



MOLUSCE

Hands-on land cover change simulations in QGIS with MOLUSCE

Webinar by NextGIS



https://nextgis.com/learn/molusce_webinar.zip

NEXTGIS

Geospatial software developers since 2011

Financial center in Estonia / Development center in Serbia / Remote

Largely open-sourced

Products. Projects. Data store

Maybe we already know each other



Core committers

30+ plugins (including MOLUSCE)

Community events, translation coordination

Most popular plugin worldwide
(QuickMapServices, ~10.000.000 downloads)



Core committers

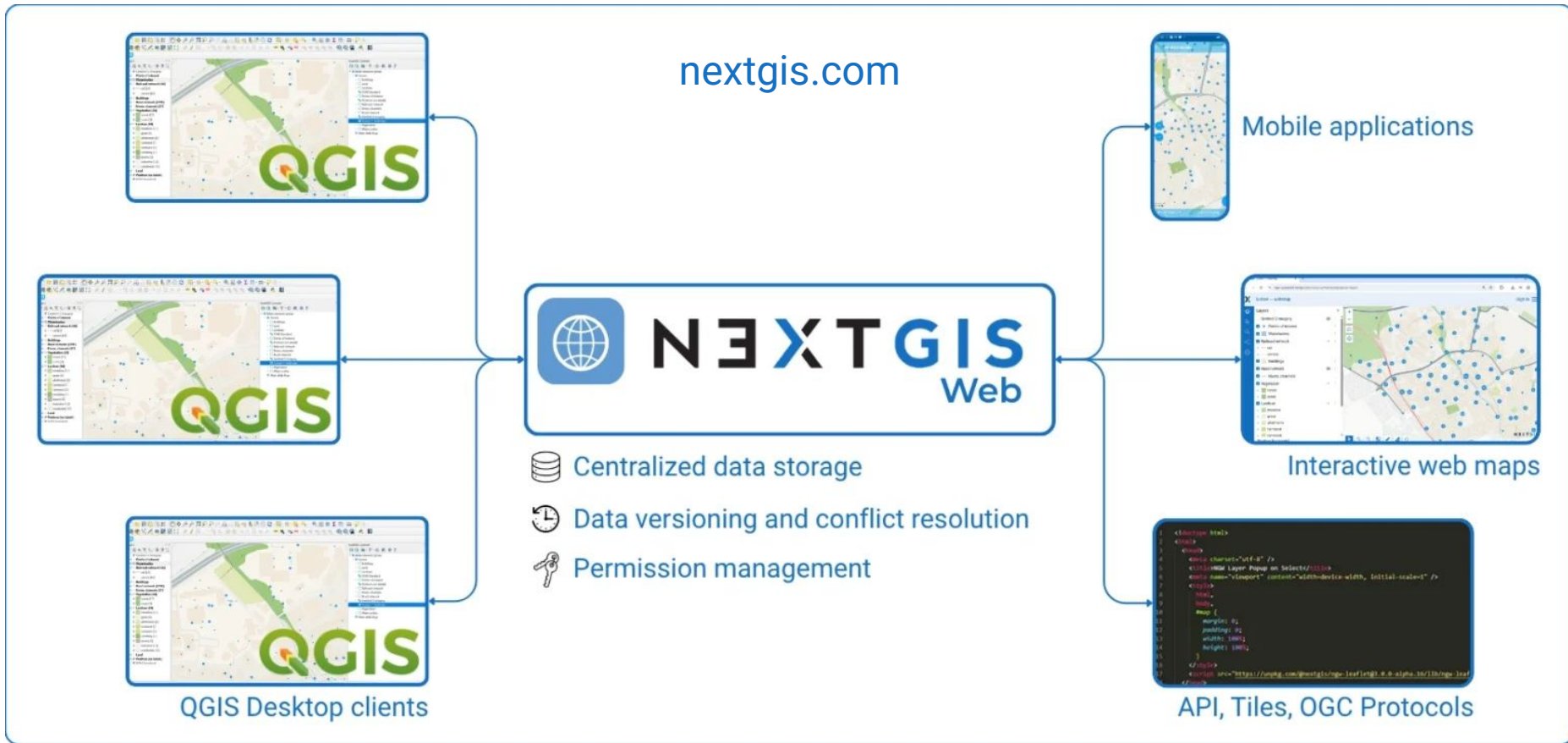
Several formats maintainers



Sponsors for 10+ years

Community events

QGIS Teamspace: ready-to-go Enterprise level solution for QGIS-based workflows



Special program for Universities: cloud subscription for free

Learn more at <https://nextgis.com/universities/>

Contact edu@nextgis.com

What we offer

✅ Free cloud access for teaching and learning + onboarding webinar

Universities receive a **free NextGIS Premium** subscription (20 users), including:

- Hosted Web GIS environment (no infrastructure required)
- Interactive Web Maps publishing system
- QGIS collaboration infrastructure (projects publishing, team editing, version control)
- Field data collecting subsystem
- User and access management

This is ideal for **courses, labs, workshops, and student projects**.

A **1-hour onboarding webinar (in English)** is included to help you get started. We'll introduce the platform, share our experience, and answer your questions.

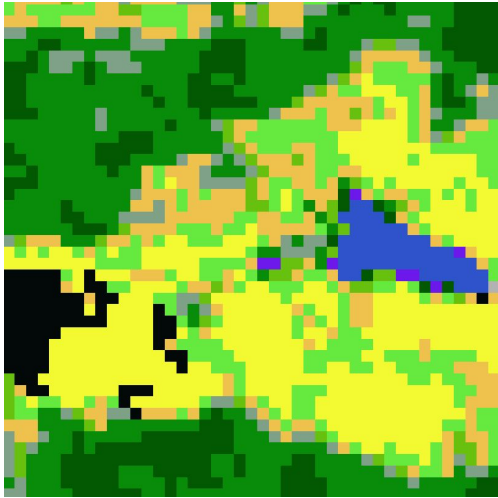
🏷 In addition to the free cloud plan, universities get 50% off:

- [On-premise \(self-hosted\) deployments](#)
- [Self-hosted basemaps server](#)
- Data at data.nextgis.com

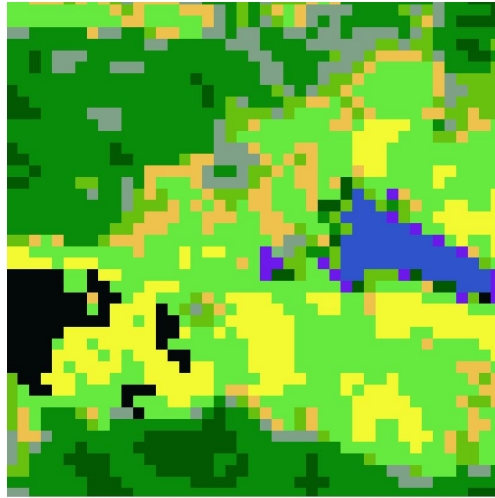
The same platform can be used for **education, research, and internal university needs**.

Land Use Change Simulation problem

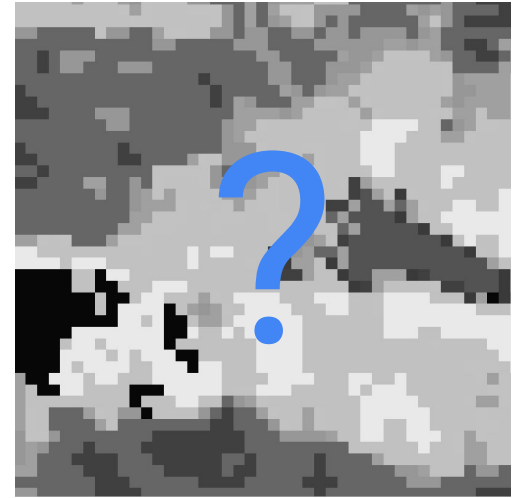
2017



2022



2027



—————→
What and how had changed?

—————→
What will happen in next 5 years?

NEXTGIS

MOLUSCE

Land Use Change Simulations in QGIS

First released in 2012

Presented at:

- FOSS4G 2012 in Japan
- FOSS4G 2013 in Nottingham
- FOSS4GE 2025 in Mostar

Version 3 published in 2013

... development on hold ...

Version 4 published in 2024

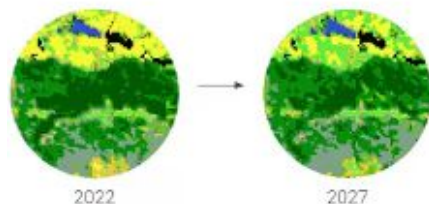
Version 5 published in 2025

Version 5.2 published in 2026

NEXTGIS

MOLUSCE 4.0

Land Use Change Simulations in QGIS



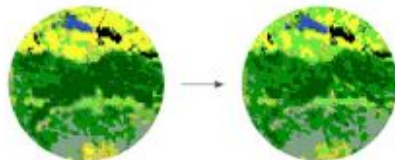
37:47

NEXTGIS

MOLUSCE 5.0

Land Use Change Simulations in QGIS

What's new?



10:46



ASIA AIR SURVEY

NEXTGIS
OPENSOURCE GEOSPATIAL SOLUTIONS

MOLUSCE

MODULES FOR LAND USE CHANGE EVALUATION


QUICK HELP

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Phenomenon in QGIS World

100k+ downloads, thousands of scientific papers, dozens of YouTube videos

Google Scholar

qgis molusce



Articles

About 3,990 results (0.14 sec)

Any time

Since 2026

Since 2025

Since 2022

Custom range...

Sort by relevance


Sort by date

Any type

Review articles

☐ include patents



☒ include citations

 Create alert

Predicting the future land use and land cover changes for Bhavani basin, Tamil Nadu, India, using **QGIS MOLUSCE** plugin

[M Kamaraj, S Rangarajan](#) - Environmental Science and Pollution ..., 2022 - Springer

... **QGIS** 2.18.24 version **MOLUSCE** plugin (MLP-ANN) model. The five criteria, such as DEM, slope, aspect, distance from the road, and distance from builtup, are used as spatial variable ...



 Save  Cite Cited by 266 Related articles All 13 versions

[PDF] [researchsquare.com](#)

Exploring LULC changes in Pakhal Lake area, Telangana, India using **QGIS MOLUSCE** plugin

[A Amgoth, HP Rani, KV Jayakumar](#) - Spatial Information Research, 2023 - Springer

... **Quantum GIS** 2.18.24 with the **MOLUSCE** plugin was used in this approach. Six LULC prediction stages were included in the **MOLUSCE** ... using the **QGIS** - **MOLUSCE** plugin model. The ...




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[PDF] [nextgis.ru](#)

[HTML] Spatiotemporal change analysis and prediction of future land use and land cover changes using **QGIS MOLUSCE** plugin and remote sensing big data: a case ...

