Welcome to today's public webinar!

"Mapping future land-use and land cover patterns"

15 February 2024, 13:00-14:00 CET, online

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Agenda –15 February 2024

13:00-13:05	**Brief introduction of the Europe-LAND project**
	Franziska Wolf (Hamburg University of Applied Sciences, Germany - HAW)
13:05-13:20	**Land use/Land cover modelling perspective to identify and manage climate change impacts and support biological diversity: forested areas, wetlands**
	Maris Klavins, Karina Stankevica and Janis Krumins (University of Latvia, Latvia - LU)
13:20-13:35	**Modelling land use/land cover changes using CLUE-S. Applications in Romania** *Gheorghe Kucsicsa (Romanian Academy, Institute of Geography, Romania - IGAR)*
13:35-13:45	**Database on existing LU/LC patterns and Database on LU/LC modelling tools – current state and further development**
	Lucie Kupkova (Charles University, Czech Republic - CU)
13:45-13:50	**Land use changes of wetlands from the perspective of stakeholders**
	Ingrida Krigere (Latvia‘s Peatland Association, Latvia)
13:50-14:00	**Q&A and end of the webinar**

15 February 2024, online

Speaker:
Franziska Wolf, Hamburg University of Applied Sciences, Germany

"Introducing the Horizon Europe project "Towards Sustainable Land-use Strategies in the Context of Climate Change and Biodiversity Challenges in Europe"

Europe LAND

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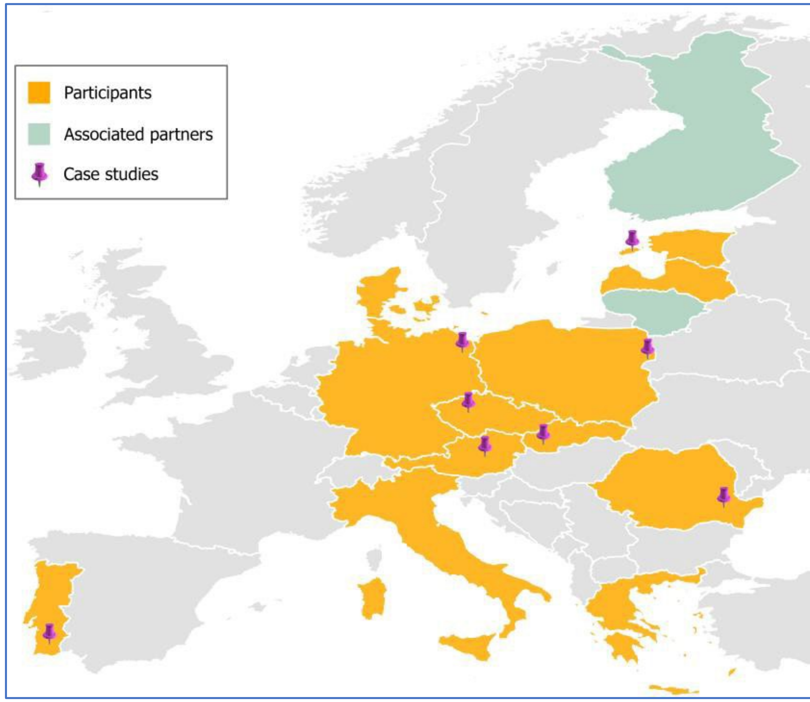
Europe-LAND in a nutshell



- **Consortium**: 13 partners (12 countries, 8 cases), 2 Associates (FIN, LIT)
- **Duration:** 1 June 2023 til 31 May 2027

Main Objective:

to identify, develop, test and implement integrated tools to **improve the understanding of the factors behind land-use decisions** as well as the **stakeholders' awareness and engagement** in terms of climate change and biodiversity challenges across Europe.

This includes **increasing the knowledge base** on how such decision can be oriented towards the efficient and socially responsible pursuit of multiple policy objectives on various scales in order to **gain a national, regional and pan-European vision** that supports land-use strategies, climate change mitigation and adaptation, as well as biodiversity conservation.

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Methodology

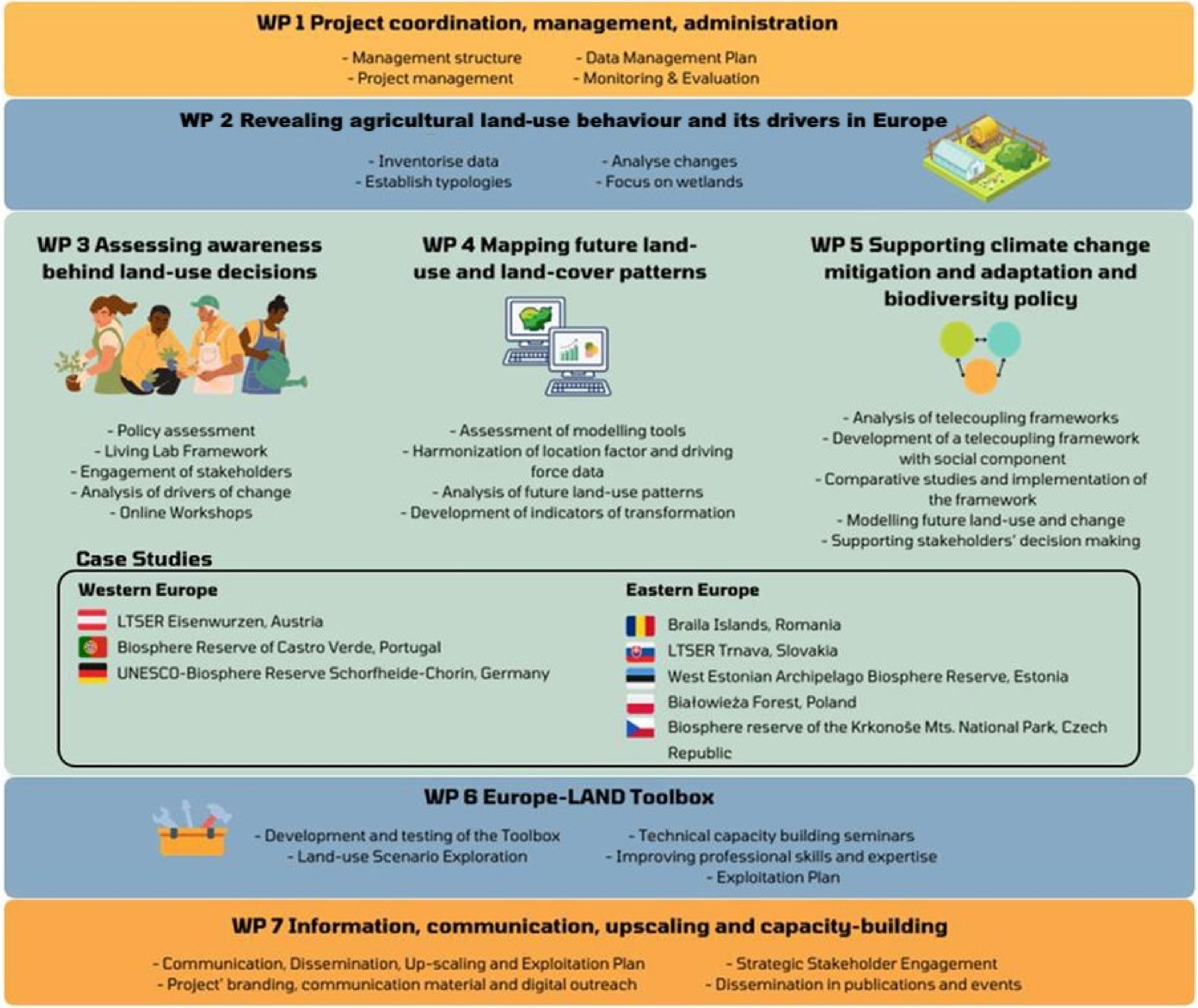
Tasks include:

- **national-level analyses** (e.g. harmonization of fragmented European data) - **land use/land management surveys**,

- **modelling** of land-use changes (basis: CLUE model), complemeted by

- **cross-cutting feature: 8 local cases** (allowing for East-West comparison) as demonstrators and

- **capacity-building** (open access!)



Save-the-dates
Upcoming project activities

- **14 Mar 2024 – Europe-LAND's 5th public webinar on "Introducing the Europe-LAND Case Studies"**
- **18 Apr 2024 – Europe-LAND's 6th public webinar on "Exploring the potential of Telecoupling for improving European land management"**
- **16 Apr 2024 - for EU Research Projects + EU Policy Officers only: EU Science Policy dialogue** (online)
- **Meet our researchers at the following conferences:**
  - 24-27 June 2024: 10th Nordic Geographers Meeting, Copenhagen, Denmark
  - 26-28 June 2024: IAMO Forum – the functions of land in times of change, Halle, Germany
  - 24.-30 Aug 2024: 35th International Geographical Congress 2024, 24th to 30th August 2024 in Dublin, Ireland

All events are announced on the project website **www.europe-land.eu**

Thank you for your attention!

Team Hamburg
Prof Walter Leal, Franziska Wolf, Jasmin Röseler, Dominique da Silva

Hamburg University of Applied Sciences, Research and Transfer Centre „Sustainable Development and Climate Change Management“, Ulmenliet 20, D-21033 Hamburg, Germany
Contact: info@europe-land.eu

Project website: www.europe-land.eu

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HAW HAMBURG

15 February 2024
Maris Klavins, Karina Stankevica, Janis Krumins
University of Latvia

Land use/Land cover modelling perspective to identify/manage climate change impacts and support biological diversity: forested areas, wetlands

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WP 4 Mapping of Future Expected Land Use and Land Cover Patterns Consistent with Long-Term Objectives

Objective: To undertake the mapping of future expected land use, with a focus on **climate change** and **biodiversity** challenges, and by analysing the current situation and future trends

Aim: Assessment of land use and land cover (LU/LC) change spatial modelling tools and databases, considering impacts of climate change, mitigation potential and biodiversity

Aim: Gathering and harmonisation of location factors and driving force data and related transition role development

Past LU/LC change (-2023)

- CORINE, USGS Land Cover data base

Driving factors (DFs) of change

- Environmental factors: e.g., *topographic related-; climate related-indicators…*
- Demographic factors: e.g., *population growth; population density; migration-related indicators…*
- Economic factors: e.g., *employees; livestock breeding…*
- Accessibility: *e.g., distance to settlements; distance to towns; distance to roads…*
- Other: e.g., *policy regulation*

assessing LU/LC pattern change for the main LU/LC categories:

- *total amount of change*
- *annual rate of change*
- *linear trend of change*

(binary) logistic parametric model (!)

assessing the effect of DFs on each LU/LC category to:

- *estimate the influence: direct(+) / inverse(-)*
- *estimate the explanatory power: low / high*
- *to rank DFs*

To estimate the contribution of determinant factors of LU/LC change

Aim – to evaluate how the static and dynamic driving factors trigger LUC change and to provide scenarios to estimate the magnitude and location of LUC transitions, according to the specific environmental and socio-economic conditions in order to provide a better understanding of LUC trajectories and, therefore, to adopt appropriate land-use planning and strategies in relation to climate change and environmental policy; a CLUE- S, TERRSET or other model approach of future expected changes, considering transitions towards sustainability, will be performed as case study

Aim - define a set of standardized indicators of LU/LC transition for the purpose of future monitoring if the desirable trajectories are followed. Data source and methods to calculate these indicators will be stated, and the indicators will be published and offered to the EU authorities for the monitoring of land-use change and evaluation of its sustainability.

Task 4.1 + 4.2

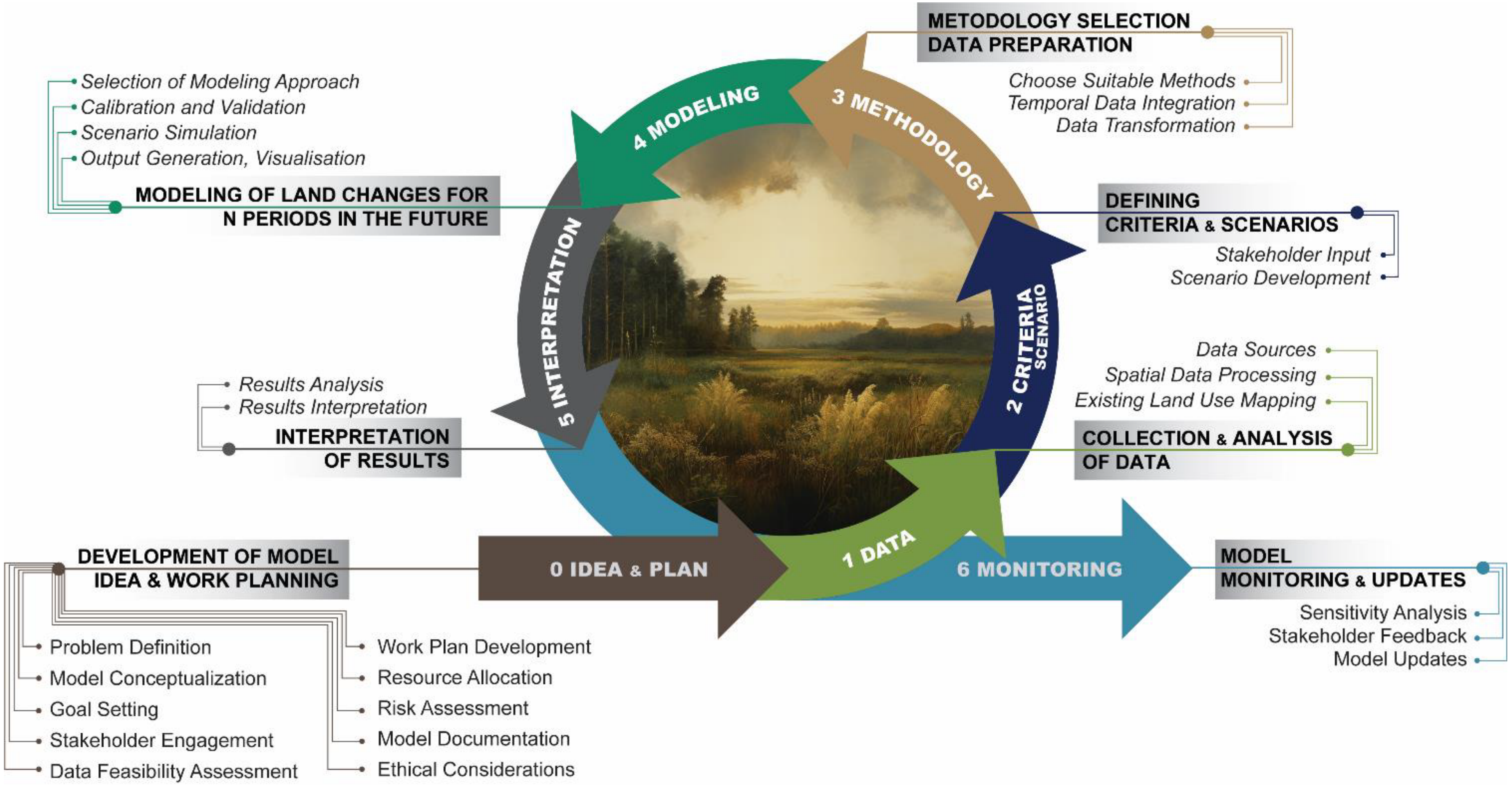
Task 4.3

Past LU/LC change
(national level)
Data coverage: >1990

Driving factors of change
(national level)
- Environmental
- Demographic
- Economic
- Accessibility

