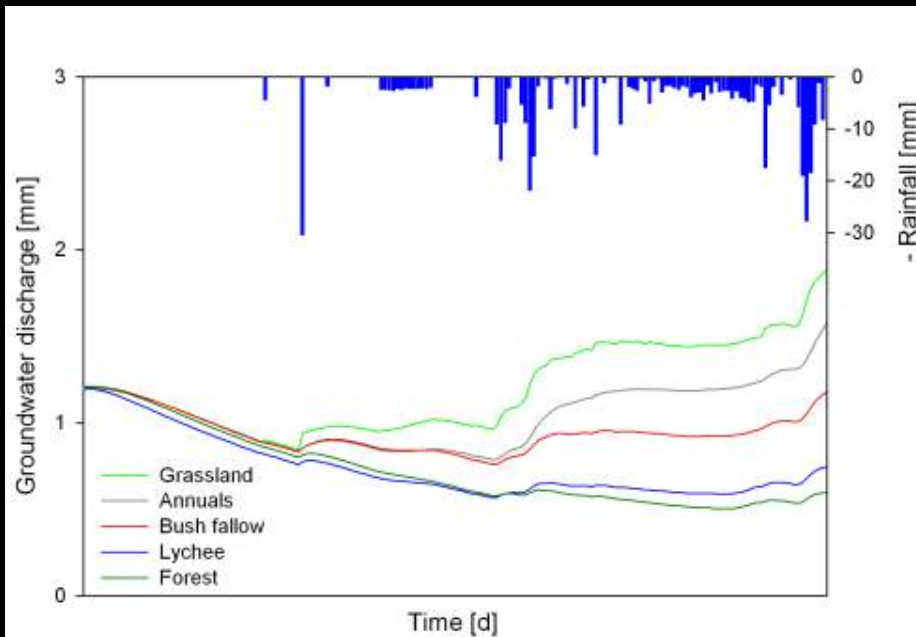


Daily time step, pixel size = plot size

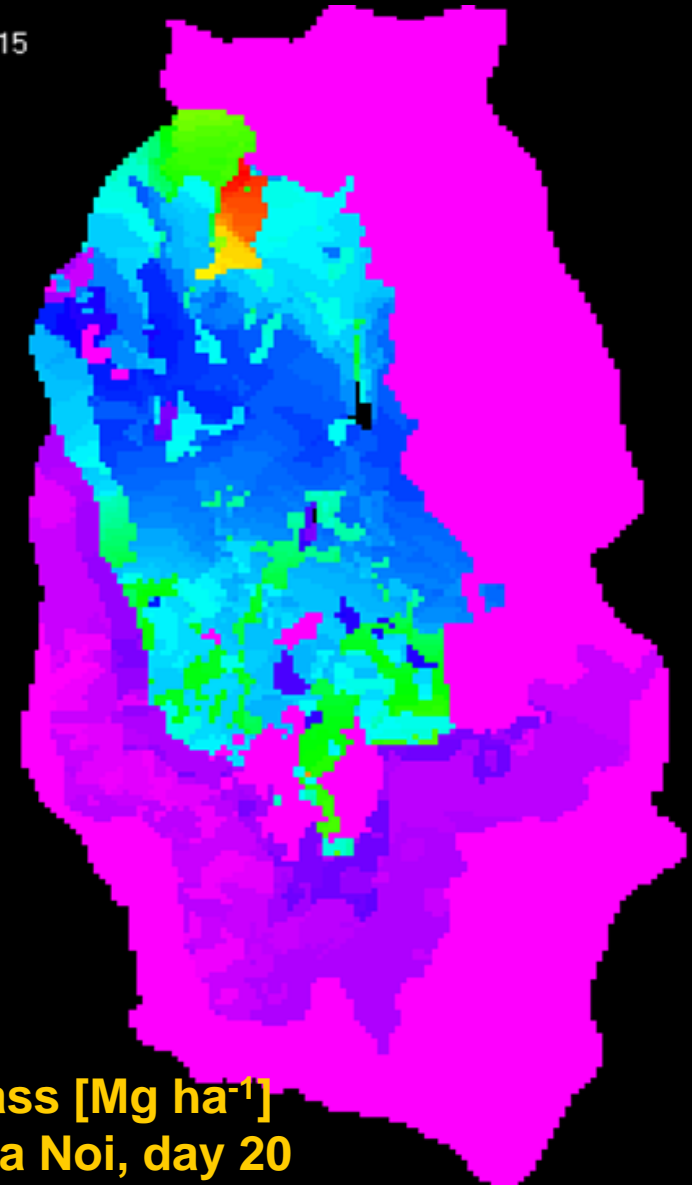
Biophysical outputs



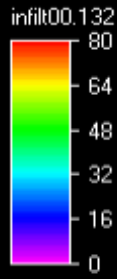
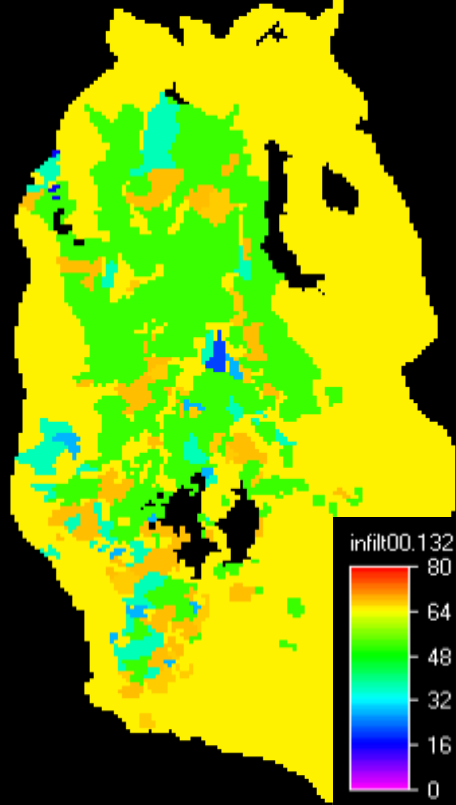