[R Muhammad, W Zhang, Z Abbas, F Guo...](#) - Land, 2022 - mdpi.com

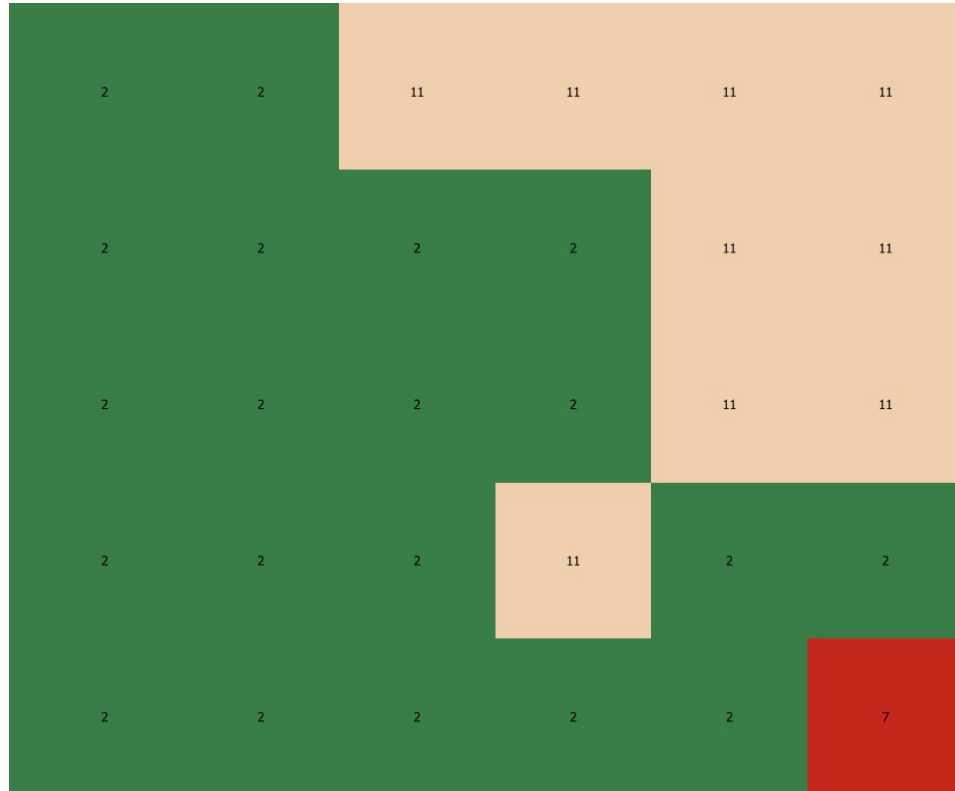
... We utilized the Modules for Land-Use Change Simulation (**MOLUSCE**) plugin inside **QGIS** to estimate spatiotemporal changes and compute the LULC transition between the research ...

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[HTML] [mdpi.com](#)

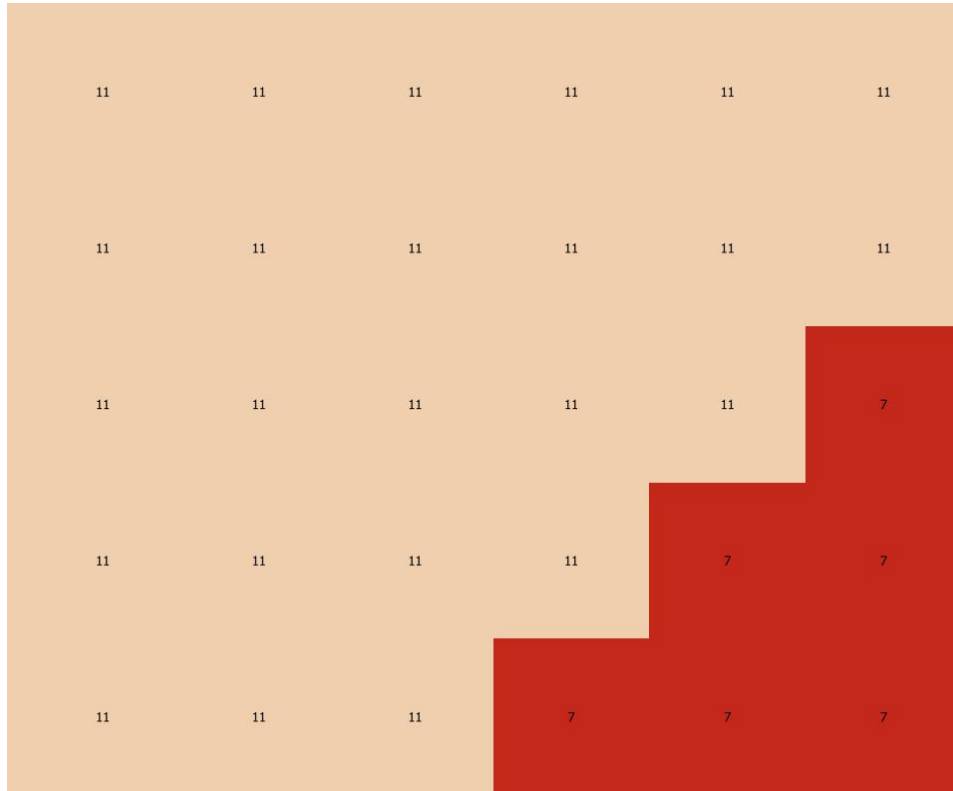
Monte Carlo Cellular Automata (MCCA) approach

First state (ex. 2020)



Monte Carlo Cellular Automata (MCCA) approach

Second state (ex. 2025)



Monte Carlo Cellular Automata (MCCA) approach





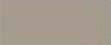
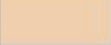
Transition matrix and map are calculated

Transition matrix

	Water	Trees	Crops	Built Area	Bare Ground	Rangeland
Water	0.8690014332775531	0.005485475870659833	0.0	0.00697128192044184	0.004524954787972475	0.11401685414337279
Trees	5.398897545121287e-06	0.8544673177737107	4.049173158840965e-05	0.005841607143821232	0.0	0.13964518445333463
Crops	0.0	0.0	0.0	0.2785714285714286	0.0	0.7214285714285714
Built Area	0.0	0.003183343370902521	0.00022943015285783935	0.9162293154377814	0.0	0.08035791103845823
Bare Ground	0.0	0.0	0.0	0.23511904761904762	0.7529761904761905	0.011904761904761904
Rangeland	0.0	0.06424083959763228	5.81036423720812e-05	0.015818716635799108	3.6314776482550754e-05	0.919846025347714

Class statistics

sq. km.

	Class color	2018	2021	Δ	2018 %	2021 %	Δ %
Water		13.33 sq. km.	11.58 sq. km.	-1.75 sq. km.	19.691697069910468	17.1124085132038	-2.5792885567066683
Trees		37.04 sq. km.	32.62 sq. km.	-4.42 sq. km.	54.74002455902367	48.204989530644845	-6.535035028378822
Crops		0.01 sq. km.	0.00 sq. km.	-0.01 sq. km.	0.020687504894811425	0.0045808046552796725	-0.016106700239531754
Built Area		3.49 sq. km.	3.73 sq. km.	0.25 sq. km.	5.152518629836997	5.517209787554101	0.3646911577171039
Bare Ground		0.03 sq. km.	0.09 sq. km.	0.05 sq. km.	0.04965001174754742	0.12722815510309027	0.07757814335554285
Rangeland		13.77 sq. km.	19.65 sq. km.	5.88 sq. km.	20.34542224586507	29.033583208838884	8.688160984252377

Monte Carlo Cellular Automata (MCCA) approach

Environmental factor 1

9,09	7,86	8,98	11,98	14,04	11,18
11,18	8,11	9,47	13,09	15,82	13,83
11,18	7,33	8,53	12,33	14,88	12,6
8,59	6,14	5,44	8,11	12,02	10,46
7,67	6,38	4,04	3,2	6,38	7,67

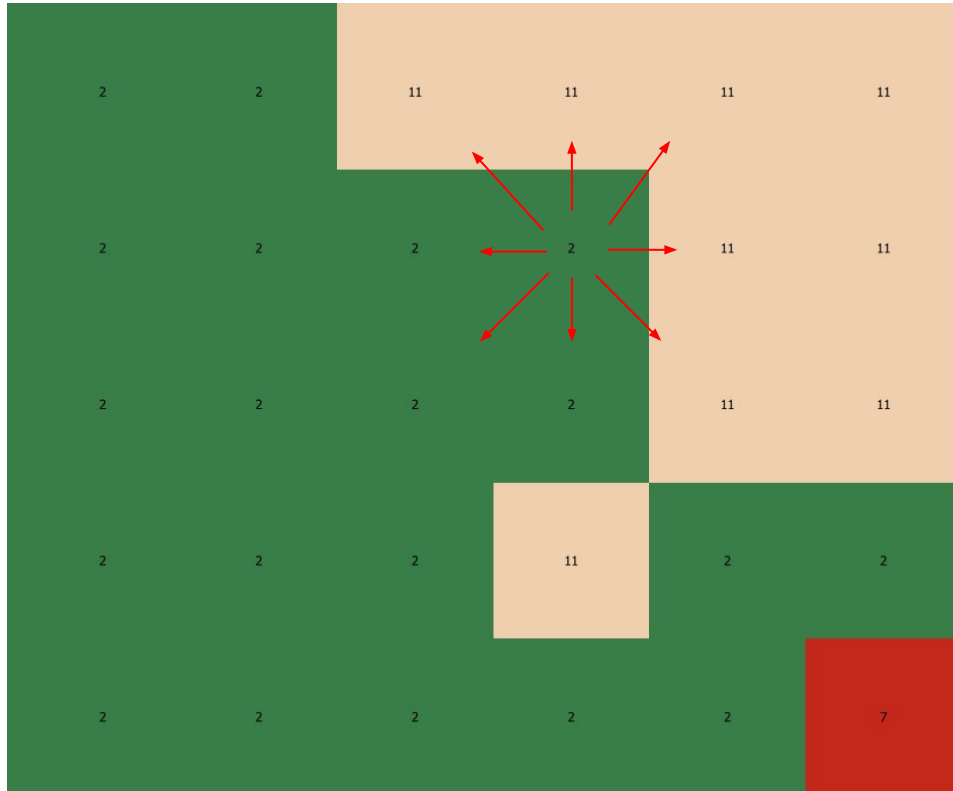
Monte Carlo Cellular Automata (MCCA) approach