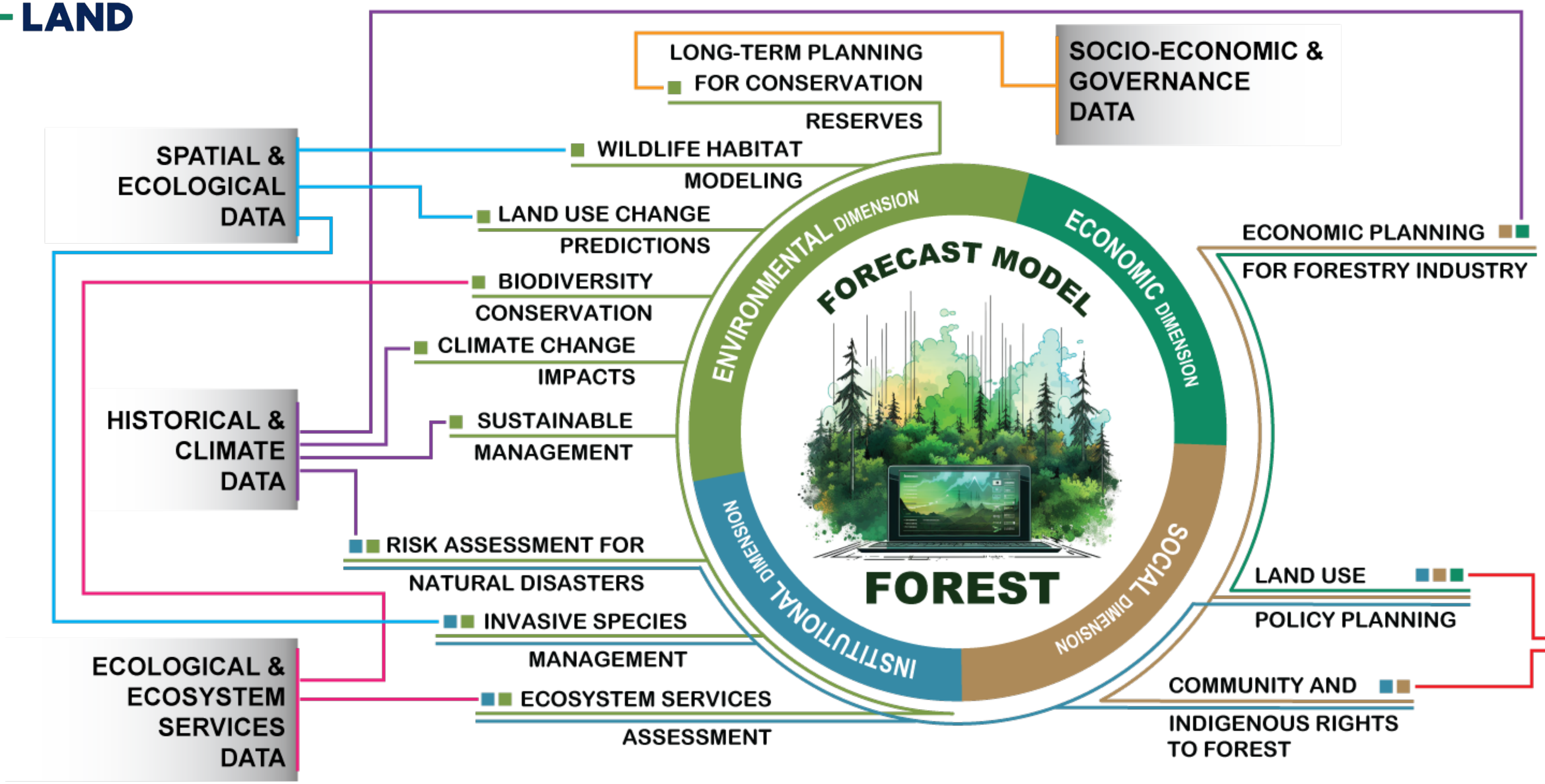
Future LU/LC change
(national level)
- Baseline scenario
- Hypothetical scenarios

Development steps for LU/LC forecast model



Development LU/LC forecast model:

0 Idea & Plan



This section covers the initial stage of developing a predictive model, which includes defining the problem, setting goals, interacting with stakeholders, and many other key aspects.

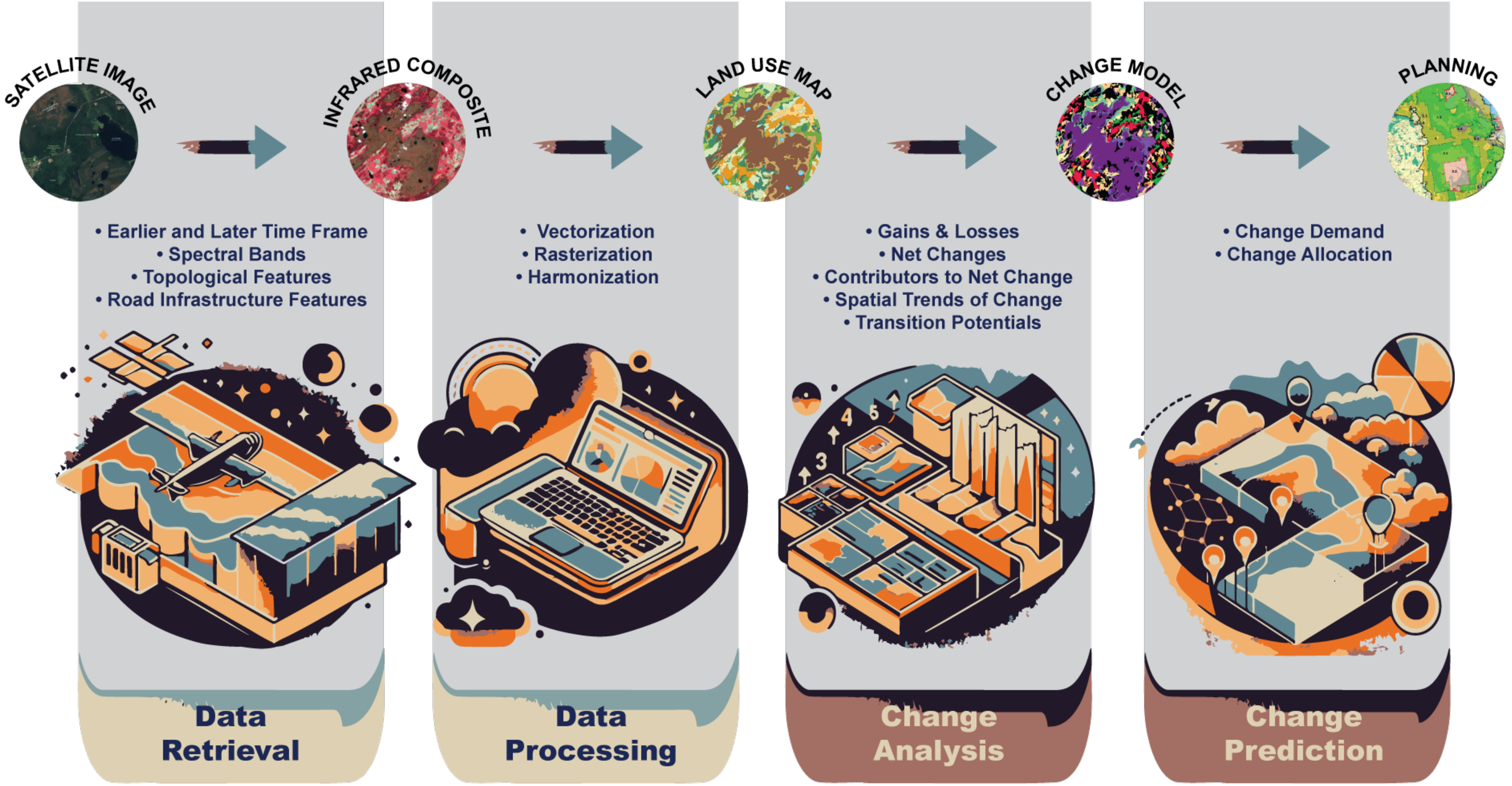
Development LU/LC forecast model:

1 Collecting & Preparing Data

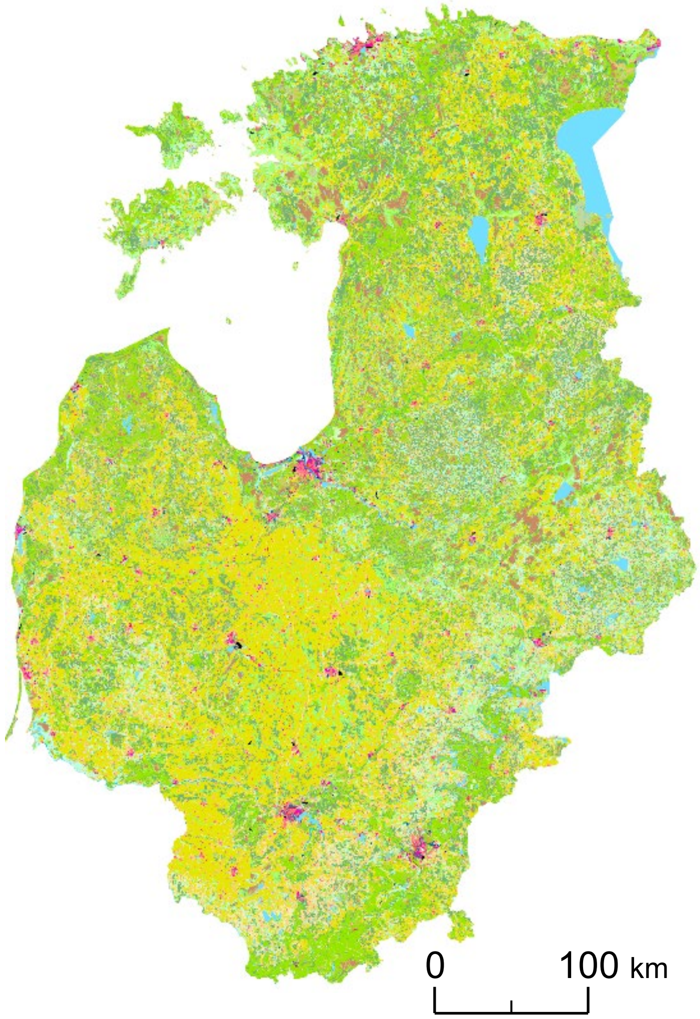
Critical Phase in Predictive Model Development

- **Data Sources**: Diverse sources including remote sensing, GIS, field surveys, and climate data.
- **Spatial Data Processing**: Steps such as cleaning, integration, and standardization to ensure data quality.
- **Mapping Existing Land Use**: Classifying land cover types and identifying regions of interest for baseline modelling.

Workflow for LC Analysis & Prediction

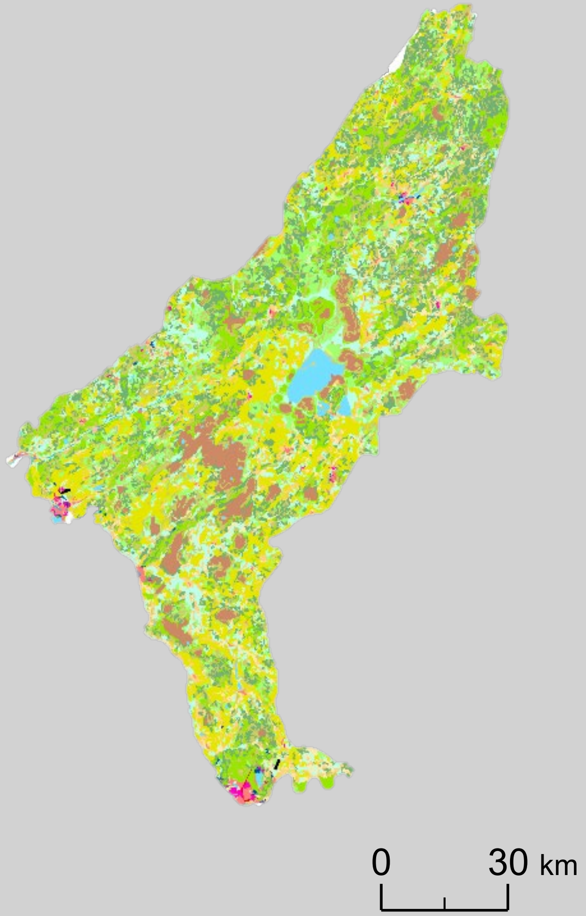


Regional Scale



Baltics

Local Scale



Aiviekstes Zeme

Case Study Polygon

Teiči Strict Nature Reserve

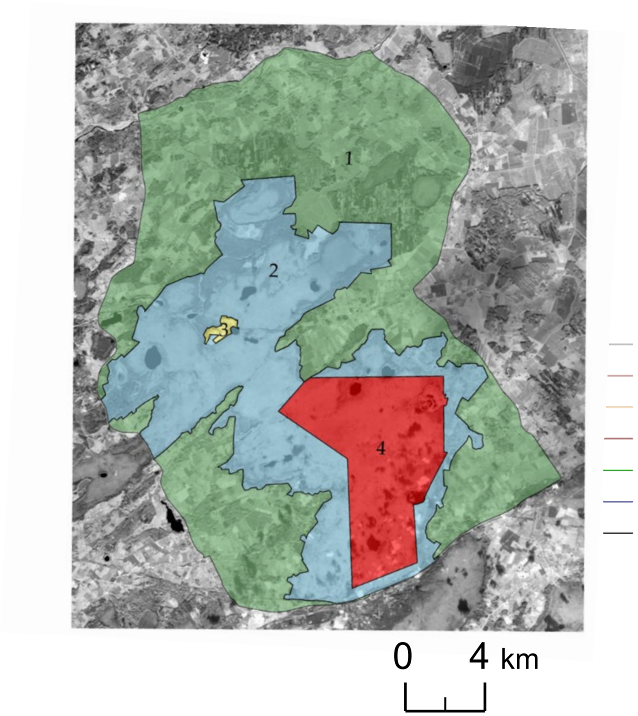
Case Study Area - Teiči Strict Nature Reserve


Author: Julita Kluša

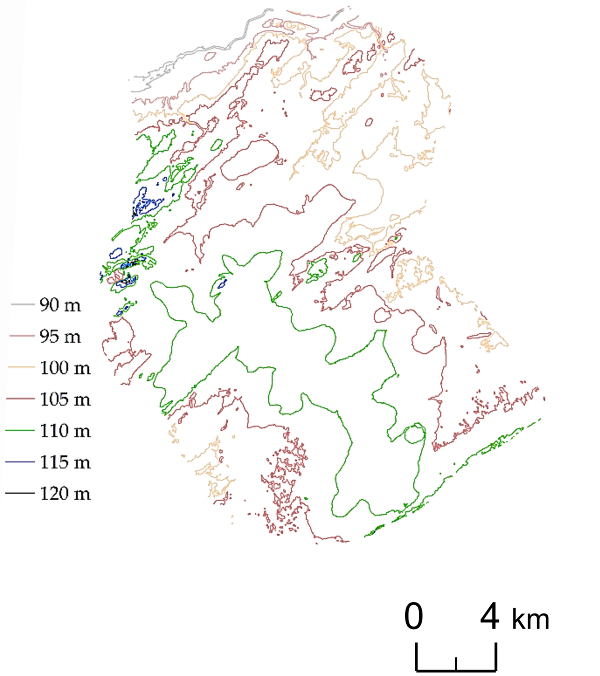
- **Strict nature reserve** – wetland, Ramsar site, unique ecosystem, of importance for biodiversity protection from regional perspective
- **Highly vulnerable** to climate change impacts
- **Human activities** might have major consequences

Teiči Strict Nature Reserve

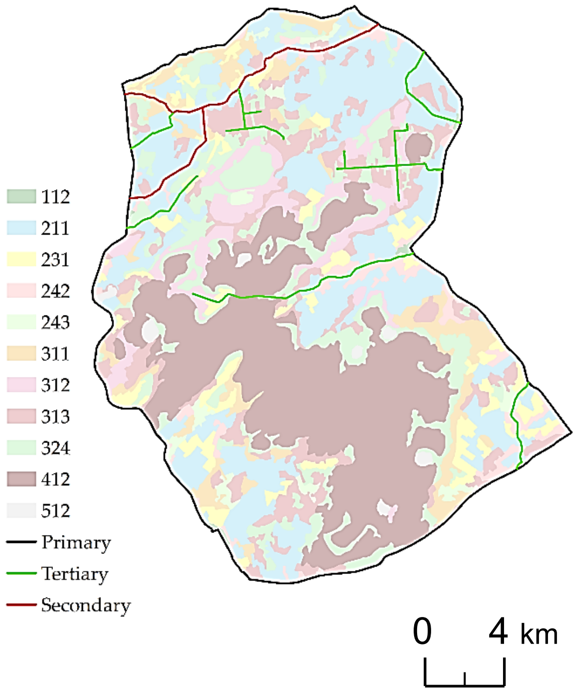
112	discontinuous urban fabric	311	broad-leaved forest
211	non-irrigated arable land	312	coniferous forest
231	pasture	313	mixed forest
242	complex cultivation pattern	324	transitional woodland-shrub
243	land principally occupied by agriculture	412	peat bog
		512	water body