Groundwater discharge [mm d^{-1}] under different LU in Mae Sa Noi



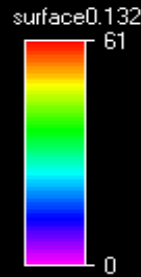
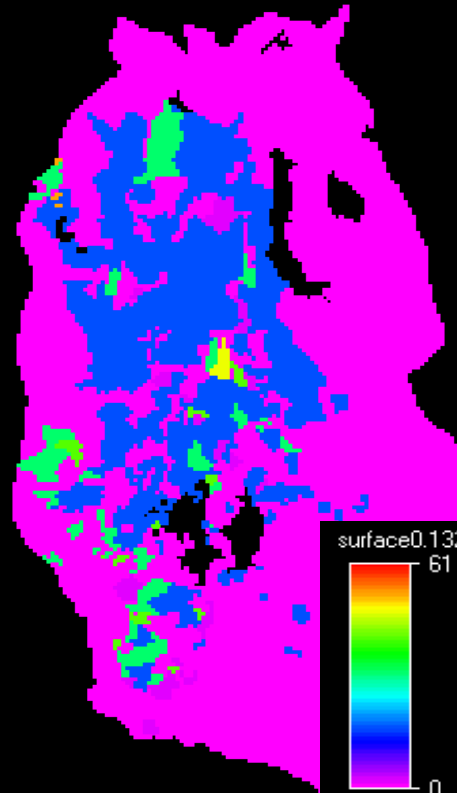
Biomass [Mg ha^{-1}] Mae Sa Noi, day 20