Environmental factor N



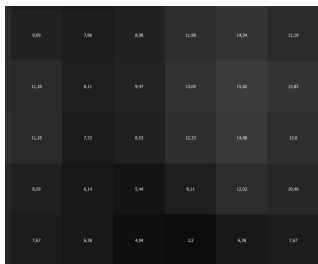
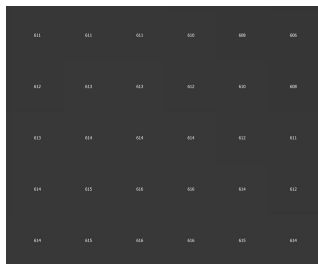
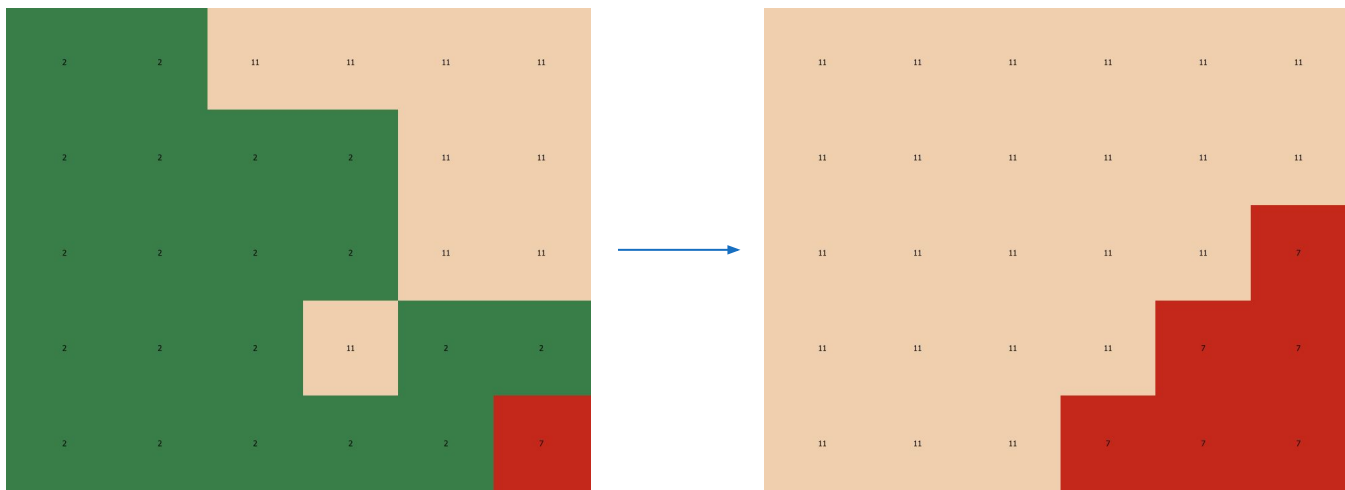
Monte Carlo Cellular Automata (MCCA) approach

State of neighbours for each pixel could be taken into account

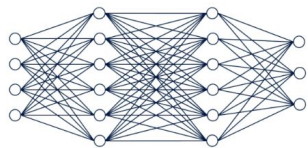


Monte Carlo Cellular Automata (MCCA) approach

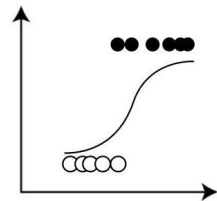
Train statistical model to explain the observed transformation



ANN



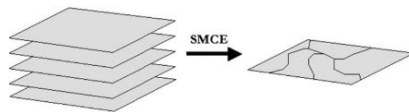
Logistic regression



Weights of evidence

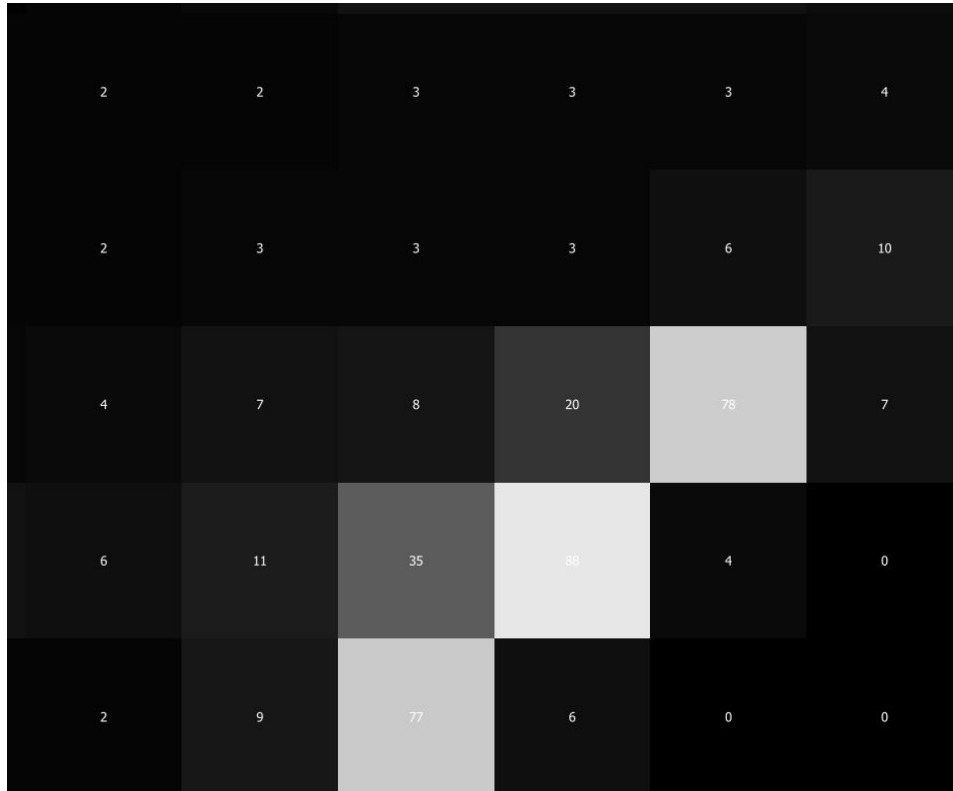
$$WOE = \ln \left(\frac{\text{Event}\%}{\text{Non Event}\%} \right)$$

MCE



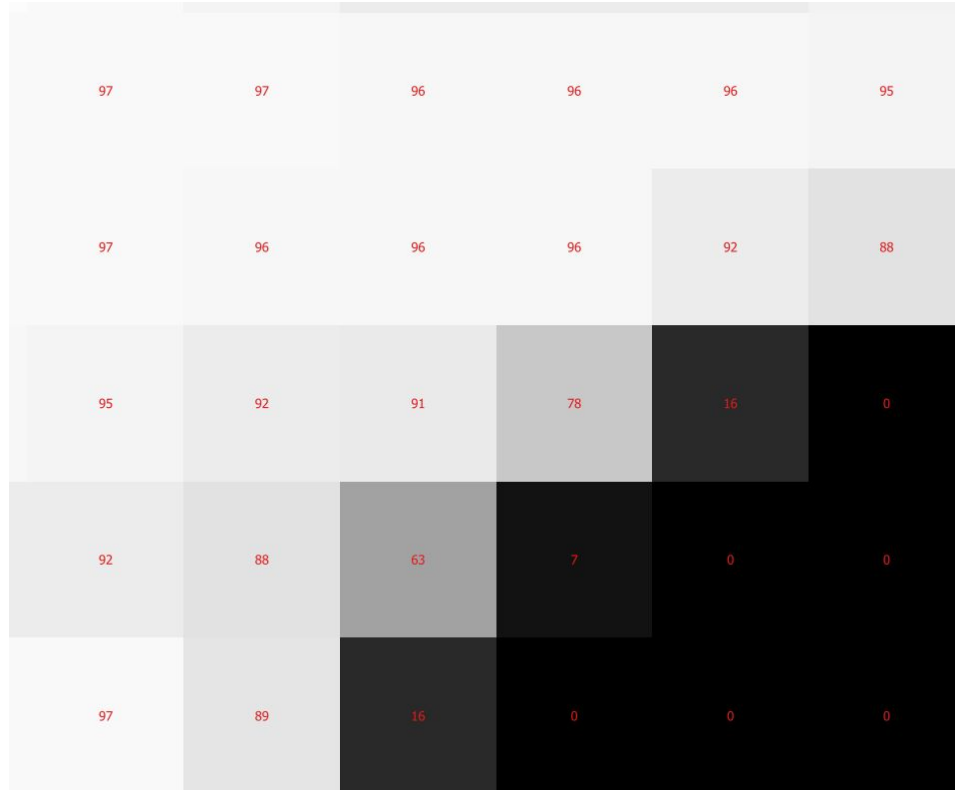
Monte Carlo Cellular Automata (MCCA) approach

Probability estimation for each transition. Example: 11 -> 7



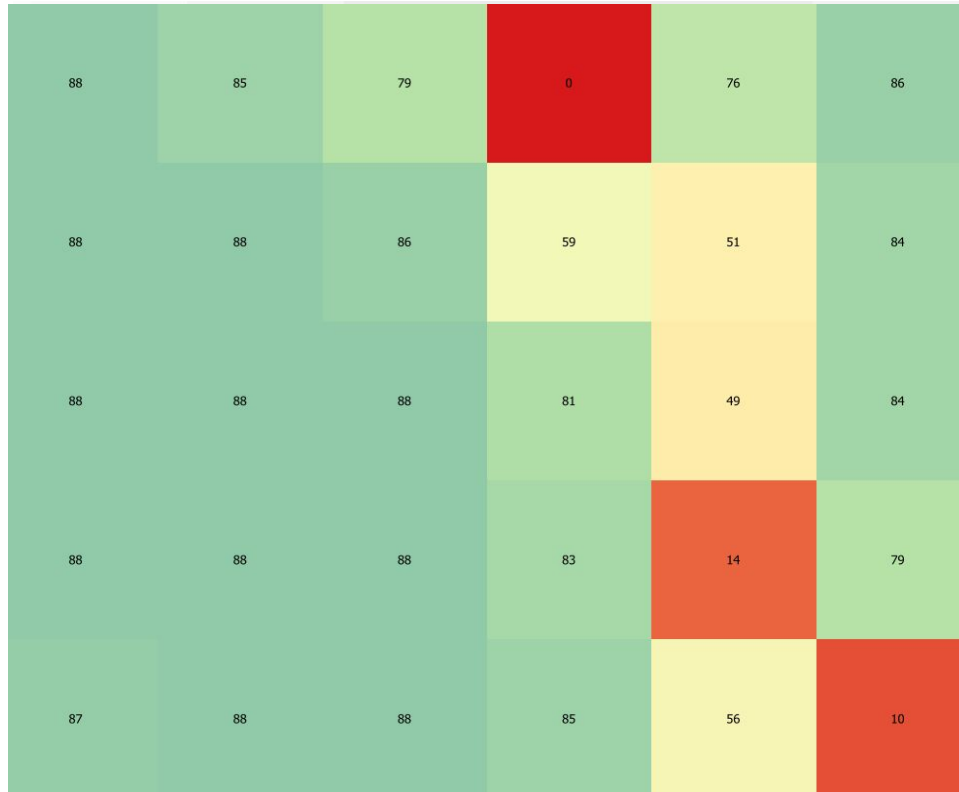
Monte Carlo Cellular Automata (MCCA) approach

Probability estimation for each transition. Example: 11 -> 11



Monte Carlo Cellular Automata (MCCA) approach

General certainty function. Difference between two largest transition potentials

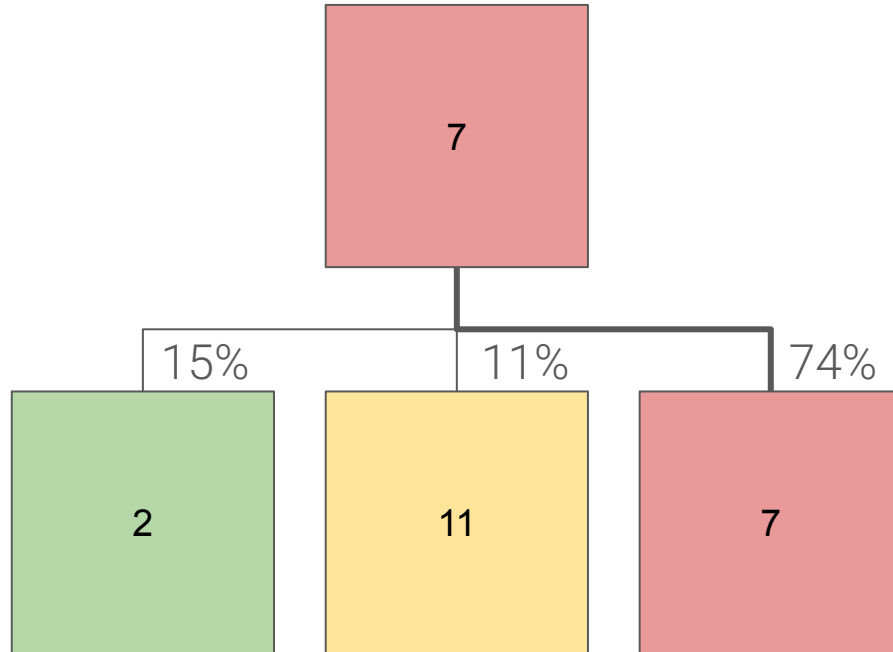


How confident model is?