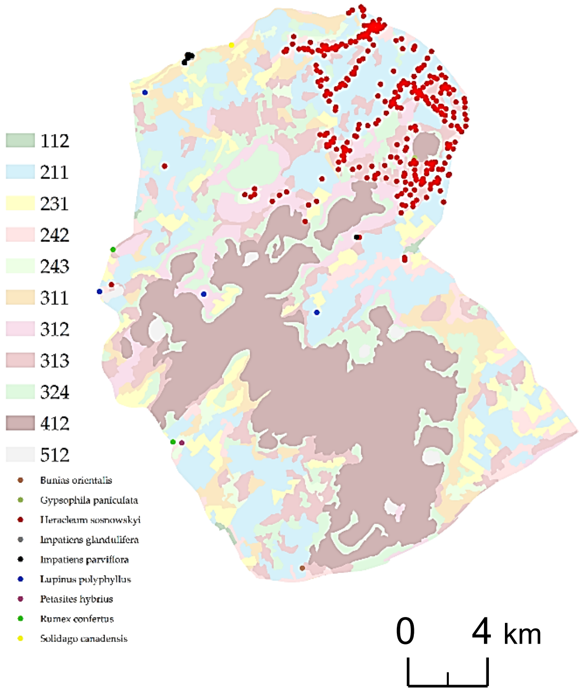
Zoning



Elevation

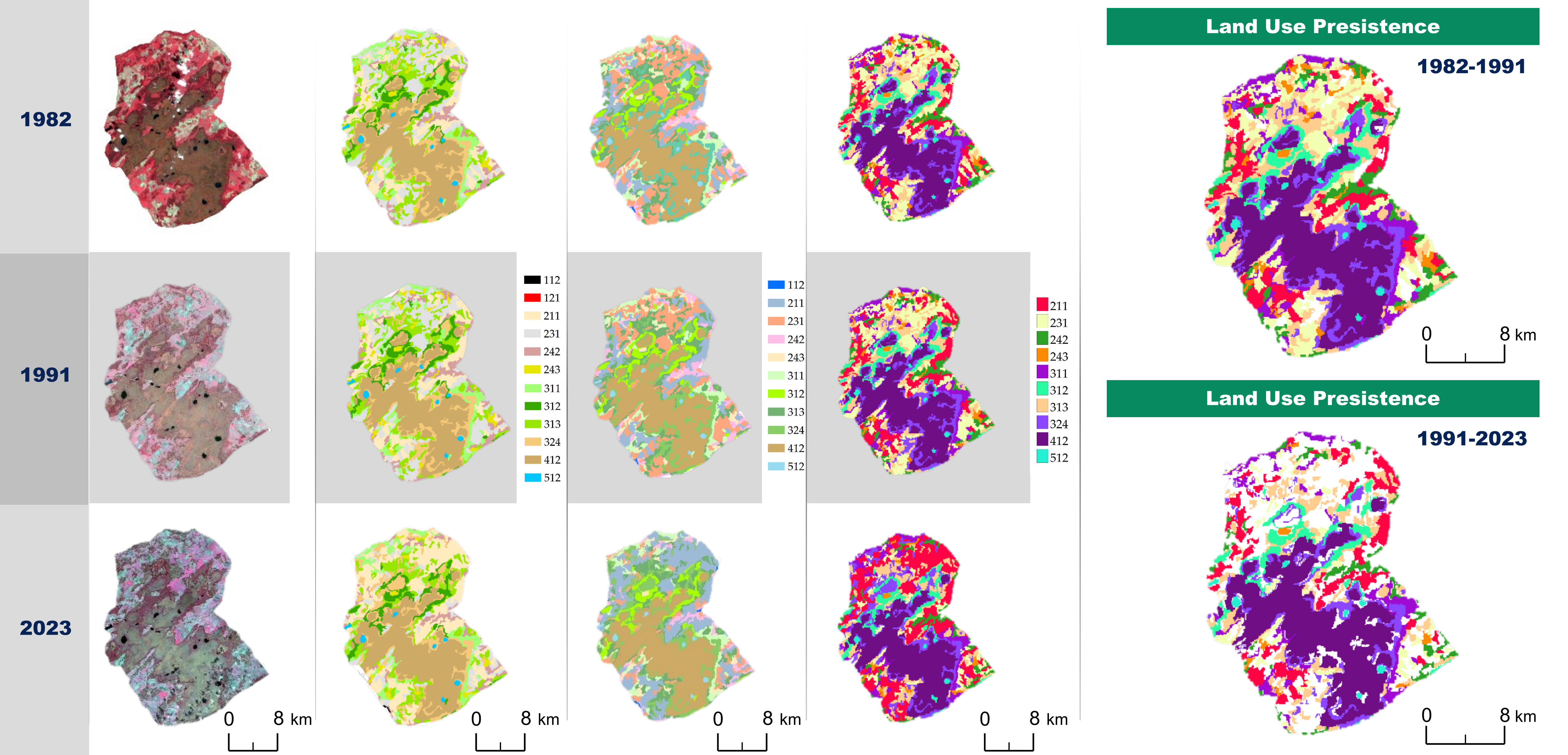


Road Infrastructure



Invasive Plants

Land Use Presistence



Teiči Strict Nature Reserve

112 discontinuous urban fabric
211 non-irrigated arable land
231 pasture
242 complex cultivation pattern
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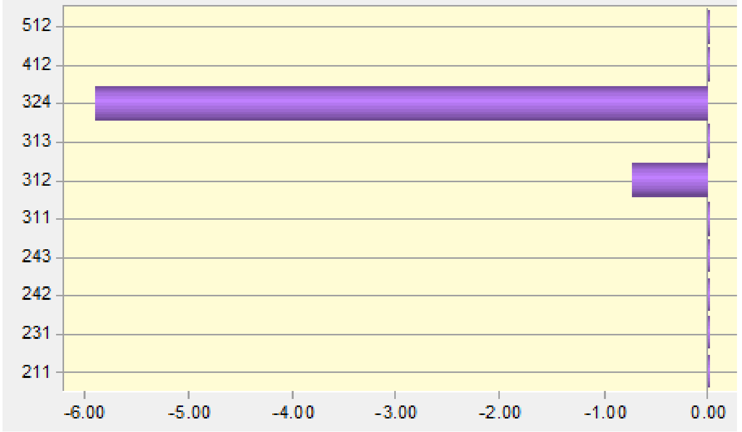
313 mixed forest
324 transitional woodland-shrub
412 peat bog
512 water body

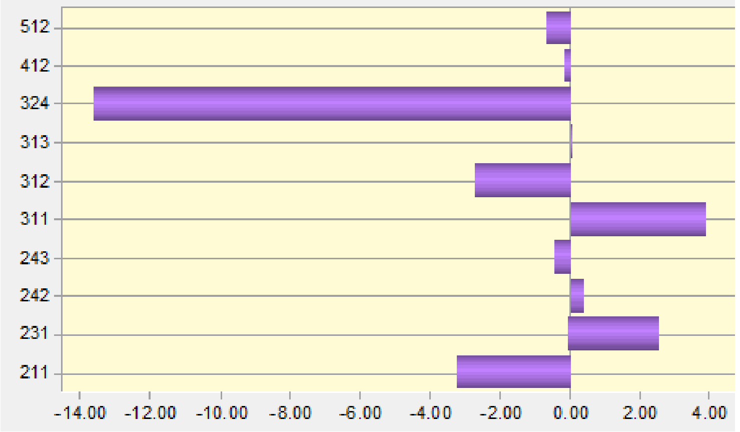
Land Cover Changes

1982 - 1991 Mixed Forests 1991 - 2023

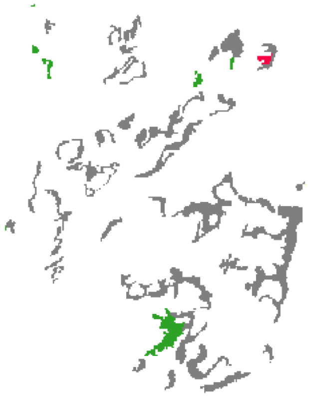
Contribution to Net Change in Mixed Forests (1982-1991)



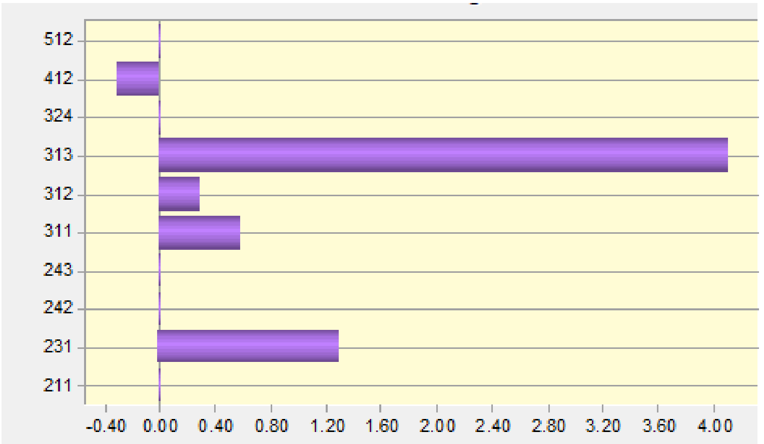
Contribution to Net Change in Mixed Forests (1991-2023)



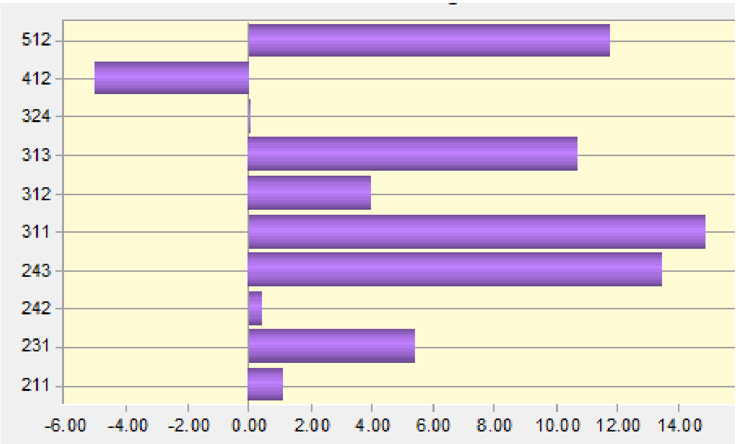
1982 - 1991 Transitional - Woodland Shrubs 1991 - 2023

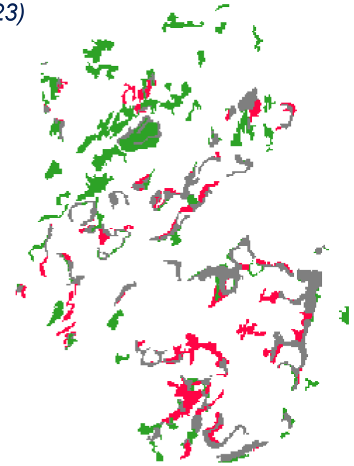


Contribution to Net Change in Transitional – Woodland Shrubs (1982-1991)



Contribution to Net Change in Transitional – Woodland Shrubs (1991-2023)





Teiči Strict Nature Reserve

- losses
- persistence
- gains

211 non-irrigated arable land
231 pasture
242 complex cultivation pattern
243 land principally occupied by agriculture
311 broad-leaved forest
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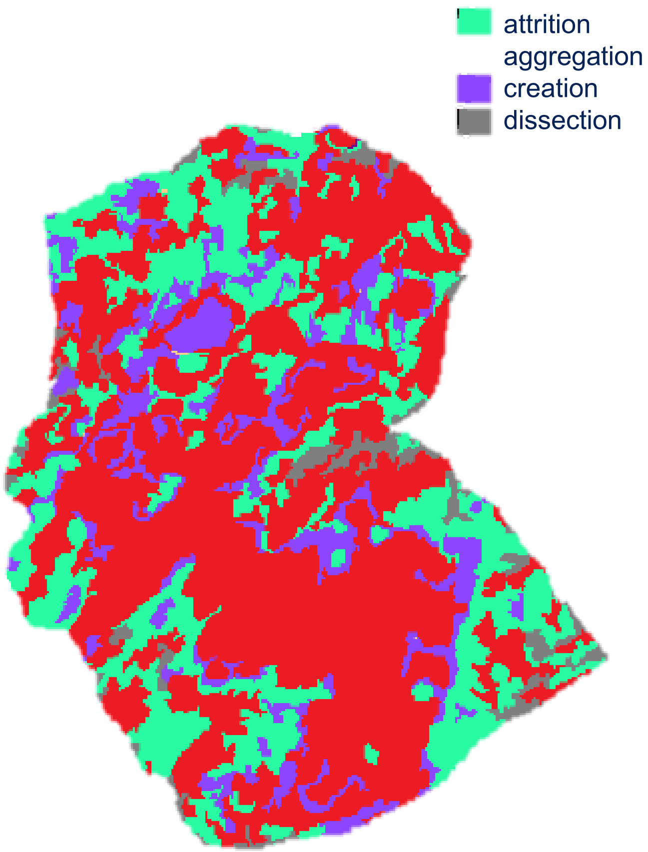
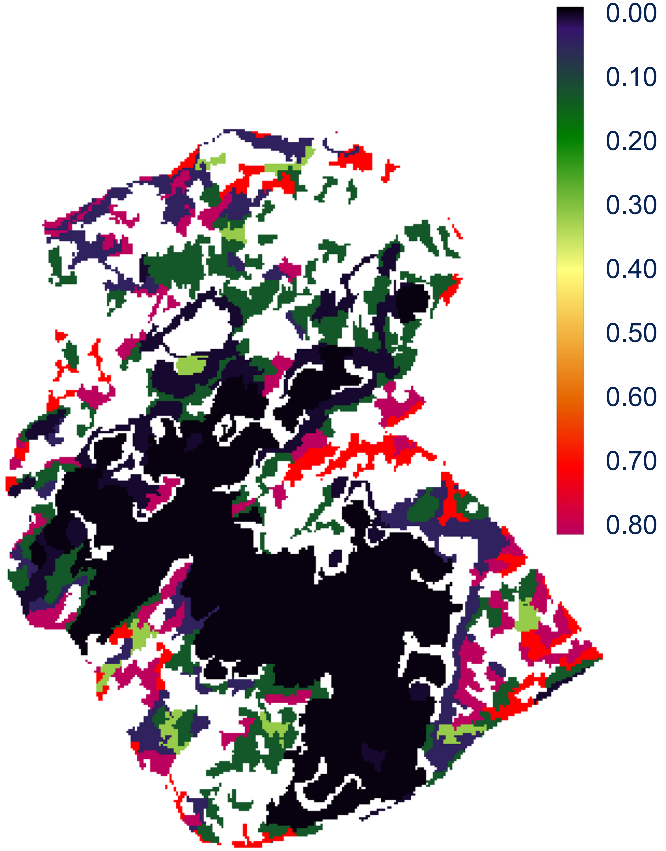
313 mixed forest
324 transitional woodland-shrub
412 peat bog
512 water body

Undergoing Change Process



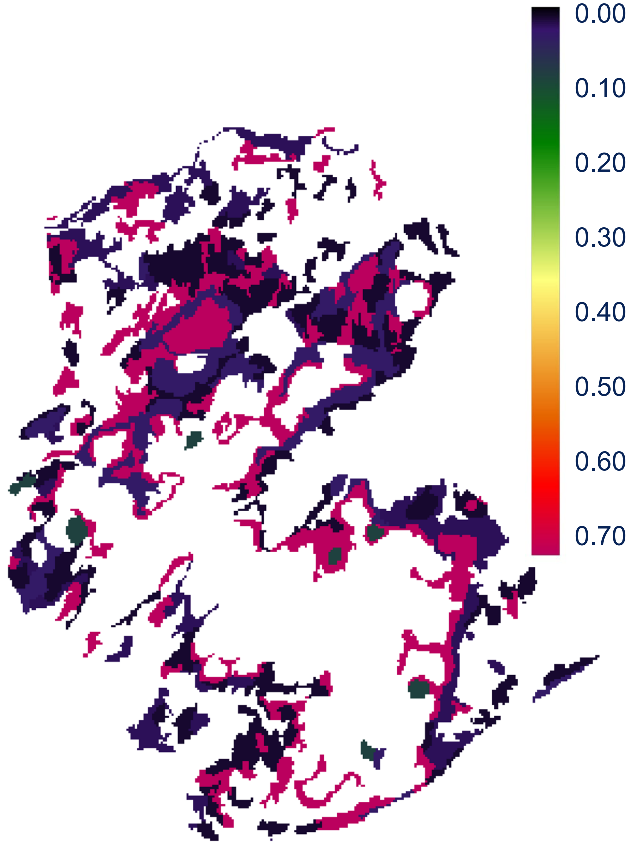
Currently undergoing land cover change processes

Markovian Conditional Probability of Being Non-Irrigated Arable Land



Probability for the land cover change to non-irrigated arable land in next 40 years

Markovian Conditional Probability of Being Peat Bog



Probability for the land cover change to peat bog in next 40 years

Outlook

- **Database on modelling tools (open access generalized database)** of main types of the modelling tools that can serve as an operational tool for users
- Focus: **modelling tools related to LU/LC changes** in agricultural land, wetlands and forests.
- **Identification** and if needed **digitization of cartographical material** of importance for characterization of LU/LC situation
- **Inputs from project partners** on socio-economic factors affecting future LU/LC change scenarious
- **Climate change impacts, nature restoration needs** as key factors at elaboration of LU/LC future change scenarious

Thank you for attention!