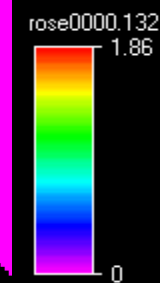
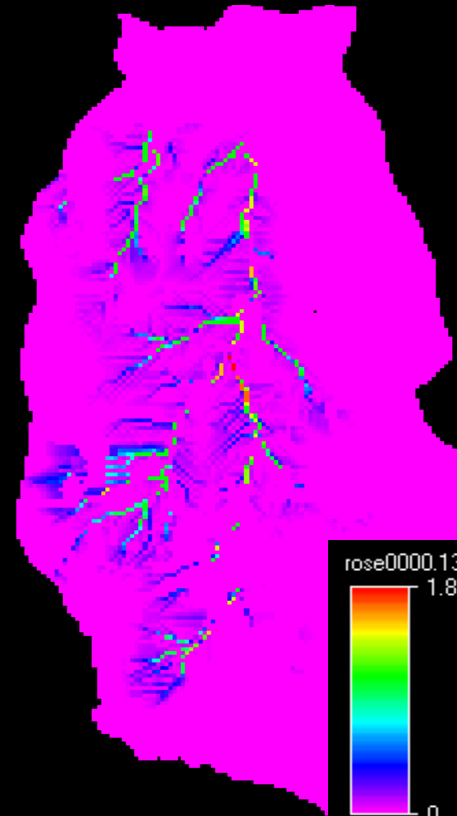
Mae Sa Noi
Rain event, 67.9mm
Mae Sa Noi watershed ~10km²



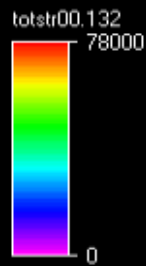
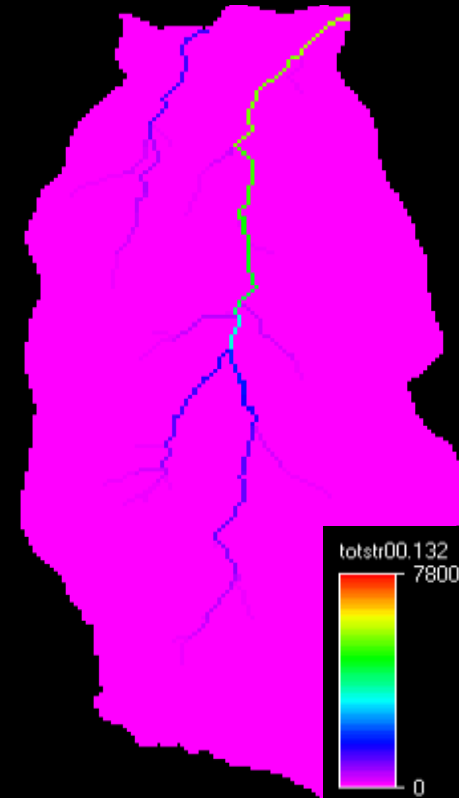
Infiltration [mm]



Surface runoff [mm]



Rose erosion [kg m⁻²]



Streamflow [m³d⁻¹]

MP-MAS:

Decision rules for plot selection

Optimisation for economic profit (solver)

High input requirements

Complementarity: No decision-making in LUCIA so far; MP-MAS plant module switched off, detailed inputs from LUCIA

LUCIA-Choice:

Less detailed, less data intensive, open source

Farmer rules rather than economic optimisation

- **Soil fertility**
- **Land suitability**
- **Cultural preferences (neighbourhood operators)**
- **Cost-benefit calculation**

LUCIA Choice – concept



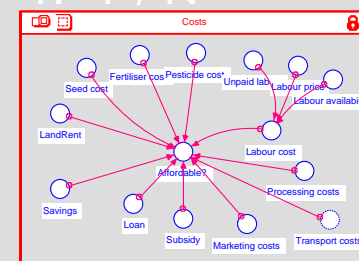
1. Step: Identify possible land cover types per pixel

Land suitability per pixel based on crop-specific requirements:

- Rootability, texture
- Irrigation, elevation
- SOM, N, P, K (fertiliser, manure?)
- Land, labour, financial capital
- Knowledge