Monte Carlo Cellular Automata (MCCA) approach

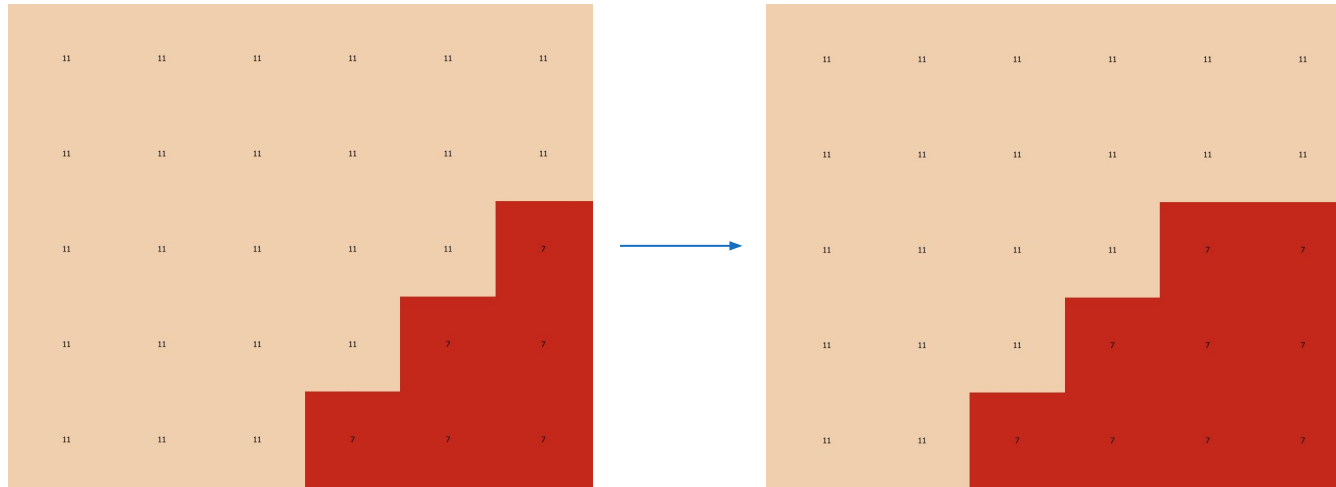
Highest probability is used to apply the transition.

If there are several very close probabilities, random among them is selected



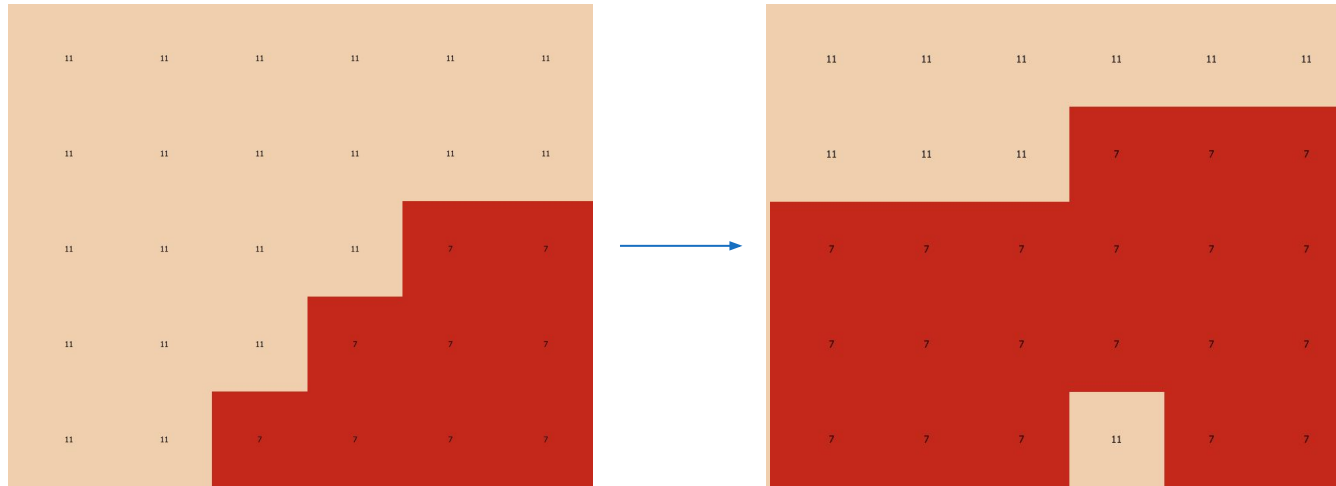
Monte Carlo Cellular Automata (MCCA) approach

Predicted state (ex. 2030)

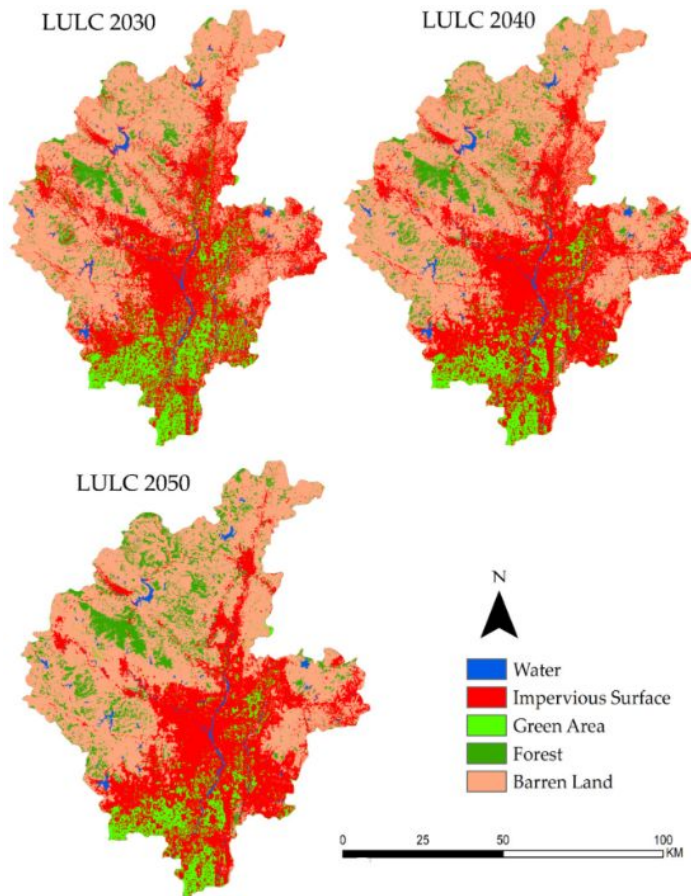


Monte Carlo Cellular Automata (MCCA) approach

Could be many iterations. Predicted state 2 (ex. 2035)



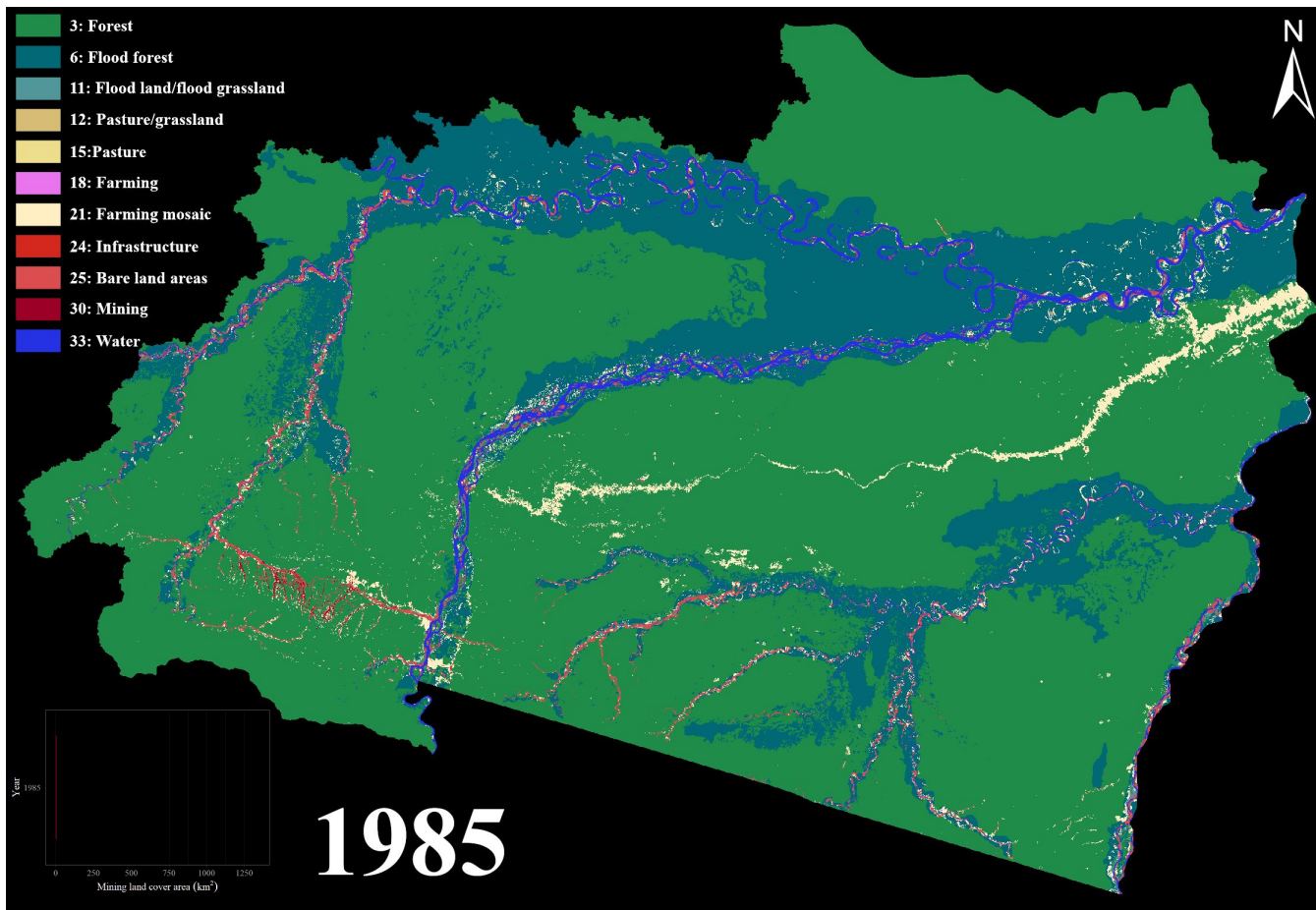
Examples of usage. General LULC dynamics



LULC Category	2030			2040			2050		
	km ²	%	Kappa	km ²	%	Kappa	km ²	%	Kappa
Forest	934.37	5.39		1308.94	7.56		1854.33	10.71	
Green area	2042.66	11.79		1292.32	7.46		1208.12	6.97	
Water	260.86	1.51	0.61	271.91	1.57	0.51	263.95	1.52	0.51
Barren land	8131.22	46.94		8472.75	48.91		8668.5	50.04	
Impervious surface	5952.50	34.36		5975.67	34.50		5326.71	30.75	

Muhammad, R.; Zhang, W.; Abbas, Z.; Guo, F.; Gwiazdzinski, L.
Spatiotemporal Change Analysis and Prediction of Future Land Use and Land Cover Changes Using QGIS MOLUSCE Plugin and Remote Sensing Big Data: A Case Study of Linyi, China. *Land* 2022, 11, 419. <https://doi.org/10.3390/land11030419>

Examples of usage. Deforestation driven by gold mining



Elera-Gonzales, D.G., da Silva, C.L.,
de Moura Melo, L. *et al.*

**Deforestation driven by illegal and
informal gold mining in the
southern Peruvian Amazon: a
predictive land use analysis over
the next 50 years.** *Environ Monit
Assess* 197, 792 (2025).