Europe LAND

15 February 2024, online

Speaker: Gheorghe KUCSICSA & Mihaela SIMA,
Institute of Geography of the Romanian Academy, Romania

Modeling land use/land cover changes using CLUE-S. Applications in Romania

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1. CONTEXT

The LUC modeling: as an essential part of understanding the potential future developments. It helps in decision-making processes and allows for the assessment of the impacts of different policies or interventions on LUC patterns.

empirical-statistical & spatially explicit models

with the purpose of explaining and predicting LUC pattern, supporting the analyses of potential LUC changes under multiple scenarios

- inductive / deductive
- pattern / agent-based
- dynamic or static
- spatial / non-spatial
- uncombined / hybrid
- regionally / globally

SVMs (Support Vector Machines)

ANN (Artificial Neural Networks)

CELLULAR AUTOMATA

MARKOV CHAINS

Logistic Regression

CLUEs

LEAM (The Land-use Evolution And Impact Assessment Model)

SLEUTH (Slope, Land use, Exclusion, Urban, Transportation, Hillshade)

LTM (Land Transformation Model)

to design appropriate plans for sustainable land management at different spatial scales: e.g. possible consequences of LUC transition on landscape diversity and biodiversity; landslide hazard and risk & hazard mitigation plans; the implications for ecosystem services or carbon allocation

2. CLUEs model (the Conversion of Land Use and its Effects at Small regional extent)

CLUEs: ….. a model specifically developed for the spatially explicit simulation of LUC change, based on an empirical analysis of location suitability combined with the dynamic simulation of the competition and interactions between the spatio-temporal dynamics of LUC systems (Veldkamp and Fresco, 1996, Verburg et al., 1999; 2004; 2010).

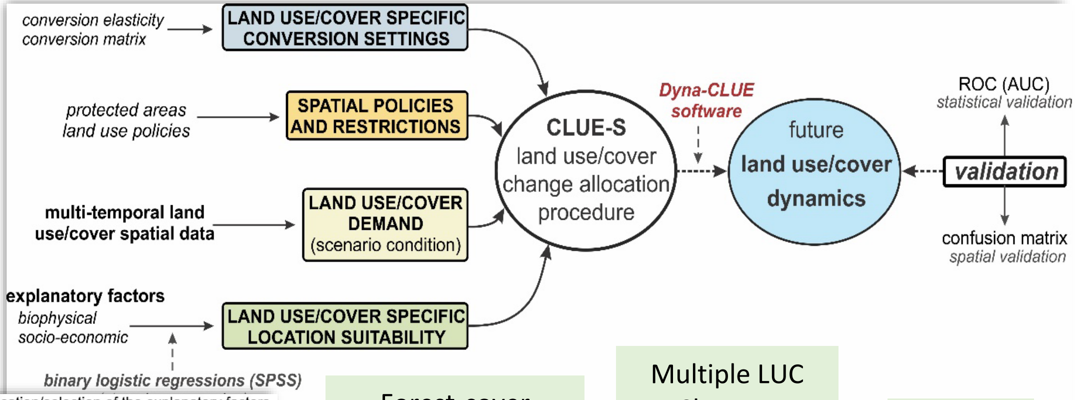
The model requires four inputs:

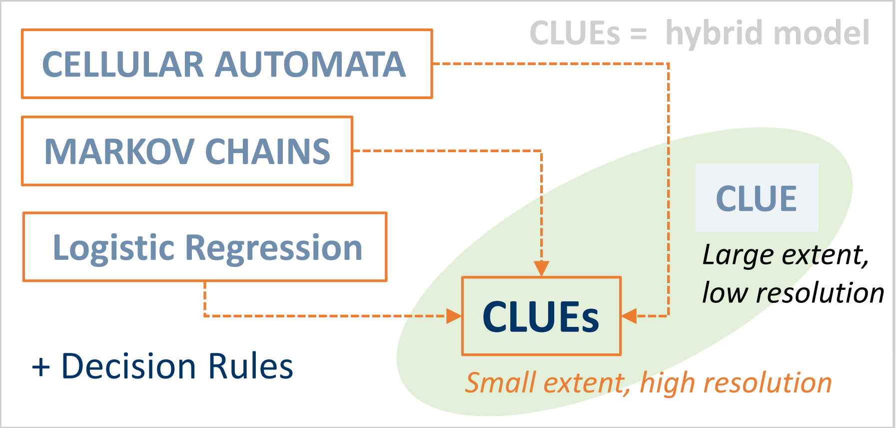
1) **LUC type-specific conversion settings**, which indicate *the conversion elasticity* (0 = easy….1 = irreversible change) and *the conversion matrix* (LUC type can/cannot be converted into any other LUC);

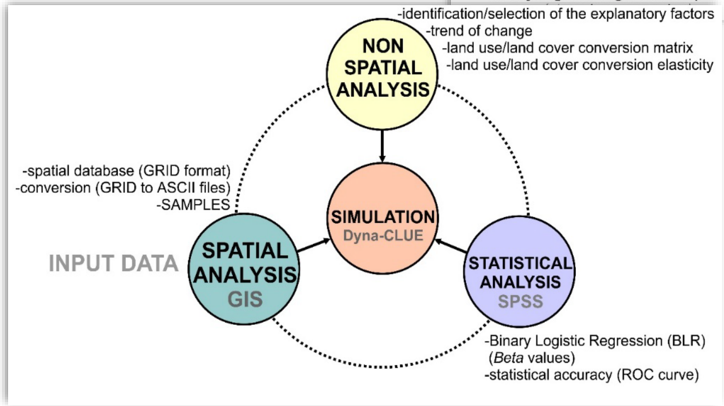
2) **Spatial policies and restrictions**, which can restrict/limit LUC change in certain areas (e.g., land-use policies, environmental policies);

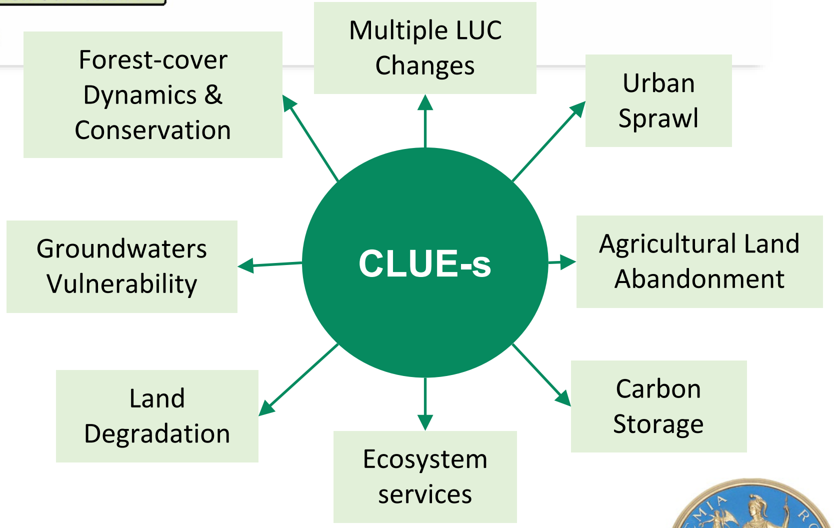
3) **LUC demand** (scenarios based on simple trend extrapolations or complex models);

4) **Location characteristics** (LUC suitability), determined as the relations between the LUC pattern and explanatory factors.





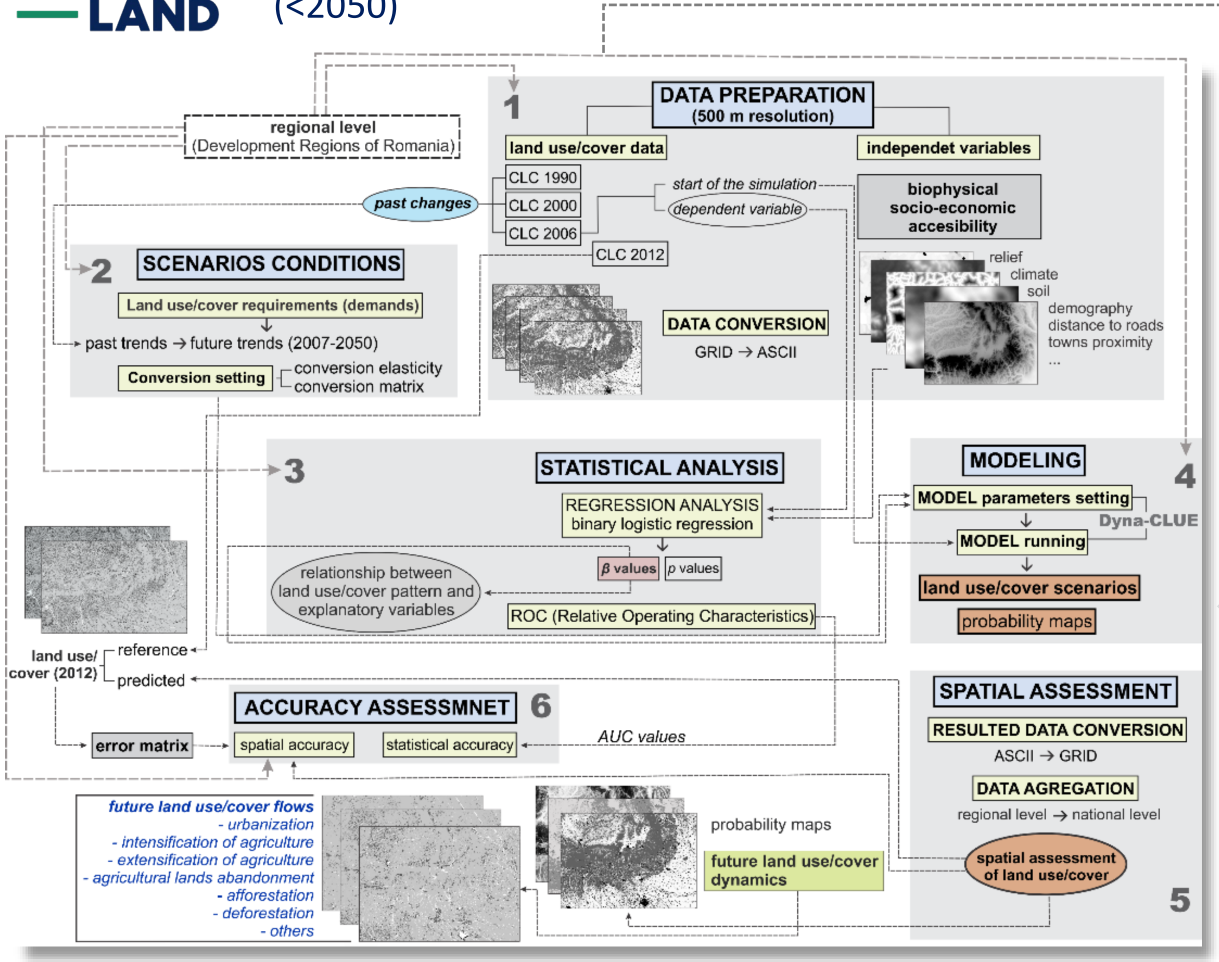




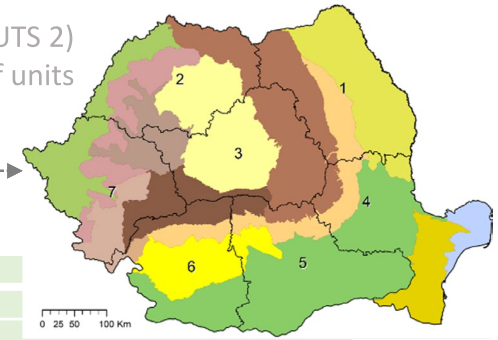
3. CLUEs model: applications for Romania

The potential future LUC pattern changes: CLC datasets + Biophysical & Socioeconomic factors

Two scenarios computed based on the past LUC trend (1990-2000; 2000-2006) → linearly extrapolated for the simulated period (<2050)



simulation = at regional level (NUTS 2)
the analysis = national scale + the major relief units

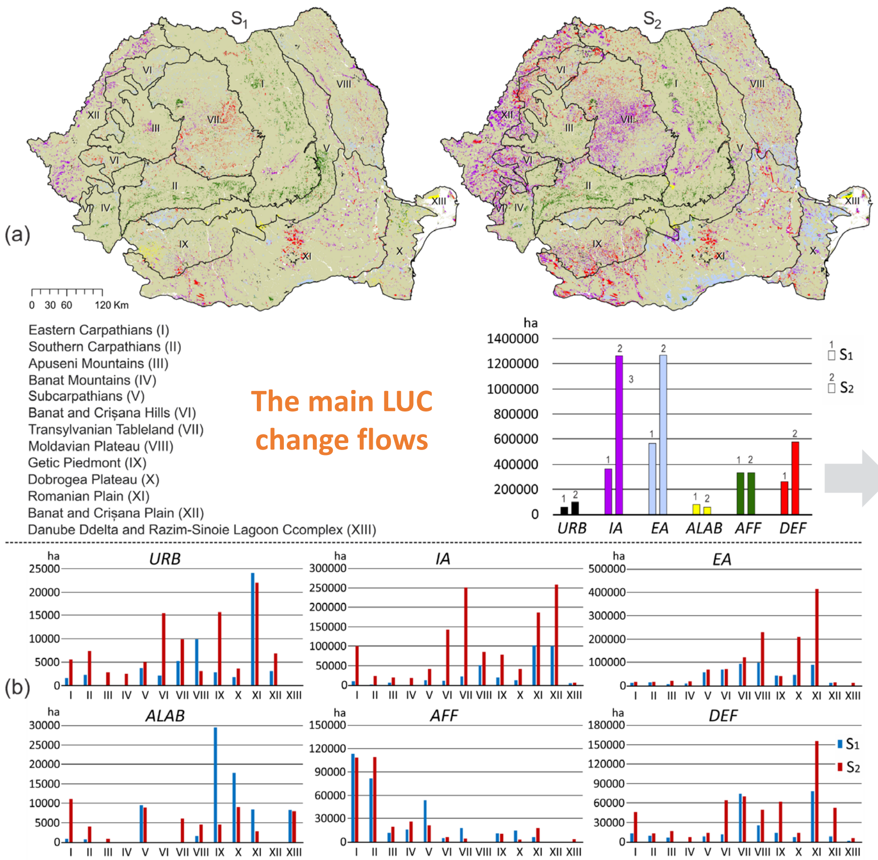


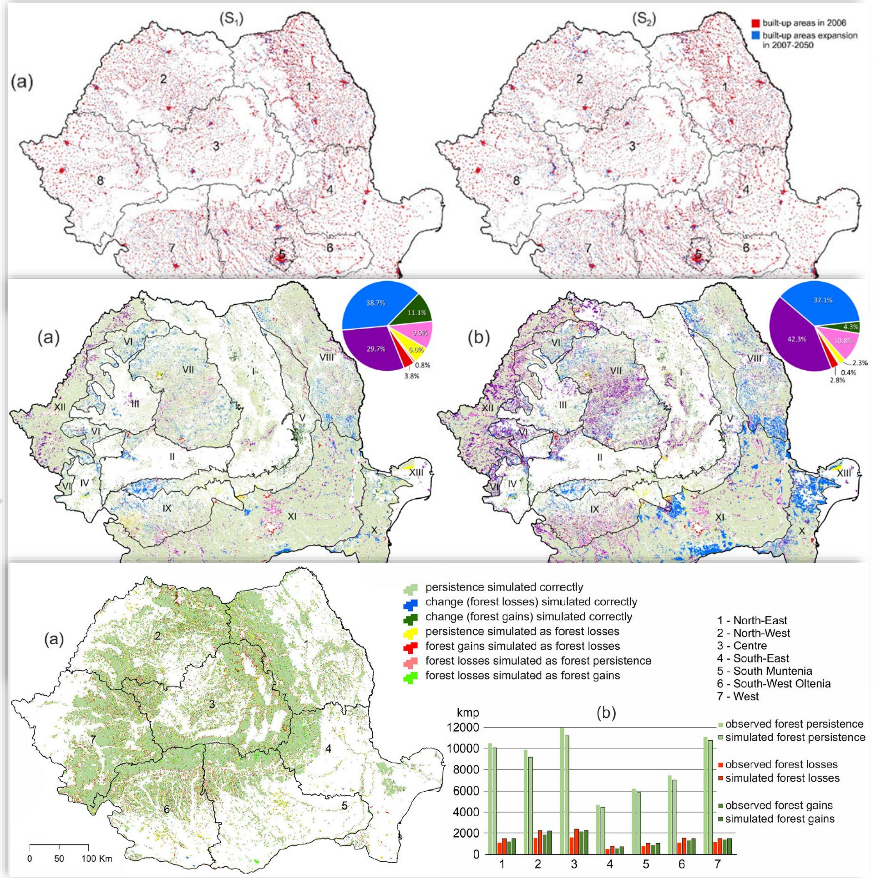
17 continuous + categorical explanatory factors