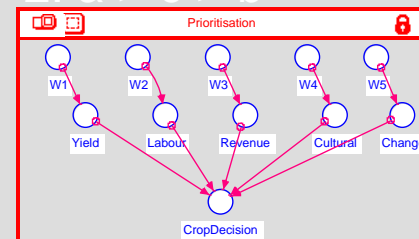
1: Y/N



2. Step: Prioritise among the possible choices

- Yield (subsistence)
- Profit (market / payment)
- Labour minimisation
- Cultural acceptance
- Resistance to change / neighbourhood influence
- Land accessibility

2: $a > c > b$



Stakeholders and users



Stakeholder interaction

- **Scenario development**
- **Plausibility validation**
- **Discussion of outputs and land use recommendations**
- **(Modelling)**

Potential model users

- **Planners (authorities, NGO)**
- **Students (future planners), researchers**
- **Farmers?**

A modeller's capital is the user community => user-friendly GUI

User interface



MainWindow File Edit Help

Initialisation Maps Landuse Soil Funktionen NPK in Plants Weather Fertiliser Manure PTF Succession Irrigation

Show Map Current map:

Landuse typs:

Name	Landuse ID	Fertiliser	Water	Consider	Annual	Irrigation	Manure	Terrestrial	Succession
1 Forest	1	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
2 Maize	2	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
3 Grassland	3	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
4 Rice	4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>

New Delete Load

Name	Landuse ID	Plantingday One	Plantingday Two	Plantingday Three	I_TDBase	I_TDMaxOne	I_TDMaxTwo	DD2Flower	DD2Harvest	I_MaintResp	Rootmax	I
1 Forest	1	1	0	0	8	35	37	800	950	0	250	1
2 Maize	2	55	0	0	8	40	42	600	990	0	80	0
3 Grassland	3	1	0	0	10	38	41	400	700	0	40	0
4 Rice	4	50	230	0	12	40	42	590	800	0	40	0

Apply

Guidance, initialisation and PTF calculations, input validation, better integration into model environment.

Model environment



Selection criteria:

- **Active developer community; freeware, open source, platform independent**
- **Compatibility of formats**
- **Coupling in / out single modules**
- **Allows integrating different time steps (hour / day / year)**

Man in the street version: Python: Relatively easy to learn, PCR compatible

[Software-wise many things are possible: PCR-excel-Python-TDT-MP-MAS...
The challenge is consistency of concepts and links (book-keeping)]

Conclusions and outlook



Characteristics of LUCIA as land use change model:

Daily time step

Process-based

Spatially explicit (no aggregation) at user-defined pixel size

Dynamic ecosystem linkages within landscape

Relatively low data requirements

User friendly

Next steps:

- **Erosion**
- **Multicropping**
- **Paddy**
- **Controlling of modules and data exchange**

Acknowledgements



Thank you for your attention!

Y.Z. Ayanu

O. Zemek

N.T. Thanh

I. Chukwumah

J. Quenzer

C. St. Macary

T. Hilger

Deutsche
Forschungsgemeinschaft

DFG

Models

Integrated Modeling | **Models** | Model Coupling

LUCIA <https://www.uni-hohenheim.de/sfb564/data/lucia.php>

1. Model Structure
2. Input Data
3. Outputs
4. Outlook

[Documentation of the LUCIA model \(PDF\)](#)

The Land Use Change Impact Assessment tool LUCIA was developed to depict and analyse landscape processes relevant for upland - lowland interrelationships in a dynamic and spatially explicit way. This includes the assessment of impacts of land use intensification on spatial distribution of soil fertility and crop productivity as well as projection of potentials for development along gradients of land use options as shown above.

Specific objectives of LUCIA development are thus to capture flows of water and other substances (soil, agrochemicals etc.) between upper and lower areas in watersheds and to simulate influences of these flows on plant / crop growth.

Fig. 1: Landscape processes analysed in LUCIA

LUCIA is written in PCRaster, a high level dynamic modelling language. PCRaster code includes GIS functions as well as model algorithms. Maps can be converted into ASCII files and are then compatible with any other GIS software.



NRCT



MOST

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