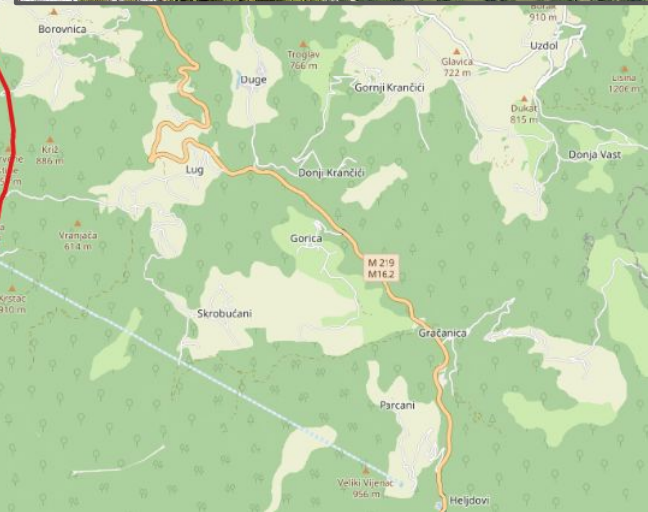
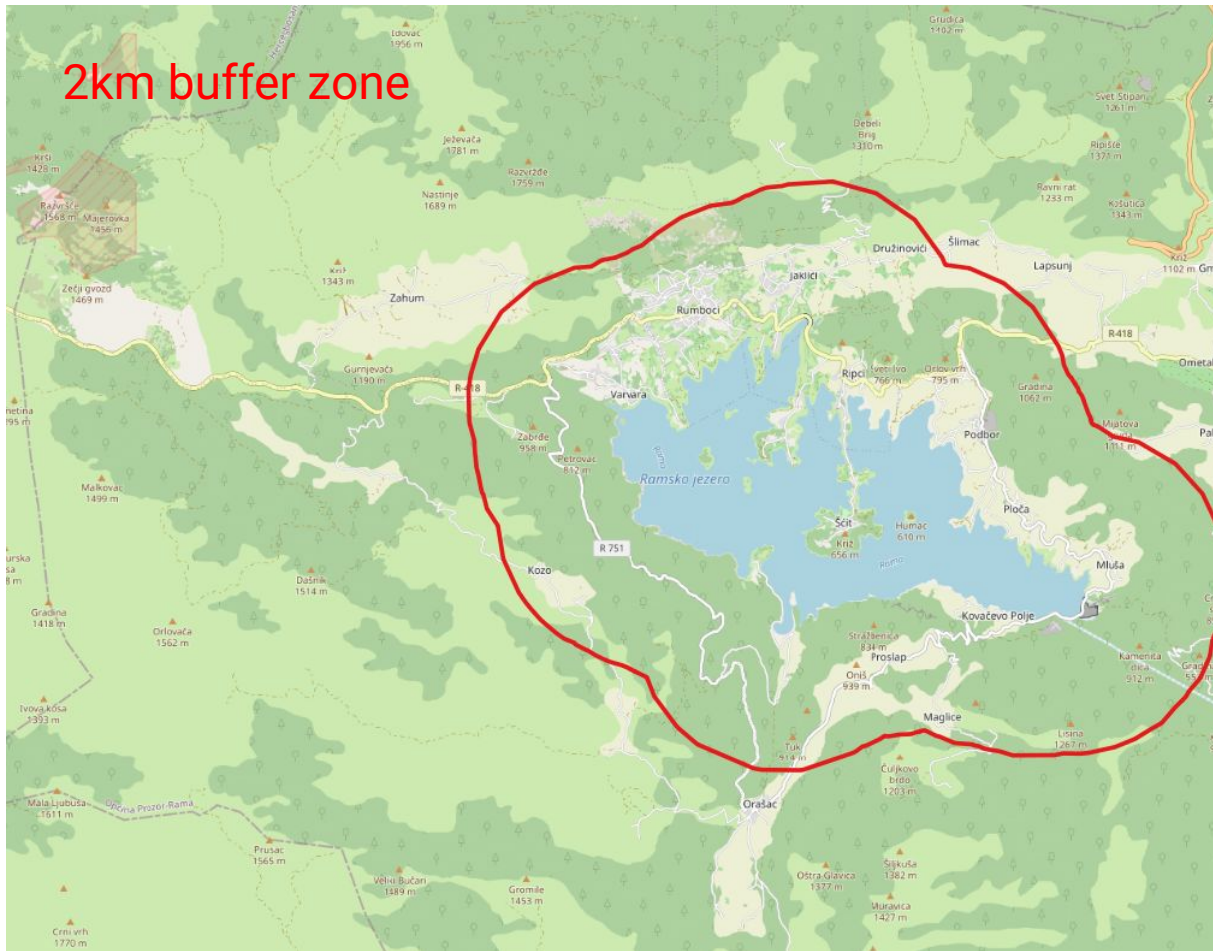
<https://doi.org/10.1007/s10661-025-14209-w>

Examples of usage. Shoreline changes

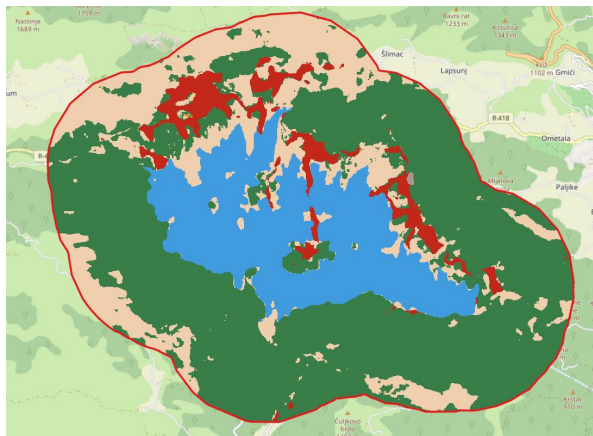


Case. Ramsko Lake

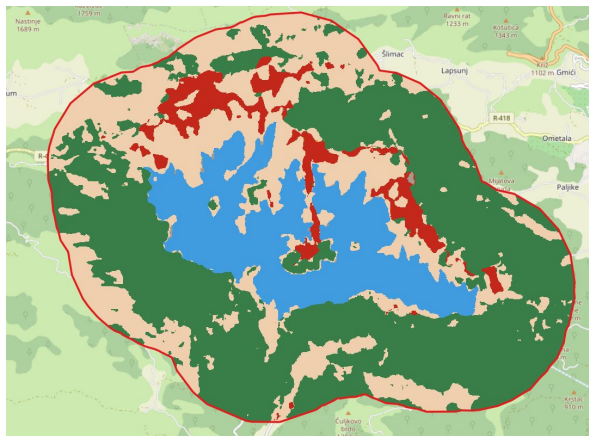
2km buffer zone



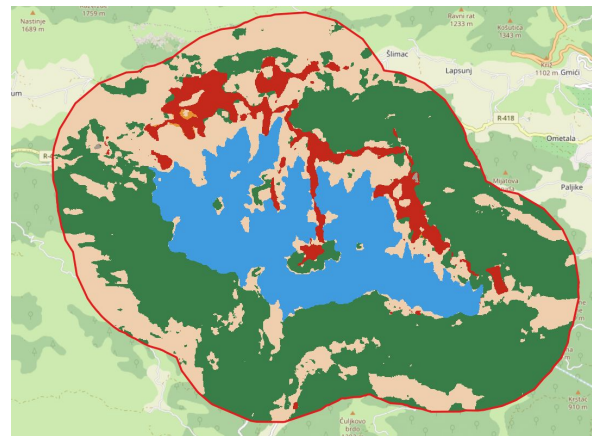
2018 Train the model



2021 Validate prediction



2024 to 2027



Case datasets

LULC Data:

- ESRI LandCover 2018
- ESRI LandCover 2021
- ESRI LandCover 2024

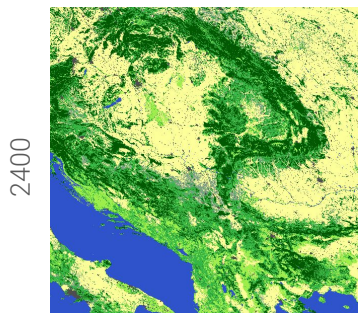
All from [ESRI LandCover Explorer](#)

Data to build spatial predictors:

- Copernicus DEM from [Copernicus Browser](#)
- OpenStreetMap (touristic points) from [Overpass Turbo](#)
- Microsoft buildings from [MS GitHub](#)
- Microsoft roads from [MS GitHub](#)