Independent variables	Description
Elevation	in m
Slope declivity	in °
Precipitation	annual average 1961-2015 (mm)
Temperature	annual average 1961-2015 (° C)
Relief fragmentation	in km/km^2
Soil	total organic matter content in topsoil
Population density	inh/km^2
Population growth	‰
Employees	no
Unemployment rate	%
Large livestock Units (LLU)	no
Employments in tertiary sector	no
Distance to nearest major wood exploitation / processing centres	buff = 1km
Built/nonagricultural ratio	%
Settlements density	ha/km^2
Distance to nearest major roads	county and national roads, European routes, motorway (buff = 1km)
Secondary roads density	communal, forestry and agricultural roads (in km/km^2)

3. CLUEs model: applications for Romania

The potential evolution of the main LUC change flows: an overall assessment of *Urbanization (URB), Intensification of agriculture (IA), Extensification of agriculture (EA), Agricultural land abandonment (ALAB), Afforestation (AFF)* and *Deforestation (DEF)*



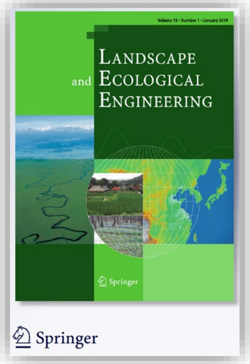


Urban growth

Changes related to agricultural lands

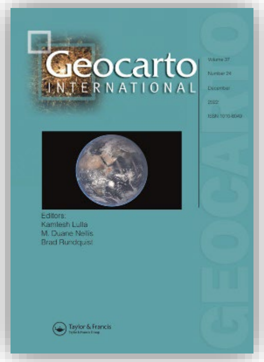
Forest-cover dynamics

Future land use/cover changes in Romania: regional simulations based on CLUE-S model and CORINE land cover database



Kucsicsa, Popovici et al., 2019

Modelling land use/cover change to assess future urban sprawl in Romania

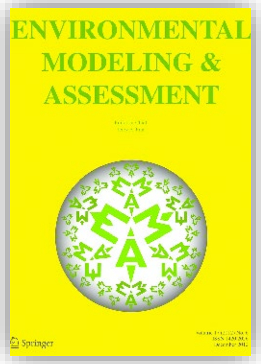


Grigorescu, Kucsicsa et al., 2019

Past and future land use/cover flows related to agricultural lands in Romania. An assessment using CLUE-s Model and Corine Land Cover database

Popovici, Kucsicsa et al., 2018

Assessing the Potential Future Forest-Cover Change in Romania, Predicted Using a Scenario-Based Modelling

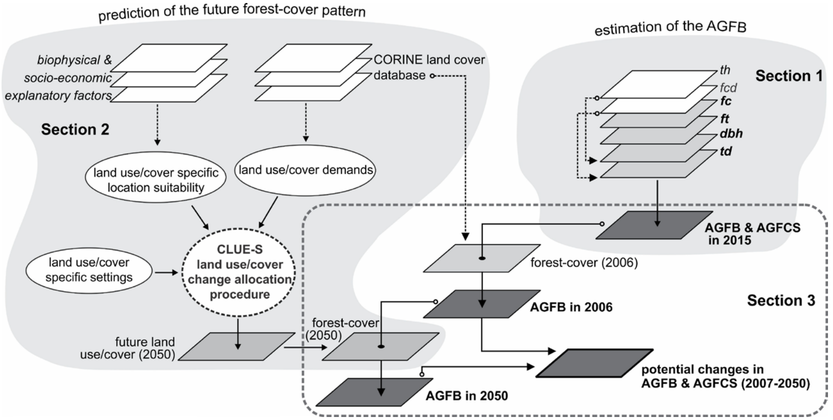


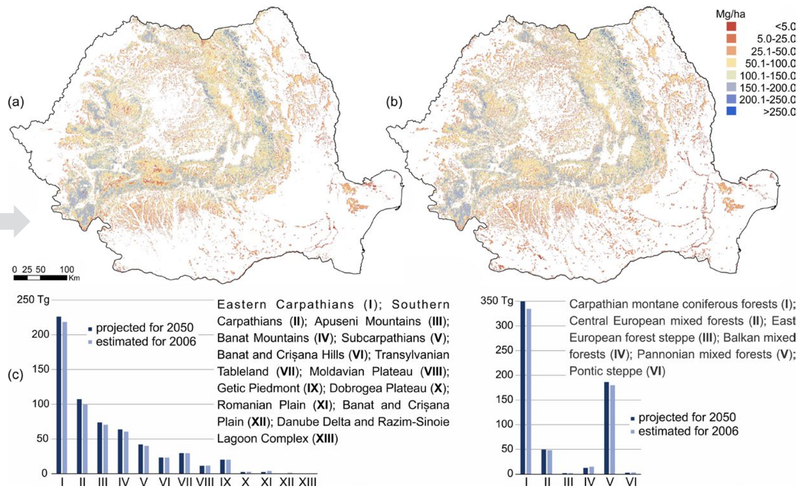
Kucsicsa, Popovici et al., 2019

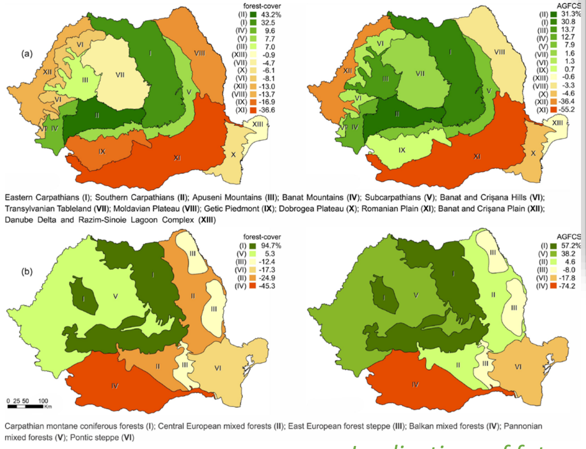
3. CLUEs model: applications for Romania

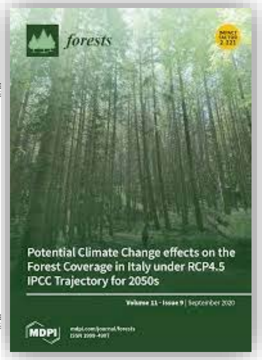
Estimation of Future Changes in Aboveground Forest Carbon Stock in Romania. A Prediction Based on Forest-Cover Pattern Scenario

LUC scenarios: *related applications to estimate future* ***Aboveground Forest Carbon Stock*** *& future* ***Landslide Susceptibility***



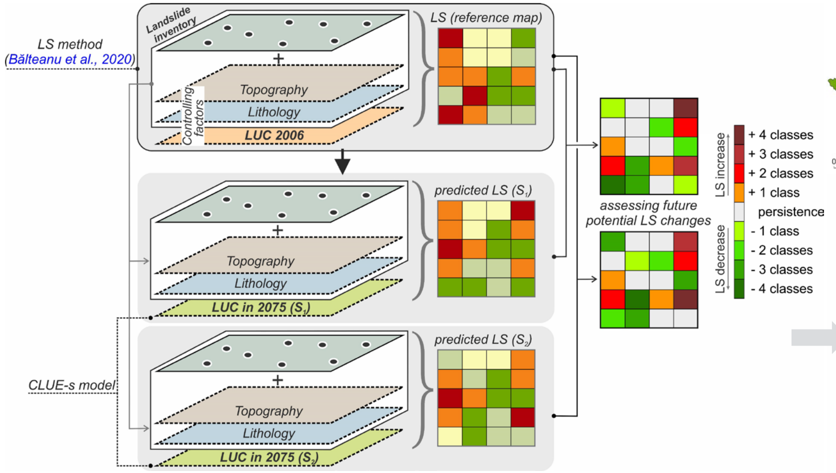


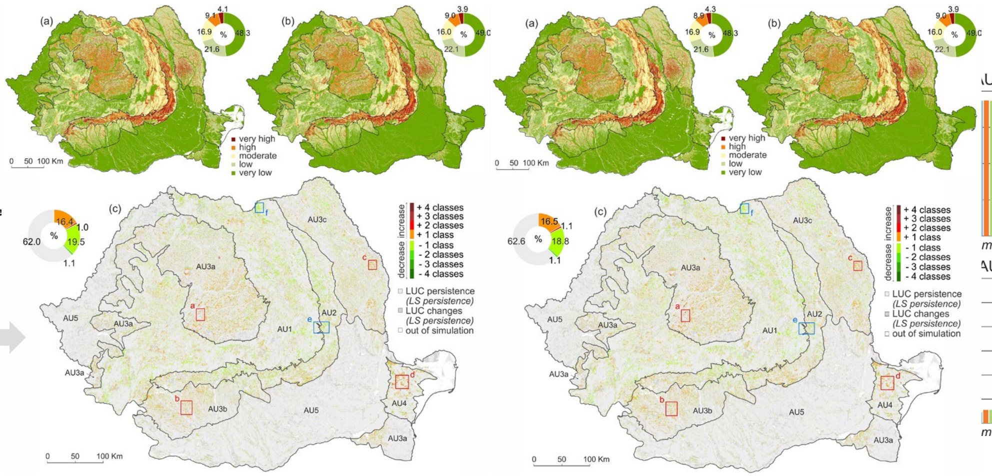


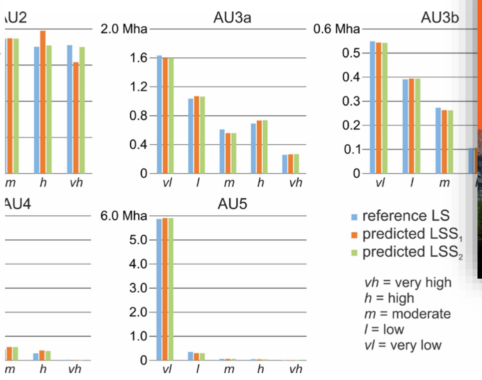


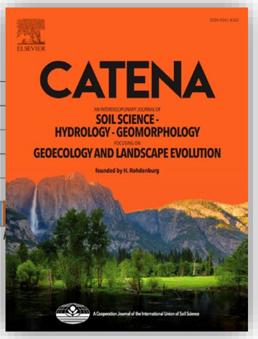
Dumitrașcu, Kucsicsa et al., 2020

Implications of future land-use/cover pattern change on landslide susceptibility at a national level: A scenario-based analysis in Romania









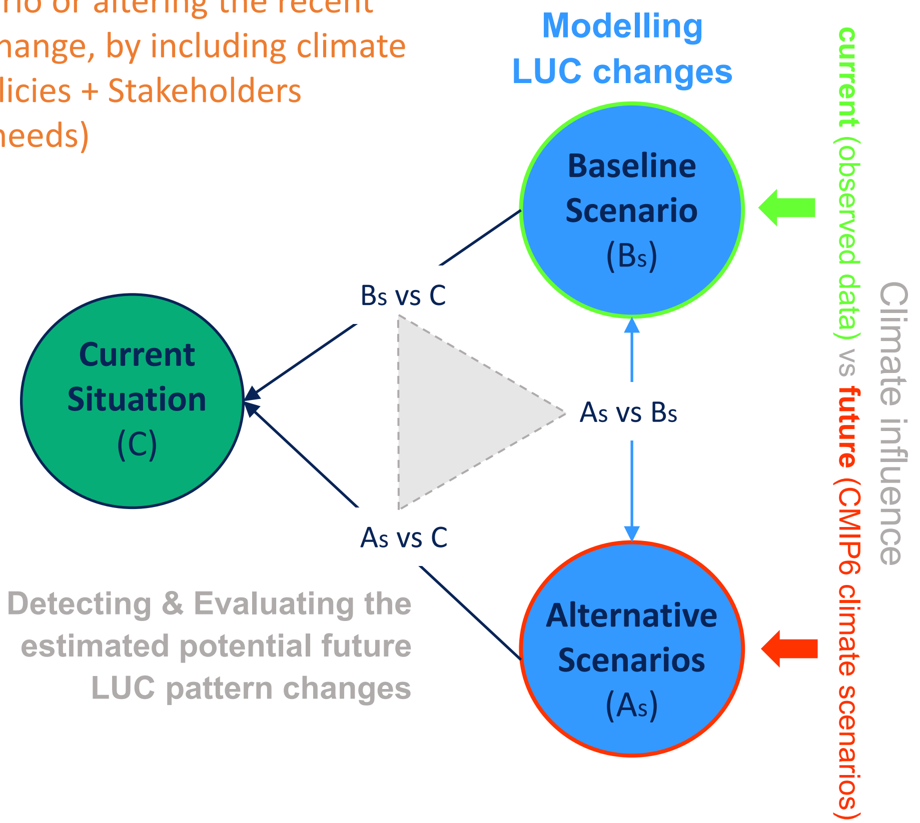
Jurchescu, Kucsicsa et al., 2023

4. What is next? LUC modelling in the context of EUROPE-LAND project
(Case study: Romania)

Developing of the new scenarios: baseline & alternative scenarios / Identifying new driving factors

by including a more appropriate factors (statics & dynamics) for agricultural and afforested lands, and assuming a continuation of the recent trend of LUC change and current situation and trends of driving factors

adjusting specific factors from the baseline scenario or altering the recent trend of LUC change, by including climate scenarios + policies + Stakeholders knowledge & needs)



Possible questions addressed:

Q1 How LUC pattern may change in response to climate change impacts? Will the climate change have a significant impact on agriculture and forestry sectors? Which regions are the most vulnerable?

Q2 Could the better implementation of conservation policies lead to the increase of the afforested areas? What will happen outside the protected areas?

Q3 What are the potential consequences of LUC change for biodiversity?

Q4 Can the appropriate land use policies prevent agricultural land abandonment?

Q5 How much the LUC pattern is related to agricultural land management, as documented in IACS data (Integrated Administration and Control System)?

Q6 How does land fragmentation influence land use decisions?

Q7 How the urbanization trends influence the uptake of agricultural land?

Q8 .....?

4. What is next? LUC modelling in the context of EUROPE-LAND project
(Case study: Romania)

Challenges to compute and understand alternative LUC scenarios

Ch1 to identify/propose a coherent and realistic set of changes that may affect LUC change in the future;

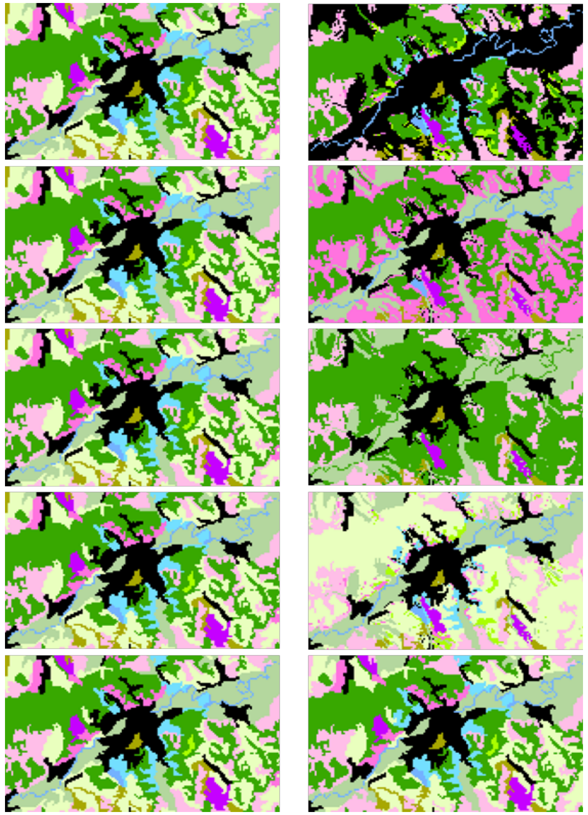
Ch2 to integrate the Policies + Stakeholders knowledge & needs into LUC modelling for alternative scenarios, in order to measure and understand the impacts of different interventions on LUC patterns. In the CLUEs model, we propose to integrate this information by altering quantitative information (LUC demand) and LUC type specific conversion settings, i.e., the conversion elasticity (easy to convert vs. irreversible change) + conversion matrix (which LUC class can/cannot be converted into other LUC class);

Ch3 to evaluate the strengths and weaknesses of alternative scenarios in capturing key drivers, processes, and outcomes of LUC pattern change;

Ch4 to understand the impact of the potential future LUC pattern change on agricultural lands and forest-cover (biodiversity) and to identify the potential vulnerabilities and the opportunities in the future;

Ch5 to identify and assess uncertainties in alternative scenario projections.