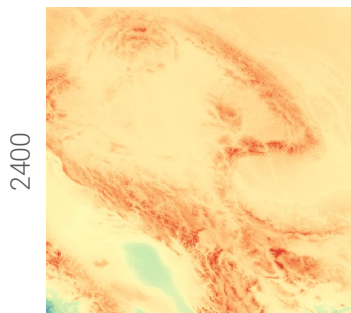
Data preparation

All inputs are rasters of same size, extent, reference system*



2400

2400



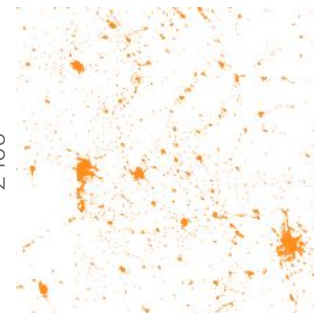
2400

2400



2400

2400



2400

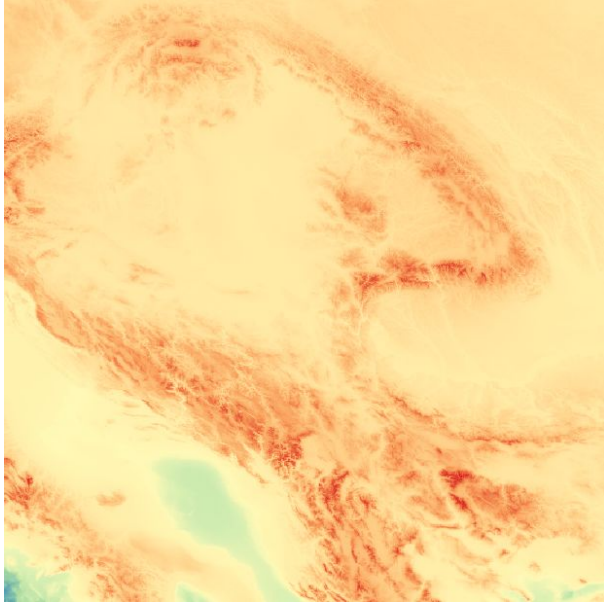
2400

Land cover maps

Predictors

*2400 is just an example. Your data could have its own size

Raster datasets



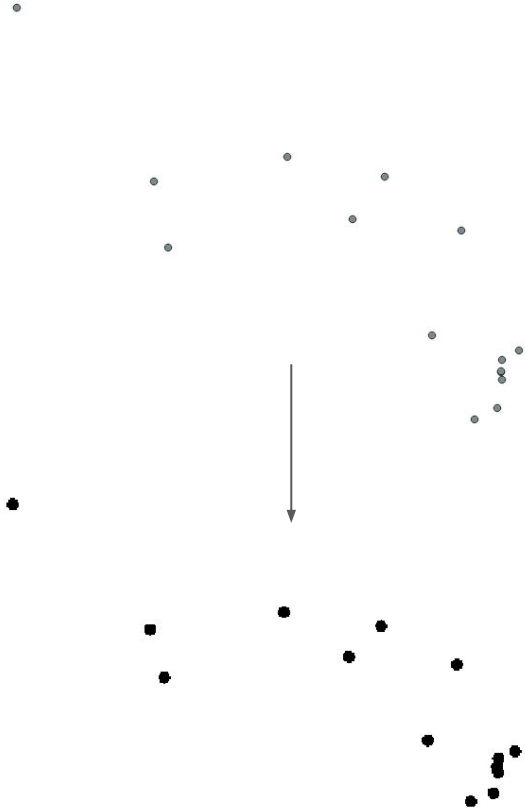
Resampling

Key tools in QGIS:

- Raster calculator
- Raster layer export
- Warp (reproject)
- Clip raster (by extent / by mask)

Pay attention to resampling method!

Point vector datasets



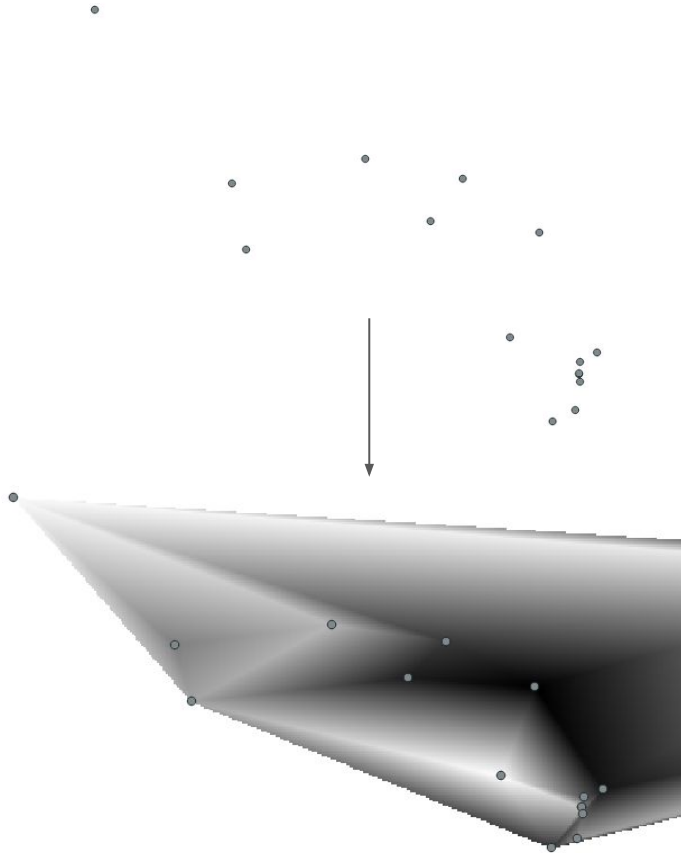
(Buffer) + Rasterization

Key tools in QGIS:

- Rasterize (vector to raster)
- Buffer

“Presence” mode

Point vector datasets



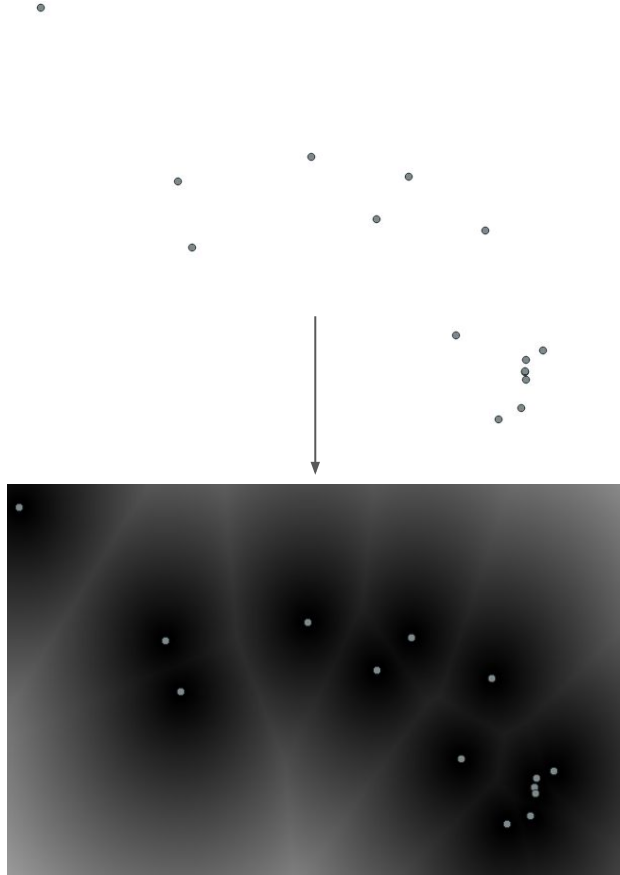
Interpolation

Key tools in QGIS:

- TIN/IDW Interpolation
- Heatmap
- SAGA interpolation tools

When some observation of continuous fields are presented in points

Point vector datasets

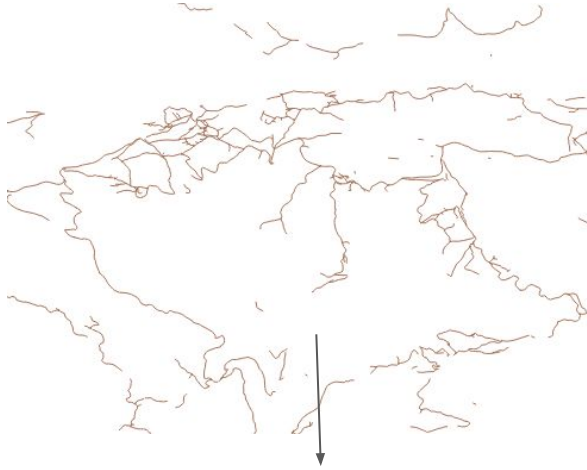


Proximity

Key tools in QGIS:

- Proximity

Linestring and polygon vector datasets

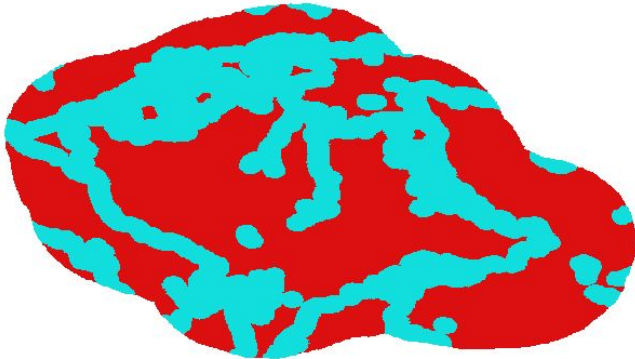


(Buffer) + Rasterization

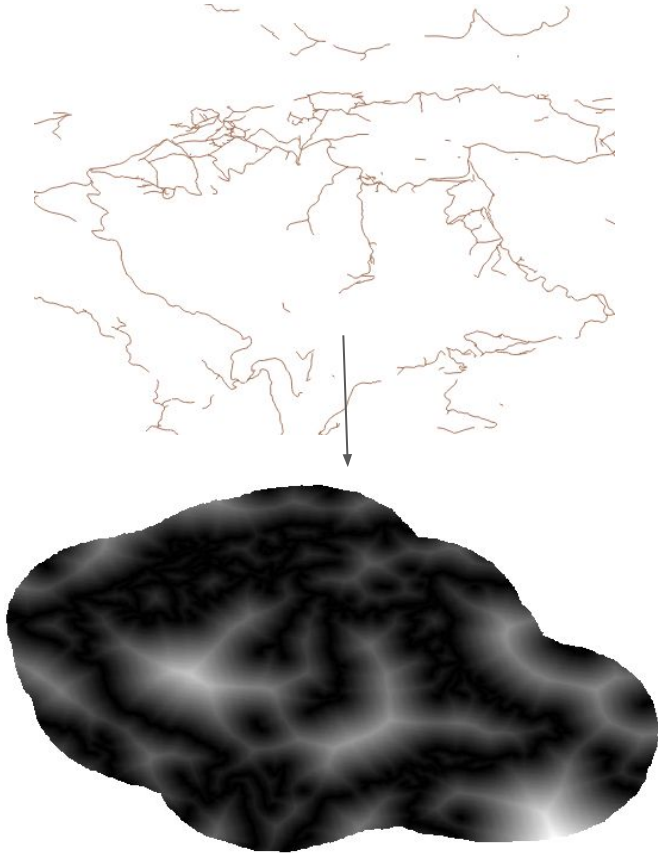
Key tools in QGIS:

- Rasterize (vector to raster)
- Buffer

“Presence” mode



Linestring and polygon vector datasets

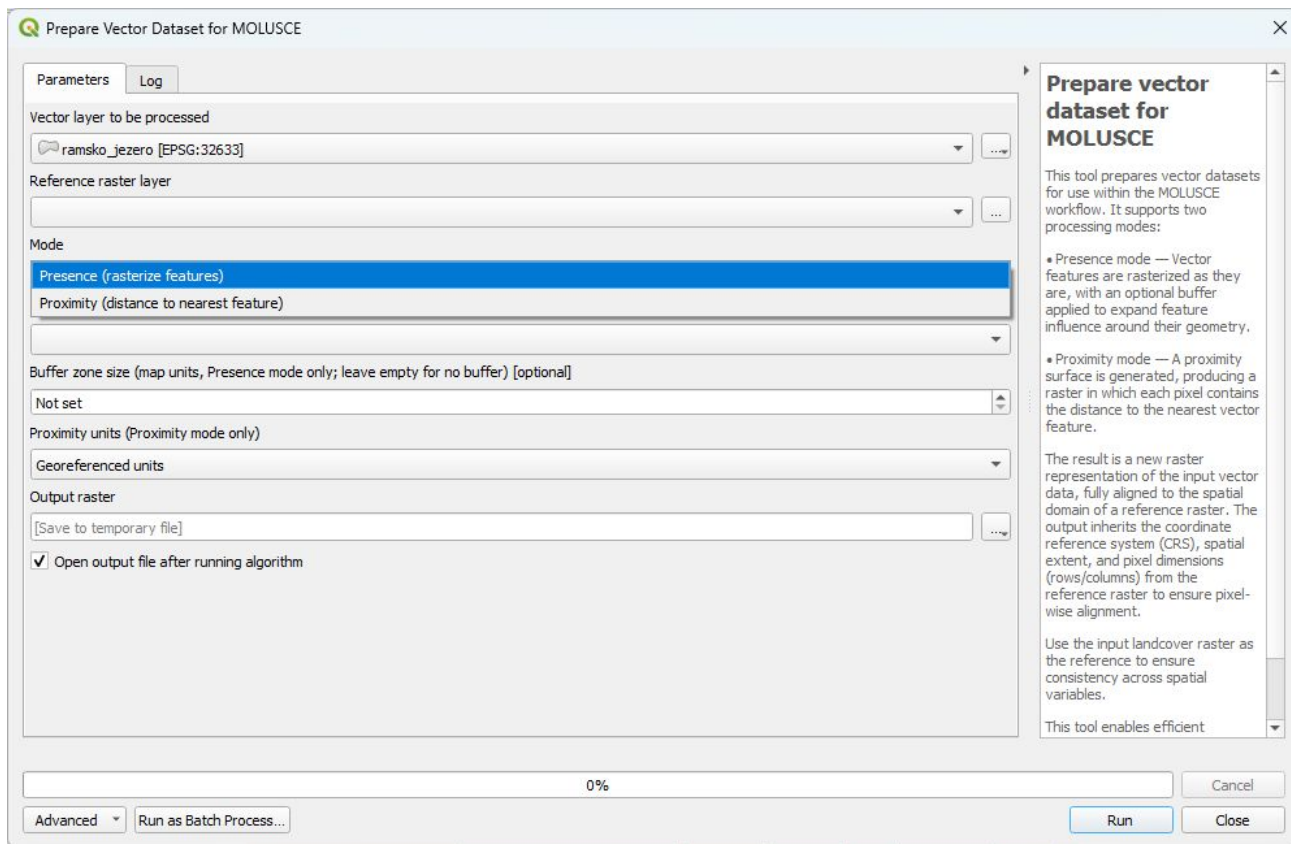


Proximity

Key tools in QGIS:

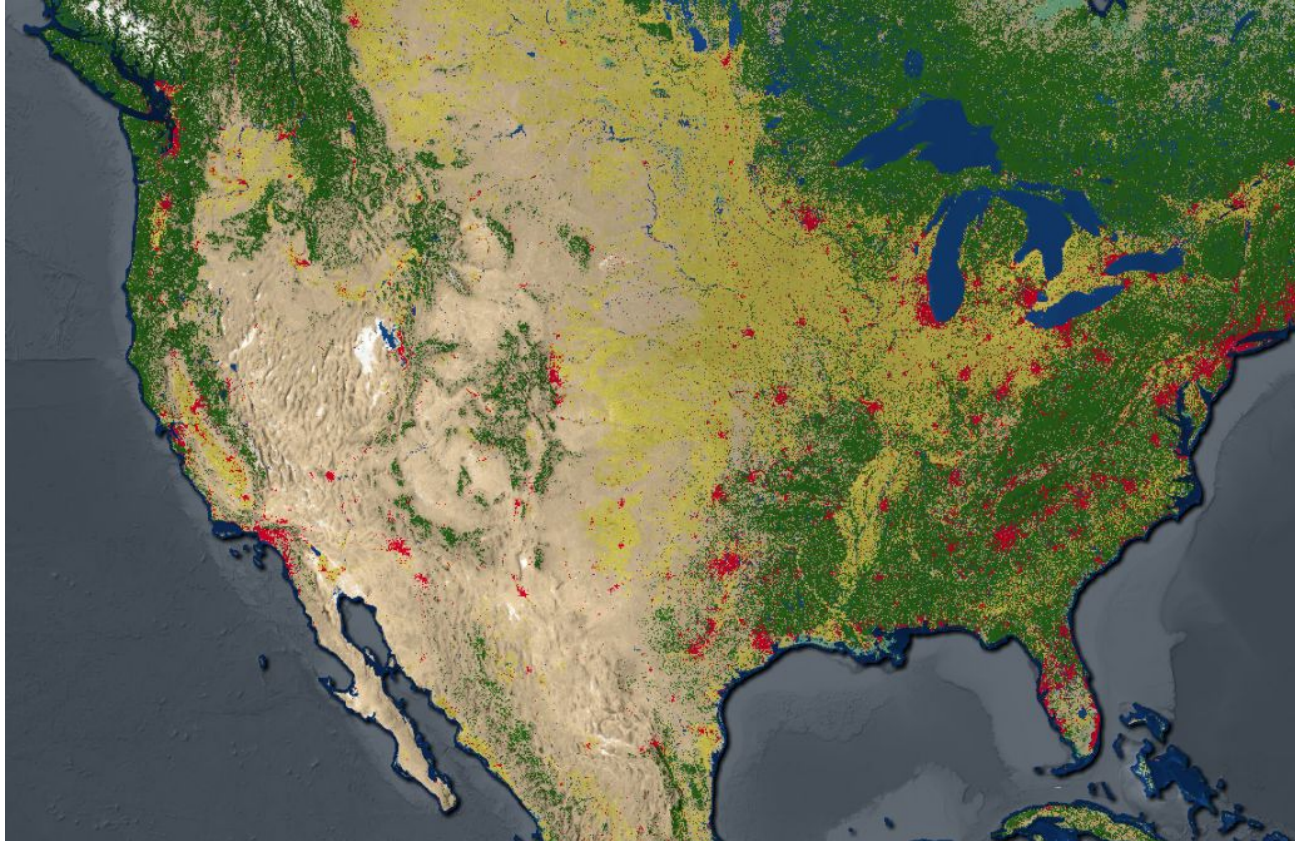
- Proximity

New built-in tools for quick data preparation



LULC data sources

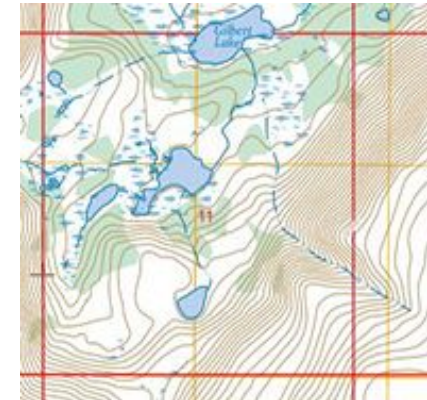
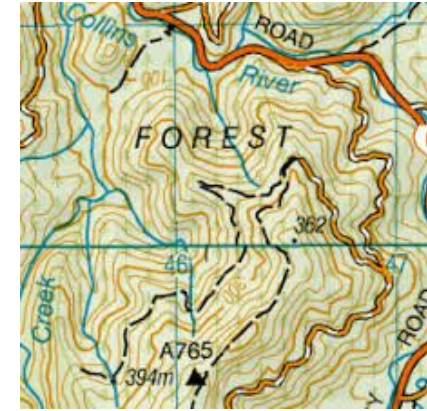
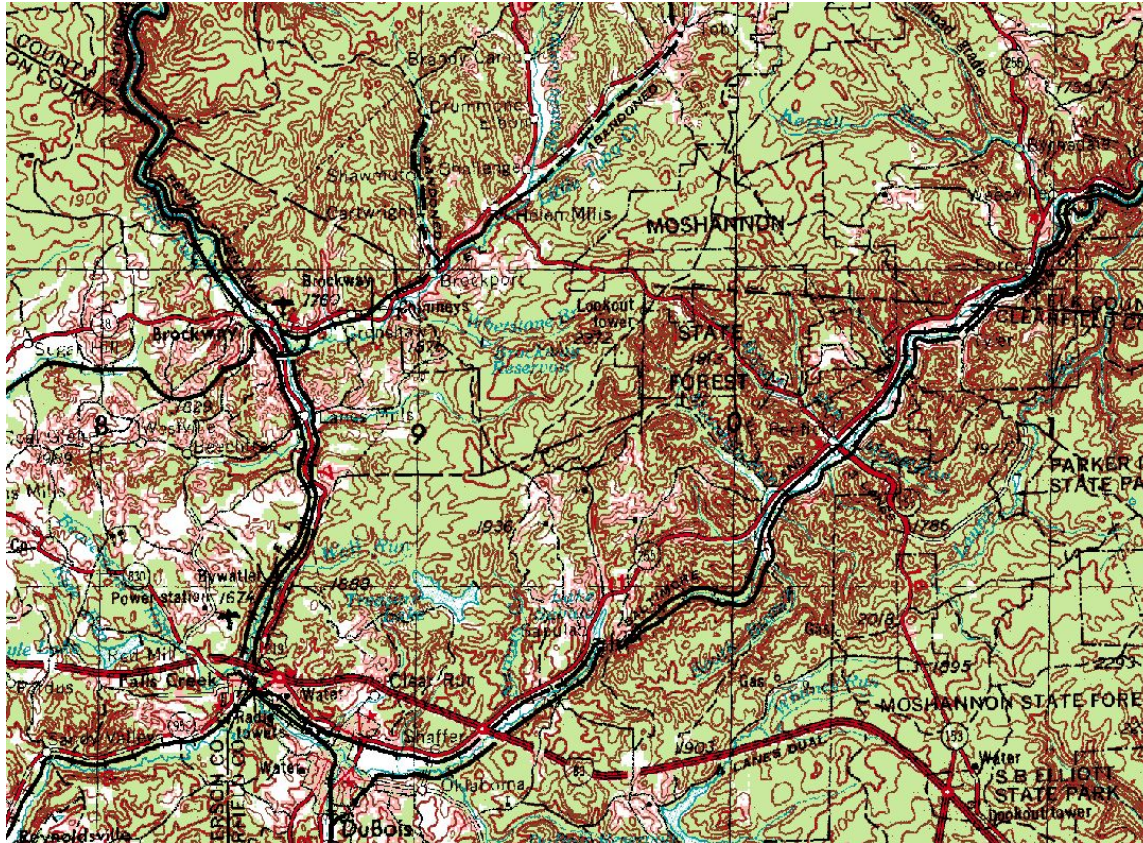
Global datasets