LUC pattern scenarios:
possible outcomes
actual vs future



related to *Urban growth*

related to *Agricultural lands expansion*

related to *Forest-cover gains*

related to *Forest-cover losses*

no significant changes

Conclusions

CLUEs = a dynamic model, suitable to simulate near-future changes in LUC pattern at high resolution;
CLUEs = a tool to understand the processes that determine changes in the spatial pattern of LUC;
CLUEs = is able to estimate the most likely location and amount of LUC pattern change in the future;
CLUEs = allows to compute the scenarios by integrating static and dynamic factors of LUC change;
CLUEs = allows to compute both baseline and alternative LUC pattern scenarios;
CLUEs = however, is a complex and time-consuming model, and the result of simulations strongly depends on the data quality, considered factors of change, the nature of the most important LUC conversions, and the model assumptions.

hybrid model
Iterative procedure
empirical analysis
raster-based system
dynamic simulation
factors of change
decision rules
LUC conversion matrix
LUC conversion elasticity

LUC change sequence
LUC location suitability
baseline vs alternative scenarios
policy options
LUC competition & interactions
spatially explicit simulation
LUC spatio-temporal dynamics
different trend extrapolations

15 February 2024, online

Speaker:
Lucie Kupková, Khalil Gholamnia, Ivan Bičík,
Vít Jančák,Přemysl Štych, Markéta Potůčková

„Database on existing LU/LC patterns and Database on LU/LC modelling tools – current state and further development“

Europe LAND

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The goals

Motivation

LU/LC datasets and dynamic spatial simulation models of LU/LC can serve as informative platforms and data sources for policy setting and decision-making processes on the use and management of land resources.

Stakeholders must have information about available modelling tools and LU/LC datasets.

The database and assessment of existing LU/LC layers/datasets can help stakeholders/decision-makers to work efficiently with available LU/LC data sources.

Goals

To provide a list/database of:

1) Existing LU/LC layers/geodatabases in the EU

2) LU/LC spatial modelling tools

Anticipated results

Anticipated results

Current LU/LC layers/geodatabases (e.g., Copernicus monitoring services, LULUCF, LUCAS, NATURA 2000, outputs from various LU/LC projects etc.) can be used by stakeholders for a comparative temporal evaluation of LU/LC change at regional, national and international levels and potentially (mainly by scientists) for the evaluation of climate change and its impact for mitigation and biodiversity preservation.

The database of LU/LC spatial modelling tools will enable the stakeholders/scientists/decision-makers to select the appropriate tool according to the modelling requirements, based on parameters that will be listed/described.

LU/LC spatial modelling tools

3 products/outputs for modelling tools:

- Database of modelling tools – based on papers dealing with modelling tools
  - Sorted by:

    a) type of used modelling approach/tool (CA models, CLUE-S models, LCM models, IAM models… etc.)

    b) special interest land use/cover categories – forests, wetlands, croplands

    c) geographical interest – Europe and particular European countries (mainly countries of project partners and countries with tradition in modelling practice)
  - Stored information (based on papers that use the tool) – name of modelling tool, topic, year of publication, authors, Access/link, Used modelling method, scale, LCLU categories, inputs to modelling, outputs, published case studies, area of interest, continent, references

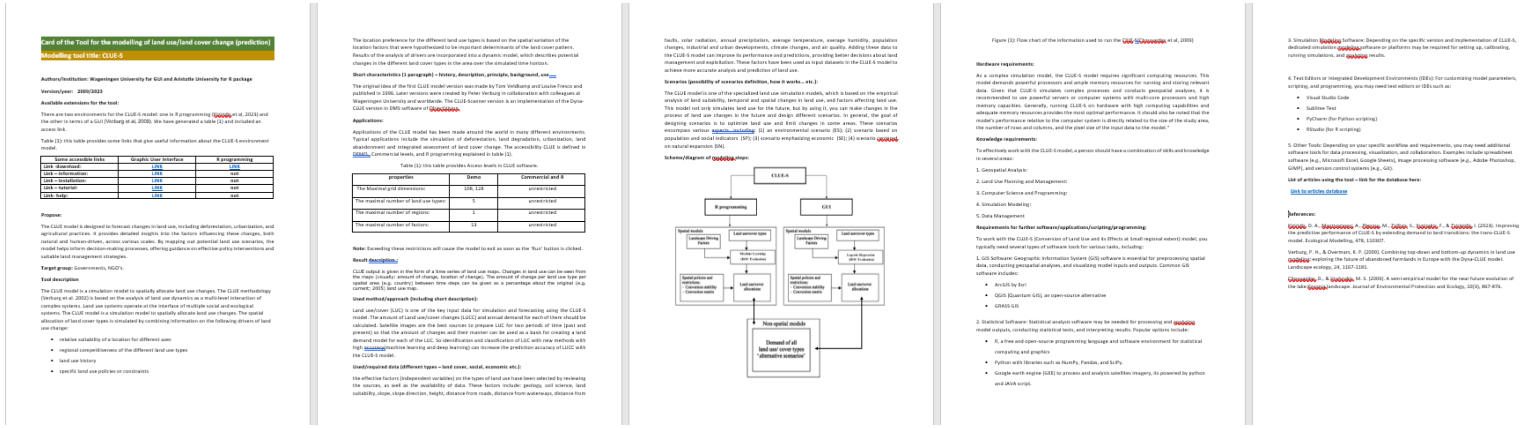
- Cards of modelling tools
- Success stories for modelling toola

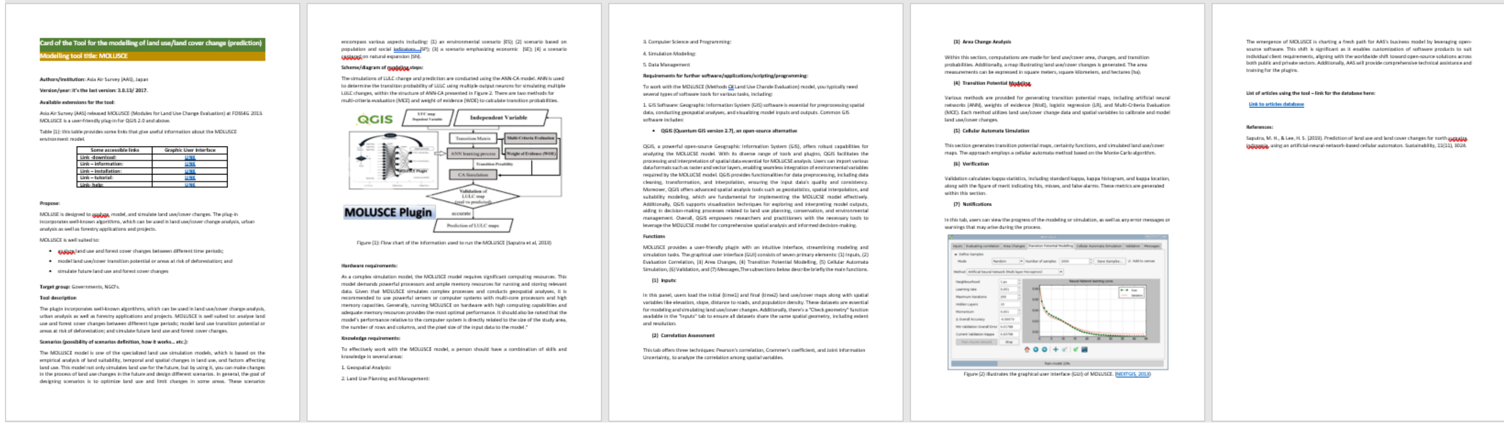
… Database, Cards and Success stories will be interconnected and published (on the project webpage or on a web connected to the project web page) fx 1- Name of modelling tool/ software

A	B	C	D	E	F	G	H	I	J	K	L	M	N	
1- Name of modelling tool/ software	1-year	topic	Author/Provider	Access (link)	free of charge or not (Y/N)	Type of model (Table 1)	Used modelling method/s	scale (local/regional/global - L/R/G)	focus - types of LCLU categories	inputs	outputs	published case studies (area, purpose, scale, categories, methods)	continent	references
A-Markov and Random Forest	2023	Modelling of land	Asif, M., Kazmi, J. H.	https://www.tar	Y	Statistical models	CA-Markov and	R	Land use and land cover ch	Satellites images of the Lands	to predict the land use map for	deserts in Punjab, Pakist	AS	Asif, M., Kazmi, J. H., Tariq, A., Zhao, N., Gu
BPNN_CA_Markov tools	2020	Spatiotemporal LU	Huang, Z., Du, H., Li	https://www.m	Y	Statistical models	BPNN_CA_Mark	L	Land use and land cover ch	Land-use data 2004, 2008	demands of each land-use type	Anji County in China	AS	Huang, Z., Du, H., Li, X., Zhang, M., Mao, F.
CA-Markov	2014	Predicting Urban L	Nouri, J., Gharagozl	https://link.spri	N	Statistical models	CA-Markov	L	distribution of urban land u	land use maps of years 1989-	spatial distribution of urban lan	Bandar Anzali in Iran	AS	Nouri, J., Gharagozlou, A., Arjmandi, R., Fa
CA-Markov	2020	Multi-scenario sim	Zhou, L., Dang, X., S	https://www.sci	Y	Statistical models	CA-Markov	L	Land use and land cover ch	Land use Land use 2000, 201	to predict the land use map for	Shanghai in China	AS	Zhou, L., Dang, X., Sun, Q., & Wang, S. (20
CA-Markov	2021	Predicting land c	Gemitzi, A	https://www.tar	y	Statistical models	CA-Markov	R	Land use and land cover ch	provided annually from 20	Future land cover projections u	Greece	E	Gemitzi, A. (2021). Predicting land cover c
CA-Markov - terrset18.31	2021	Land Use and La	Mathewos, M ; Le	https://www.m	Y	Statistical models	CA-Markov	L	Land use and land cover ch	Landsat TM for 1991, ETM+ f	prediction LUCC for 2050	Matenchose Watershed,	AF	Mathewos, M., Lencha, S. M., & Tsega
CA-Markov and InVEST model	2019	Assessing the effe	Zhao, M., He, Z., Du	https://www.sci	Y	Statistical models	CA-Markov and	L	Land use and land cover ch	The 16-day 1000 m MODIS N	LUCC between 2001 and 2029	Heihe River IN cHINA	AS	Zhao, M., He, Z., Du, J., Chen, L., Lin, P., &
CA-Markov and SWAT	2021	Future Runoff Vari	Ji, G., Lai, Z., Xia, H.	https://www.m	Y	Statistical models	CA-Markov and	L	Future Runoff Variation and	The land use data ,the month	future period (2040–2060) all s	yellow river basin in Chi	AS	Ji, G., Lai, Z., Xia, H., Liu, H., & Wang,
CA-Markov model module in t	2022	Comparison of mu	Lin, Z., & Peng, S.	https://www.sci	Y	Statistical models	CA-Markov and	L	Land use and land cover ch	five high-resolution remote s	Land use and land cover change	Lake basin in China,	AS	Lin, Z., & Peng, S. (2022). Comparison of m
CA-Markov- terrset18.31	2023	Land use and cove	Olipa Simon, James	https://link.spri	N	Statistical models	CA-Markov	L	Land use and land cover ch	satellite imagery from Landsa	prediction LUCC in 2030	Dar es Salaam metropoli	AF	Simon, O., Lyimo, J., & Yamungu, N. (2
CA-Markov- terrset18.31	2018	Assessing tempora	Zheng, F., & Hu, Y.	https://link.spri	Y	dynamic model	CLUE-S and Ma	R	simulating spatial temporal	spatial temporal evolution of	temporal-spatial land use simul	Beijing in China	AS	Zheng, F., & Hu, Y. (2018). Assessing tempo
Cellular automata (CA) and c	2019	A geographical dir	Firozjaei, M. K., Sed	https://www.sci	Y	Statistical models	Cellular automa	L	Mapping development pc	Google Earth, 2013	The results are further compare	Tainan City, Taiwan	AS	Firozjaei, M. K., Sedighi, A., Argany, M., Jel
CLUE-s and RUSLE tools	2017	Investigating effec	Zare, M., Nazari Sar	https://link.spri	N	dynamic and Statistical m	CLUE-s and RUS	R	Predicting soil erosion chan	Three land use maps were cr	to simulate land use for the yea	north of Iran	AS	Zare, M., Nazari Samani, A. A., Mohamma
DEMATEL tools and Markov m	2021	Urban ecological s	Ghosh, S., Chatterje	https://www.sci	Y	Statistical models	CA-Markov and	L	Urban ecological security a	satellite data, Google Earth i	Changes and prediction of UES	Kolkata Metropolitan Ar	AS	Ghosh, S., Chatterjee, N. D., & Dinda, S. (2
GEE and Markov module of ID	2023	Evaluation and pre	Yang, Z., Dai, X., Lu,	https://www.sci	Y	Statistical models	CA-Markov	R	Land use and land cover ch	sing supervised classification	Comparison between the real L	Yellow river basin in Chi	AS	Yang, Z., Dai, X., Lu, H., Liu, C., Nie, R., Zha
InVEST 3.10.2 software an	2022	Spatiotemporal Ev	Zhong, C., Bei, Y., G	https://www.m	Y	Statistical models	Cellular Autom	L	The Spatiotemporal Distrib	the degree of the habitat deg	2025 were predicted and analy	Wanhe Watershed in Ch	AS	Zhong, C., Bei, Y., Gu, H., & Zhang, P.
LCM is a module of IDRISI	2019	Assessment and p	Yadav, V., & Ghosh,	https://www.tar	Y	Statistical models	LCM	L	urbanisation, LULC change	Landsat data (1981 - 2011)	Land Use Land Cover (LULC) (20	Chennai district in india	AS	Yadav, V., & Ghosh, S. K. (2021). Assessme
logistic-CA-Markov and WI	2019	Dynamic simulatio	Guan, D., Zhao, Z.,	https://link.spri	N	Statistical models	logistic-CA-M	L	simulate land use structure	land use data in 2000, 2005,	to simulate spatial pattern of la	Chongqing, China	AS	Guan, D., Zhao, Z., & Tan, J. (2019). D
LUCC	2017	Trends in land use	Kamwi, J. M., Kaets	https://link.spri	N	Statistical models	landuse change	R	Land use and land cover ch	Landsat TM and ETM+ image	fill this gap by analyzing the rel	Zambezi Region, Namib	AF	Kamwi, J. M., Kaetsch, C., Graz, F. P., Chirw
Markov module and Logistic	2018	Urban growth dyn	Siddiqui, A., Siddiqu	https://www.sci	Y	Statistical models	Markov module	L	Land use and land cover ch	landsat images for year 1993	to simulate land use change for	Uttar Pradesh in India	AS	Siddiqui, A., Siddiqui, A., Maithani, S.,
Markov module of IDRISI	2020	Simulating spatial-	Saadani, S., Laaja	https://link.spri	N	Statistical models	CA-Markov	L	Land use and land cover ch	Land use/cover change (LUCC	urban growth modelling (2010-	El Jadida city, Morocc	AF	Saadani, S., Laajaj, R., Maanan, M., Rhinan
Markov module of IDRISI	2023	A CA-Markov-Base	Gasirabo, A., Xi, C.,	https://www.m	Y	Statistical models	CA-Markov	L	Land use and land cover ch	evaluate the changes in LU	predict future fluctuations un	Nyabarongo River Bas	AF	Gasirabo, A., Xi, C., Hamad, B. R., & Edovia
Markov module of IDRISI	2023	Scenario-Based LU	Gebresellase, S. H.,	https://www.m	Y	Statistical models	CA-Markov	L	Land use and land cover ch	landsat data 1972 to 2017	to predict the land use map for	Upper Awash Basin (UAE	AF	Gebresellase, S. H., Wu, Z., Xu, H., & Muha
Markov module of IDRISI	2022	Analysis and mode	Kisamba, F. C., & Li,	https://link.spri	N	Statistical models	CA-Markov	L	Land use and land cover ch	analyze LULC changes from 2	simulate future changes for the	Dodoma urban district in	AF	Kisamba, F. C., & Li, F. (2023). Analysis
Markov module of IDRISI	2023	Predicting land use	Fogang, L. F., Tio	https://www.sci	Y	Statistical models	CA-Markov	L	Predicting land use/land co	Landsat images used in	Projected land use/land cover r	West-Cameroon	AF	Fogang, L. F., Tiomo, I. F., Kamga, B. Y., Kpo
Markov module of IDRISI	2020	Analysing past lan	Hishe, S., Bewket, W	https://www.tar	Y	Statistical models	CA-Markov	L	Land use and land cover ch	aerial photographs from 193	to simulate from 2015 to 2030.	Middle Suluh Valley in Et	AF	Hishe, S., Bewket, W., Nyssen, J., & Ly
Markov module of IDRISI	2023	Future land use la	Atef, I., Ahmed, W.,	https://link.spri	Y	Statistical models	CA-Markov	L	Land use and land cover ch	Landsat images obtained 200	Predicted LULC map for years 2	El-Fayoum Egypt	AF	Atef, I., Ahmed, W., & Abdel-Maguid, R. H.
Markov module of IDRISI	2022	Assessment of lan	Hind, M., M'hamm	https://link.spri	N	Statistical models	CA-Markov	L	Land use and land cover ch	analyze a series of satellite in	assess changes in each land use	Algiers, Algeria	AF	Hind, M., M'hammed, S., Djamal, A., & Zou
Markov module of IDRISI	2021	Analysis of the Fut	Matlhodi, B., Kenab	https://www.m	Y	Statistical models	CA-Markov	L	Land use and land cover ch	Classified Landsat images fro	to simulate the likely LULCs in 2	Gaborone dam catchme	AF	Matlhodi, B., Kenabatho, P. K., Parida, B. P.
Markov module of IDRISI	2021	Future Scenarios o	Beroho, M., Briak, H	https://www.m	Y	Statistical models	CA-Markov	L	Land use and land cover ch	Satellite images for the years	to simulate LULC for years 2028	Mediterranean Watersh	AF	Beroho, M., Briak, H., Cherif, E. K., Boulahf
Markov module of IDRISI	2023	Stochastic modelir	Megersa, W., Deribe	https://www.tar	Y	Statistical models	CA-Markov	L	examine the process of urb	The Landsat images of 19	to simulate Built-up area for 20	Mettu area in southwes	AF	Megersa, W., Deribew, K. T., Abreha, G., Li
Markov module of IDRISI	2022	Modelling and Ass	Weslati, O., Bouaziz	https://link.spri	N	Statistical models	CA-Markov	L	Land use and land cover ch	Landsat images (ETM + and O	predict future LULC changes	Mellegue Catchment, N	AF	Weslati, O., Bouaziz, S., & Sarbeji, M. M. (2
Markov module of IDRISI	2022	Quantitatively Ass	Daba, M. H., & You,	https://www.m	Y	Statistical models	CA-Markov	L	Land use and land cover ch	landsat data 1984- 2019	Future land use simulated in 20	Awash River in Ethiopia	AF	Daba, M. H., & You, S. (2022). Quantitative
Markov module of IDRISI	2022	Analysis of land us	Mwabumba, M., Ya	https://www.sci	Y	Statistical models	CA-Markov	L	Land use and land cover ch	LULC maps for the years 199	projected for 2025 and 2035 ur	Ngorongoro Conservatio	AF	Mwabumba, M., Yadav, B. K., Rwiza, M. J.,
Markov module of IDRISI	2023	Predicting future c	Lopes, N. D. R., Li, T	https://www.sci	Y	Statistical models	CA-Markov	L	Land use and land cover ch	landsat images 2000–2020 ar	The projected coastal LULC that	Guinea-Bissau's	AF	Lopes, N. D. R., Li, T., Zhang, P., Matomela,
Markov module of IDRISI	2018	Deriving suitability	Fu, X., Wang, X., & Y	https://www.sci	Y	Statistical models	CA-Markov	L	Land use and land cover ch	Land cover data in two perioc	Simulation of land use for 2011	Ohio in the United State	AMN	Fu, X., Wang, X., & Yang, Y. J. (2018).
Markov module of IDRISI	2021	Future scenarios b	da Cunha, E. R., San	https://www.sci	Y	Statistical models	CA-Markov	L	Land use and land cover ch	GeoEye, RapidEye and Lands	cenarios of LULC based on the (	Serra da Bodoquena reg	AMS	da Cunha, E. R., Santos, C. A. G., da Silva, R
Markov module of IDRISI	2014	Assessing spat	Puertas, O. L., Henr	https://www.sci	Y	Statistical models	CA-Markov	L	Land use and land cover ch	LUC data from 1975 to 2010,	Future land use simulated in 20	Santiago Chile	AMS	Puertas, O. L., Henríquez, C., & Meza, F. J. (
Markov module of IDRISI	2022	Occurrence Predic	Liu, D., & Zhang, X.	https://www.m	Y	Statistical models	CA-Markov	L	Prediction of Pine Wilt Dise	factors, such as weather, terr	PWD in 2030 is predicted basec	Anhui is located in Eas	AS	Liu, D., & Zhang, X. (2022). Occurrenc
Markov module of IDRISI	2018	MCR-Modified CA-	Li, X., Wang, M., Liu	https://www.m	Y	Statistical models	CA-Markov	L	simulation of urban expa	land use change 1996 to 200	The expansion of the Wuhan m	Wuhan metropolitan a	AS	Li, X., Wang, M., Liu, X., Chen, Z., Wei, X., &
Markov module of IDRISI	2022	CA-Markov model	Mokarram, M., & Pl	https://www.sci	Y	Statistical models	CA-Markov	R	predict crop yield using re	land use data in 2000, 2010,	predict yield of two crops in 20	southern Iran	AS	Mokarram, M., & Pham, T. M. (2022). C

Cards of modelling tools

- Author/Institution
- Version/year/Extension
- Purpose/Target group
- Tool description
- Used method, Approach, Scheme
- Used/required data (data format)
- Scenarios, results/outputs
- Hardware requirements
- Knowledge requirements
- List of articles using the tool – connection to the Database of modelling tools - applications





Card of the Tool for the modelling of land use/land cover change (prediction)

Modelling tool title: CLUE-S

Authors/Institution: Wageningen University for GUI and Aristotle University for R package

Version/year: 2009/2023

Available extensions for the tool:

There are two environments for the CLUE-S model: one in R programming (Kiziridis et al, 2023) and the other in terms of a GUI (Verburg et al, 2009). We have generated a table (1) and included an access link.

Table (1): this table provides some links that give useful information about the CLUE-S environment model.

Some accessible links	Graphic User Interface	R programming
Link -download:	LINK	LINK
Link – information:	LINK	not
Link – installation:	LINK	not
Link – tutorial:	LINK	not
Link- help:	LINK	not

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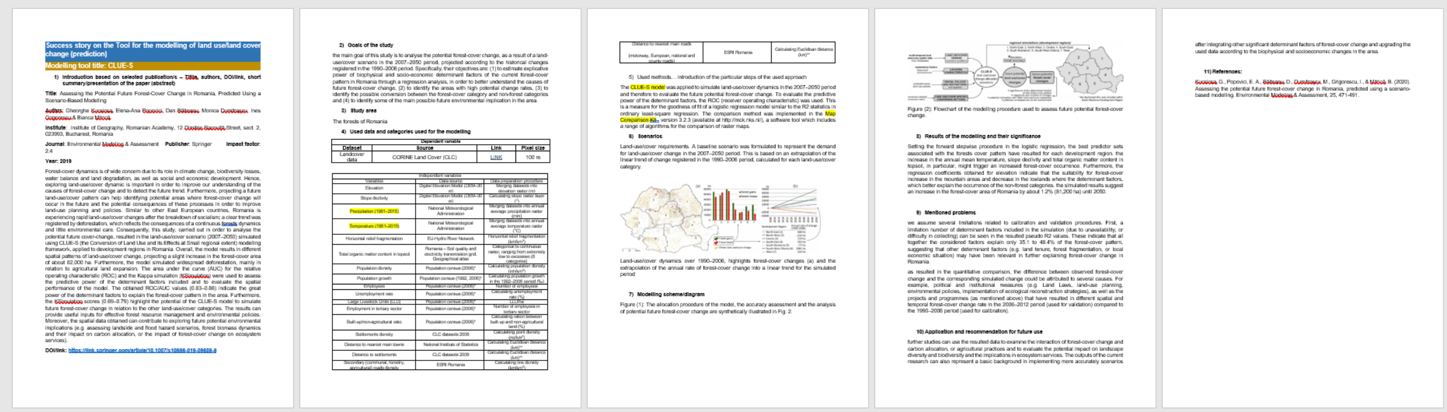
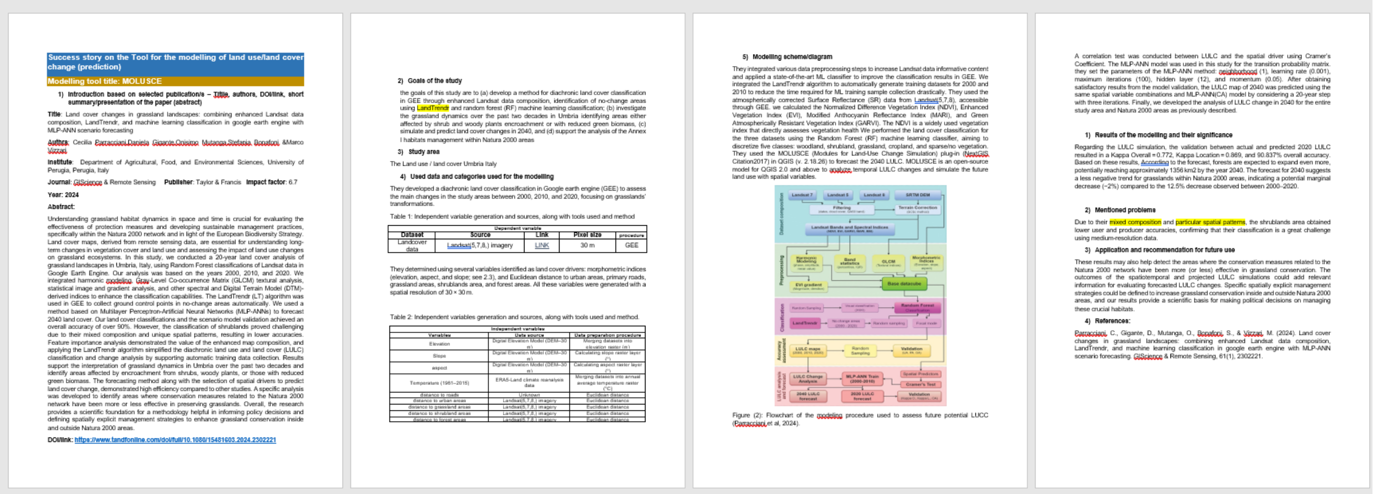
Success stories for modelling tools

Based on selected open source publication

- Title/Author/Institution/Journal
- Year, DOI/Link
- Abstract/Goals of the study
- Study area, data, methods
- Modelling scheme/diagram
- Results, Mentioned problems
- Applications and recommendation for future use
- Outputs from project case studies will also be used





Success story on the Tool for the modelling of land use/land cover change (prediction)

Modelling tool title: CLUE-S

1) **Introduction based on selected publication/s – Titile, authors, DOI/link, short summary/presentation of the paper (abstract)**

Title: Assessing the Potential Future Forest-Cover Change in Romania, Predicted Using a Scenario-Based Modelling

Authrs: Gheorghe Kucsicsa, Elena-Ana Popovici, Dan Bălteanu, Monica Dumitrașcu, Ines Grigorescu & Bianca Mitrică

Institute: Institute of Geography, Romanian Academy, 12 Dimitrie Racoviță Street, sect. 2, 023993, Bucharest, Romania

Journal: Environmental Modeling & Assessment **Publisher**: Springer **Impact factor**: 2.4

Year: 2019

Abstract:

Forest-cover dynamics is of wide concern due to its role in climate change, biodiversity losses, water balance and land degradation, as well as social and economic development. Hence, exploring land-use/cover dynamic is important in order to improve our understanding of the

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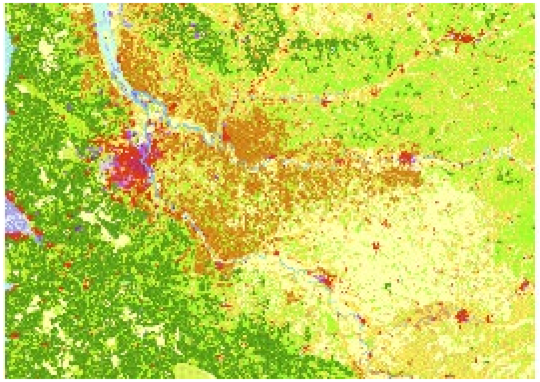
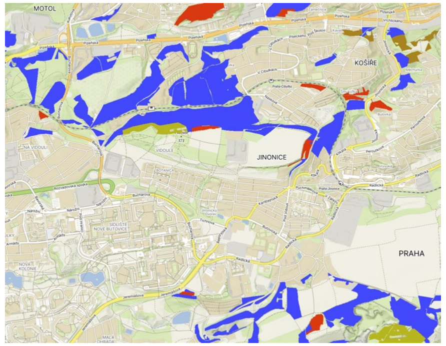
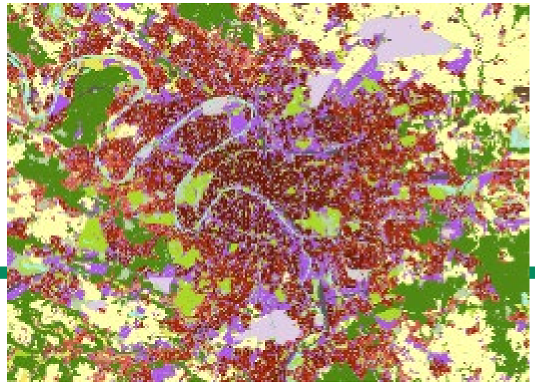
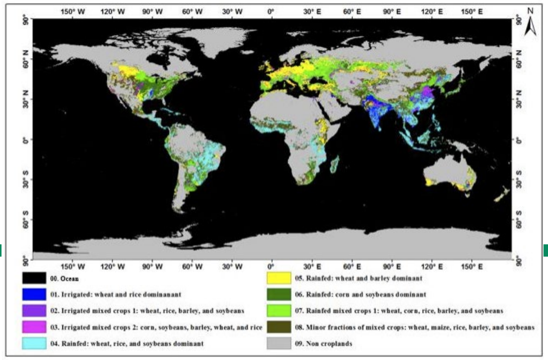
Database of the of existing LU/LC layers in the EU

- Mainly based on remote sensing resources (Copernicus layers) and national resources
- Database sorted to:
    a) General LU/LC layers for Europe/Word
    b) Thematic LU/LC layers (forests, croplands, urban, others)
    c) Country data – for each partner country – **contributions from project partner will be requested soon (links for the sources, CU will fill in the database based on the inputs/links from partners)**
- Information stored for each layer
    - Provider
    - Layer name
    - Temporal resolution
    - Source of data
    - Data processing
    - Data format
    - Download/visualization link
    - Pixel size
    - Accuracy
    - Area
    - Accessibility
    - Legend/Number of categories
- Integrated Administration and Control System IACS – harmonization WP2









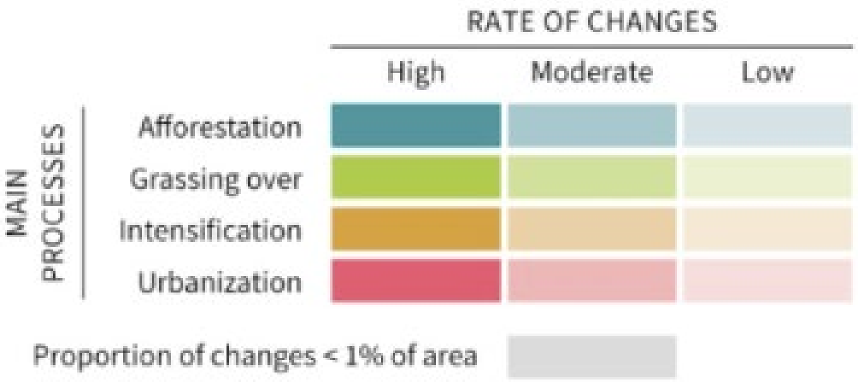
Database of existing LU/LC layers in the EU

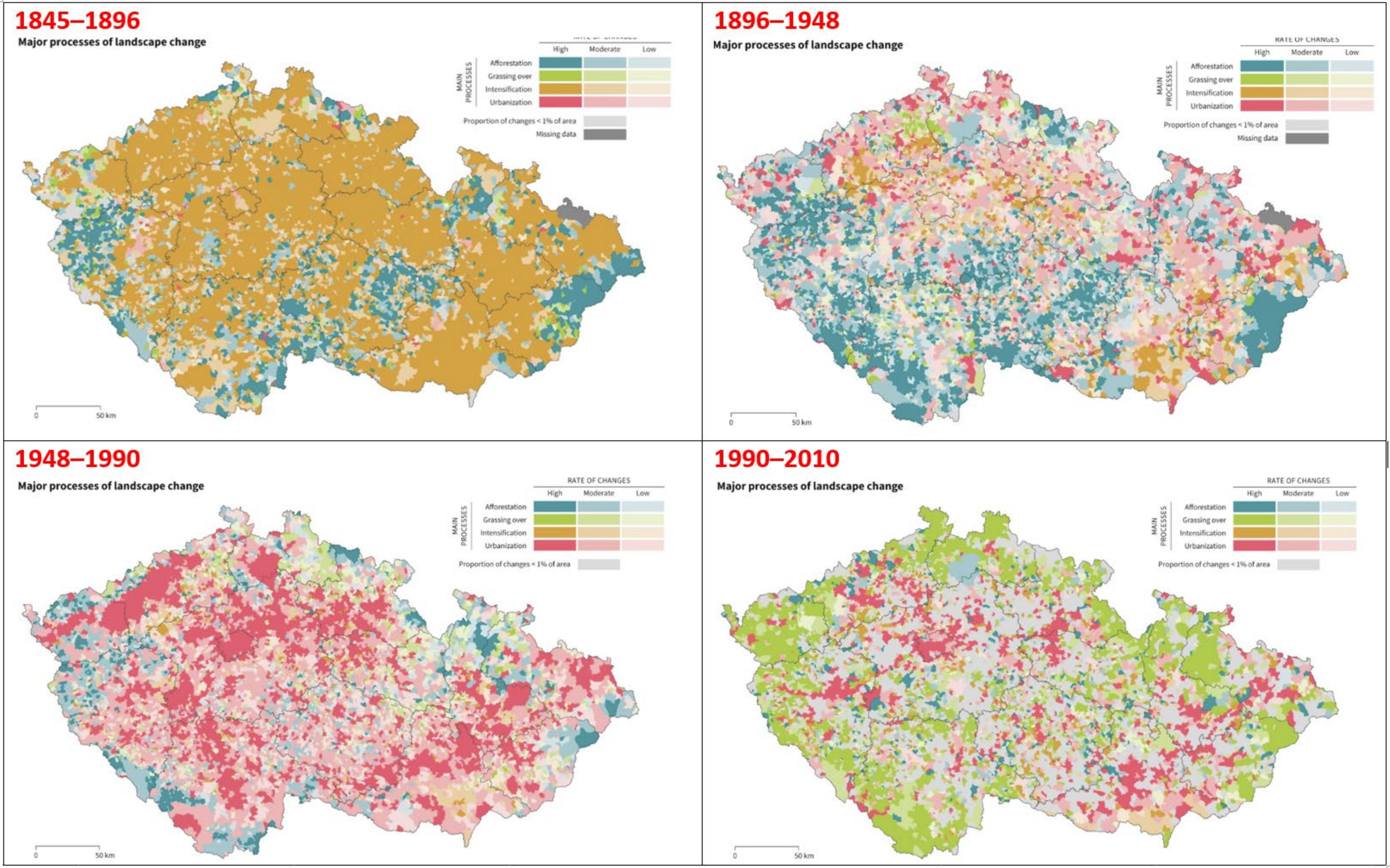
provider	layer name	one time/series	timespan	source data	data processing	data format	download link	visualisation link	pixel size/geome	thematic accura	area	accesibility	number of	legend	
Copernicus program	Corine Land Cover	one time	1986-1998	Landsat-5 MSS/TM	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 85 % (probabl	27 participat	free downloa	41	https://www.eea.euro	
Copernicus program	Corine Land Cover	one time	2000 +- 1 yea	Landsat-7 ETM, sin	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 85 % (achieve	39 participat	free downloa	41	https://www.eea.euro	
Copernicus program	Corine Land Cover	one time	2006 +- 1 yea	SPOT-4/5 and IRS I	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 85 %	39 participat	free downloa	41	https://www.eea.euro	
Copernicus program	Corine Land Cover	one time	2011-2012	IRS P6 LISS III and	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 85 % (probabl	39 participat	free downloa	41	https://copernicus.di	
Copernicus program	Corine Land Cover	one time	2017-2018	Sentinel-2 and Lanc	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 85 %	39 participat	free downloa	41	https://image.discom	
Copernicus program	Dynamic Land Cover	one time	2015	Proba-V Satellite	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 80 %	global	free downloa	23	https://land.copernic	
Copernicus program	Dynamic Land Cover	one time	2016	Proba-V Satellite	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 80 %	global	free downloa	23	https://land.copernic	
Copernicus program	Dynamic Land Cover	one time	2017	Proba-V Satellite	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 80 %	global	free downloa	23	https://land.copernic	
Copernicus program	Dynamic Land Cover	one time	2018	Proba-V Satellite	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 80 %	global	free downloa	23	https://land.copernic	
Copernicus program	Dynamic Land Cover	one time	2019	Proba-V Satellite	classification	raster - geotif/v	https://land.copern	https://land.copernicu	100 m	≥ 80 %	global	free downloa	23	https://land.copernic	
EUROSTAT	LUCAS	one time	2006	survey - primary dat	survey - primary	points with coo	https://ec.europa.e	-	2 km	-	EU countries	free downloa	7	https://ec.europa	http
EUROSTAT	LUCAS	one time	2009	survey - primary dat	survey - primary	points with coo	https://ec.europa.e	-	2 km	-	EU countries	free downloa	7	https://ec.europa	http
EUROSTAT	LUCAS	one time	2012	survey - primary dat	survey - primary	points with coo	https://ec.europa.e	-	2 km	-	EU countries	free downloa	7	https://ec.europa	http
EUROSTAT	LUCAS	one time	2015	survey - primary dat	survey - primary	points with coo	https://ec.europa.e	-	2 km	-	EU countries	free downloa	7	https://ec.europa	http
EUROSTAT	LUCAS	one time	2018	survey - primary dat	survey - primary	points with coo	https://ec.europa.e	https://ec.europa.eu/	2 km	-	EU countries	free downloa	7	https://ec.europa	http
EUROSTAT	LUCAS	one time	2018	survey - primary dat	survey - primary	points with coo	https://ec.europa.e	-	2 km	-	EU countries	free downloa	7	https://ec.europa	http
ESA, article doi:10.3	Sentinel-2 global land	one time	2017	Sentinel-2, CLC for	classification	WMS/Geotif	https://s2glc.cbk.w	https://browser.creod	10 m	86 % https://s2g	Europe with	free downloa	13	https://s2glc.cbk.wav	
ESA Climate Chang	CCI Land Cover	series	yearly 1992-2	satellite data, Lands	classification	tif and other	http://maps.elie.uc	-	300 m	≥ 71 %	global	free downloa	38	https://maps.elie.ucl.	
NASA	MODIS/Terra+Aqua L	series	yearly 2001-2	MODIS Terra and A	classification	tif and other	https://earthexplor	https://earthexplorer.	500 m	74 %	global	free downloa	17	https://svs.gsfc.nasa	
article https://doi.org	Dynamic world	series	very often 19	Sentinel-2	deep learning classification		https://developers	https://dynamicworld	10 m	≥ 75 %	global	available at (	?		
PhD project from Wa	Hilda (HIstoric Land D	series	every decade	unknown	unknown	ArcGIS map pa	https://www.wur.nl	http://www.geo-inforr	1 km	unknown	EU countries	free downloa	6	namely:Settleme	als
RIVM (The National	Pelcom - Pan-Europe	one time	1990s	MARS (Monitoring /	classification	ESRI-grid, ERD	http://www.geo-inf	http://www.geo-inforr	1 km	lower than 70 %	Europe + Tu	free downloa	15	http://www.geo-inforr	
UMD	UMD Land Cover	one time	1992/93	UMD GLAD Landsa	decision tree cla	tif	https://storage.goo	https://glad.earthengi	1 km	Expected to be	global	free downloa	14	see visualisation at	
USGS	GLCC 2.0 Global	one time	1992/93	1-km AVHRR 10-da	classification	tif and other	https://earthexplor	https://earthexplorer.	1 km	82 %	global	free downloa	17		
Joint Research Cent	GLC 2000	one time	1999/2000	SPOT-4-VGT	classification	tif	https://www.eea.e	https://www.eea.euro	1 km	82 %	global	free downloa	23	https://www.eea.euro	
Internatinal Water M	GMRCA LULC	one time	2000	AVHRR, SPOT	classification	tif	http://waterdata.iw	http://waterdata.iwmi	10 km	unknown	global	free downloa	10	http://waterdata.iwmi	
Geo-Wiki	Geo-Wiki Hybrid globa	two maps	2000/2005	1 km MODIS data	classification	text	https://iiasa.ac.at/	https://iiasa.ac.at/mo	300 m	Expected to be	global	free downloa	10	https://iiasa.ac.at/mo	
FAO (Food and Agri	LADA LUC map	one time	2007	interpretation of LU(	interpretation ar	tif	https://data.apps.f	https://storage.googl	5 arc minutes	unknown	global	free downloa	40	https://storage.googl	
FAO (Food and Agri	GLC-SHARE	one time	2014 and bef	combination of "bes	interpretation ar	tif	https://data.apps.f	https://storage.googl	30 arc seconds	Expected to be	global	free downloa	11	https://data.apps.fao	
OSM	OSM Landuse/Landco	one time	hard to tell	OSM, Sentinel-2, La	classification	.tiff	https://data.osmla	https://osmlanduse.org/#8.833346399831107/7.90058			global	on request to	14	https://maps.heigit.o	
Tsinghua University	GLASS-GLC	series	annual 1982-	GLASS satellite Clir	classification an	tif	https://doi.pangae	https://www.research	5 km	85 %	global	free downloa	8	https://www.research	
National Science Fo	GLC30	three maps	2000,2010,20	GLAD Landsat Ana	object based cla	tif	https://storage.googleapis.com/earthenc		30 m	Expected to be	global	free downloa	10	https://data.apps.fao	
Tsinghua University	GLC250	two maps	2001, 2010	slope, latitude, MOI	random forest c	tif	https://data-starcloud.pcl.ac.cn/resource		250 m	Expected to be	global	free downloa	25		
International Steerin	GLCNMO	three maps	2003, 2008, 2	MODIS data	classification	tif	https://globalmaps	https://globalmaps.gi	1 km(2003), 500	Expected to be	global	free downloa	20	https://globalmaps.g	
ESA in cooperation	GlobCover	two maps	2005,2009	MERIS satellite data	classification (cc	tif	http://due.esrin.esa.int/page_globcover.		300 m	Expected to be	global	free downloa	23	https://www.esa.int/E	
Tsinghua University	FROM-GLC	three maps	2010,2015,20	Landsat or Sentinel	different classifi	tif	should be available from https://data-sta		30 m, 250 m, 50	Expected to be	global	free downloa	8		
Geo-harmonizer pro	Annual Land Cover P	series	2000-2019	CLC, Lucas to train	machine learnin	tif	https://ecodatacub	https://ecodatacube.e	30 m	unknown	Europe	free downloa	33		
ESA	GlobCorrine	two maps	2005,2009	CLC, GlobCover, M	same as GlobC	tif	https://maps.elie.u	https://maps.elie.ucl.	300 m	>49 % or >79 %	Europe	free downloa	17	https://maps.elie.ucl.	

+ ≡ general LC for Europe/World ▾ | Tematic LC ▾ | Country data - Czechia ▾ | Germany ▾ | Romania ▾ | Greece ▾ | Estonia ▾ | Denmanrk ▾ | Portugal ▾ | Italy ▾ | Poland ▾ | Latv

LUCC Database Czechia – an example of unique European Land Use Change dataset

- Based on the records of Stable cadaster (and later cadastral data)
- Years 1845, 1868, 1948, 1990, 2000, 2010, 2020
- Temporal consistency (cadasters merged in case when change of total area exceeded 2%)
- Categories – arable land, permanent grasslands, permanent cultures, forest areas, built-up areas, water areas, remaining areas
- Evaluation of temporal changes – indexes, trends – major processes of landscape change

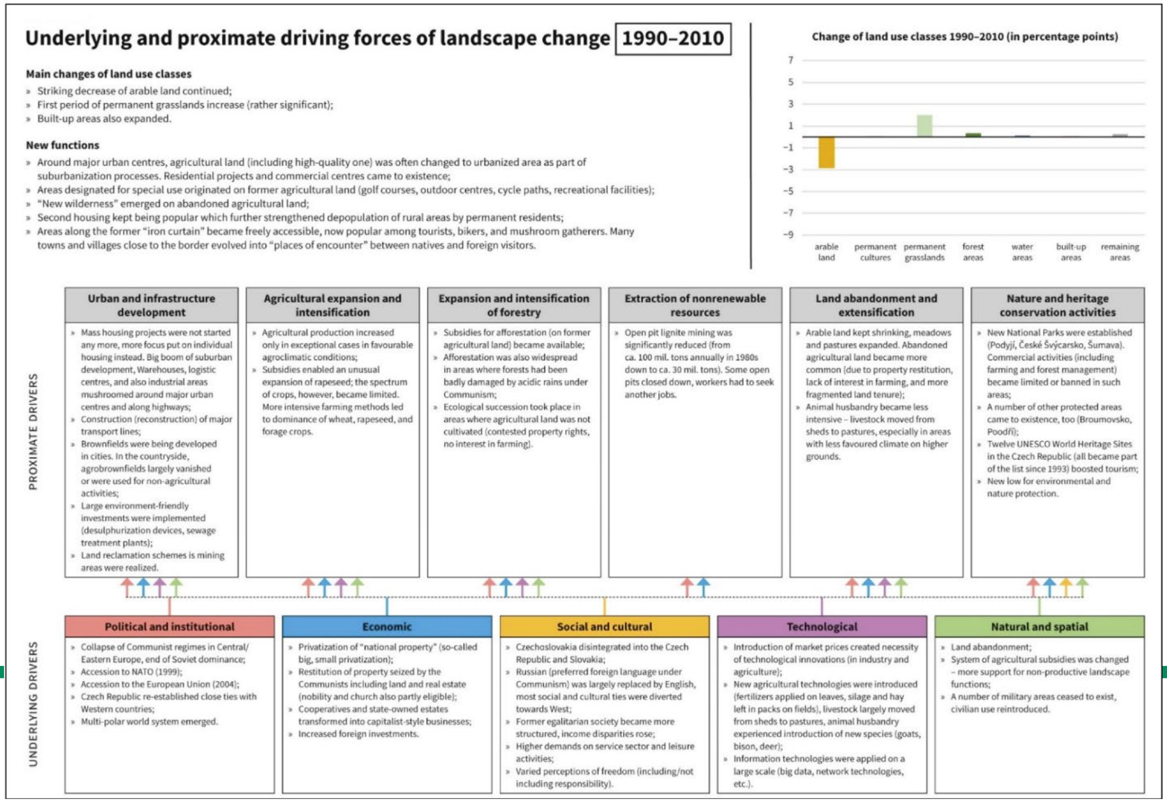


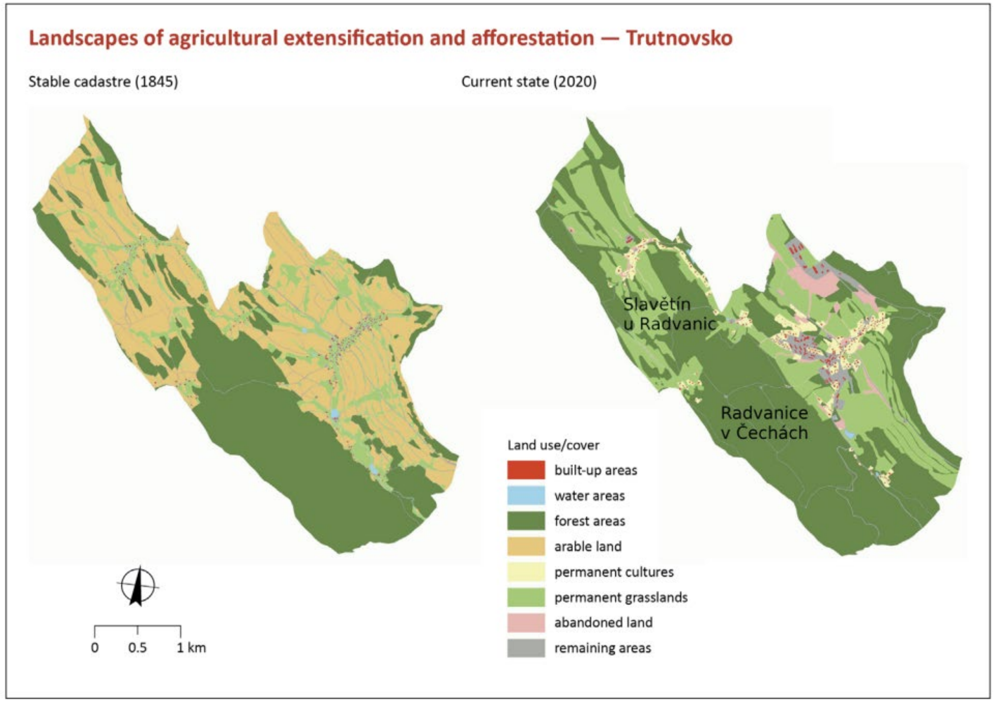


Kupková, L.; Bičík, I.; Jeleček, L. At the Crossroads of European Landscape Changes: Major Processes of Landscape Change in Czechia since the Middle of the 19th Century and Their Driving Forces. *Land* **2021**, *10*, 34. https://doi.org/10.3390/land10010034

LUCC Database Czechia – an example of unique European Land Use Change dataset

- Two spatial levels – cadasters (stable territorial units) + parcel level
- Driving forces evaluation
- Will be used for modeling within Europe – LAND project





CHARLES UNIVERSITY
Faculty of Science

Thank you for your attention!

lucie.kupkova@natur.cuni.cz