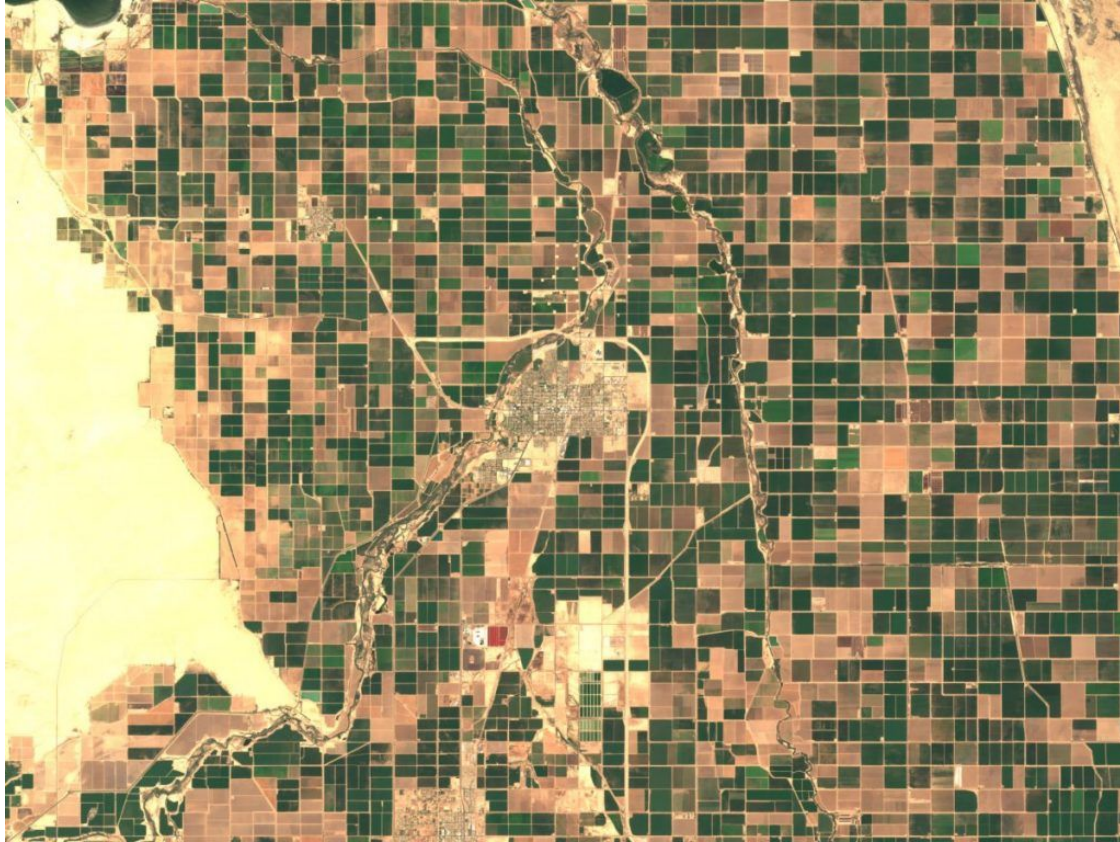
MODIS MCD12Q1
ESRI Land Cover
ESA WorldCover
Dynamic World
GLC_FCS30D
GLAD

...

Topographic/Thematic maps



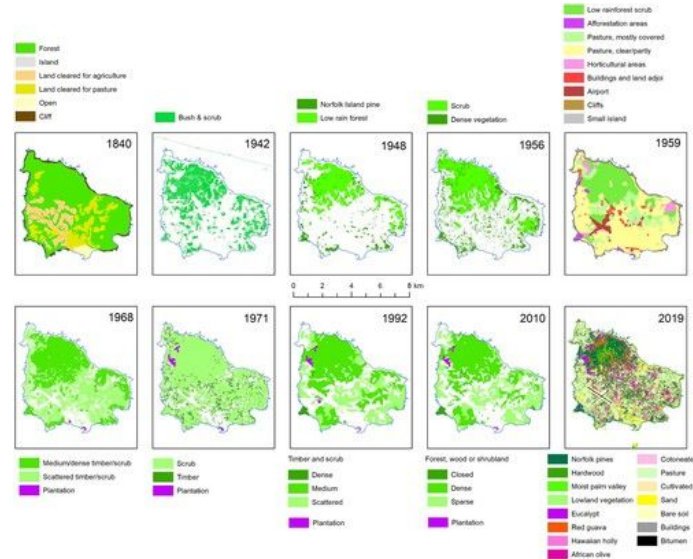
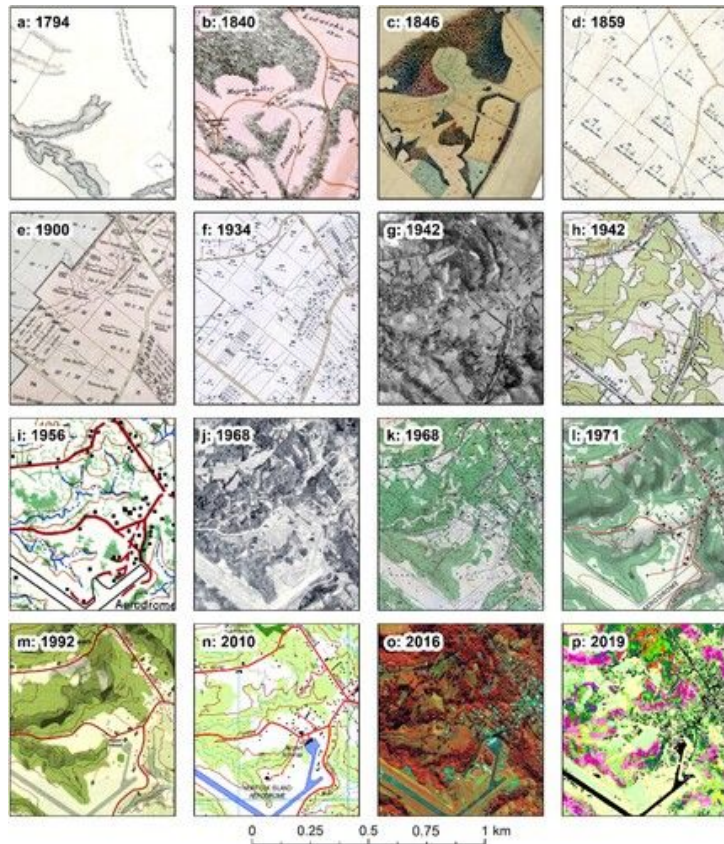
Satellite/Aerial imagery



National cadastre



Sometimes all together gives a long perspective

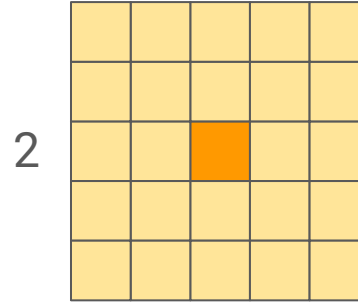
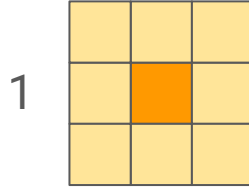


Levin, N., & Kark, S. (2023). **From Historical Maps to Remote Sensing: Reconstructing Land Use Changes on Norfolk Island over the Past 250 Years.** *The Cartographic Journal*, 60(3), 194–215. <https://doi.org/10.1080/00087041.2022.2150367>

Algorithms setup

ANN parameters

Neighbourhood - how many neighbour pixels to use for each case



Learning rate - the step of the learning process, how much to change the model in response to the estimated error

The lower this value, the more cautious your model is.

ANN parameters

Maxim iterations - the limit of learning cycles.

You can decrease it to make process faster and to avoid overfitting in some cases, but too low value could cause model underfitting.

Number of hidden layers - the more this number is, the more complex the neural network would be, with a larger amount of internal parameters to be optimized

Momentum - defines the influence of the previous learning process step on the next learning process step

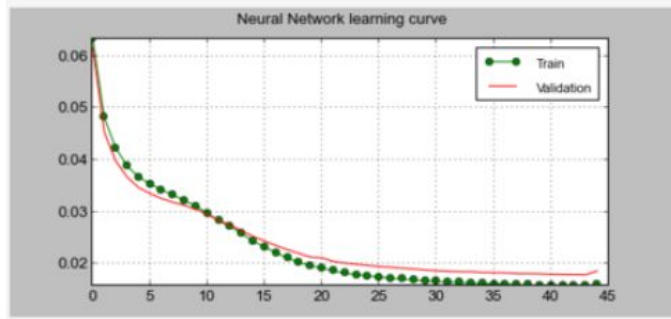
Point sampling policies

All — use all pixels for training process. Impossible for large rasters

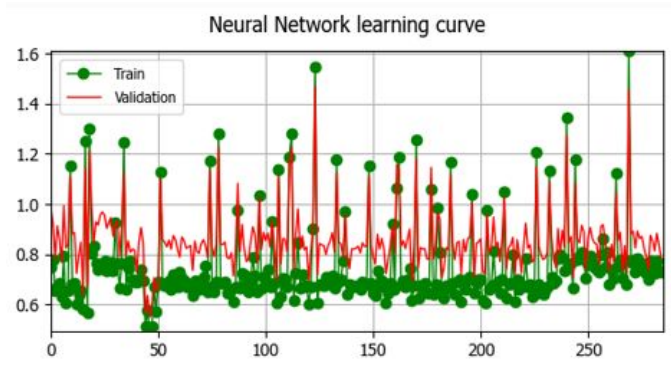
Random — randomly place given number of points for training

Stratified — this mode randomly undersamples major categories (large areas) and oversamples minor categories (small areas) to ensure their presence

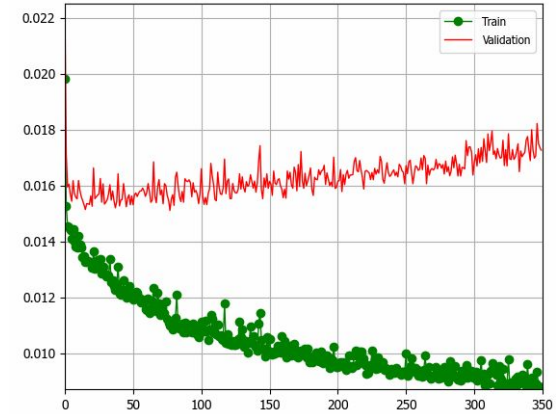
ANN typical learning curves



~ Ideal. Smooth improvement at every iteration for both lines. Hypothesis is right.



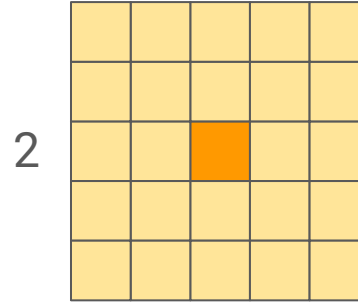
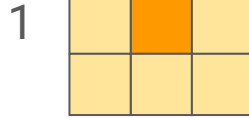
~ Bad. Chaotic peaks at both lines, no improvements with iterations. Hypothesis is wrong.



Overfitting.
Decrease number of neurons.
increase sample count.

Logistic regression

Neighbourhood - how many neighbour pixels to use for each case



Set of regression coefficients for each transition pair

Multi Criteria Evaluation

Manual describing of spatial variables mutual importance **for one particular transition** (e.g. 7 -> 11) using Saaty's scale:

Scale	Numerical rating	Reciprocal
Equal importance	1	1
Equal to moderate importance	2	1/2
Moderate importance	3	1/3
Moderate to strong importance	4	1/4
Strong importance	5	1/5
Strong to very strong importance	6	1/6
Very strong importance	7	1/7
Very strong to the extreme importance	8	1/8
Extreme importance	9	1/9

Weights of Evidence

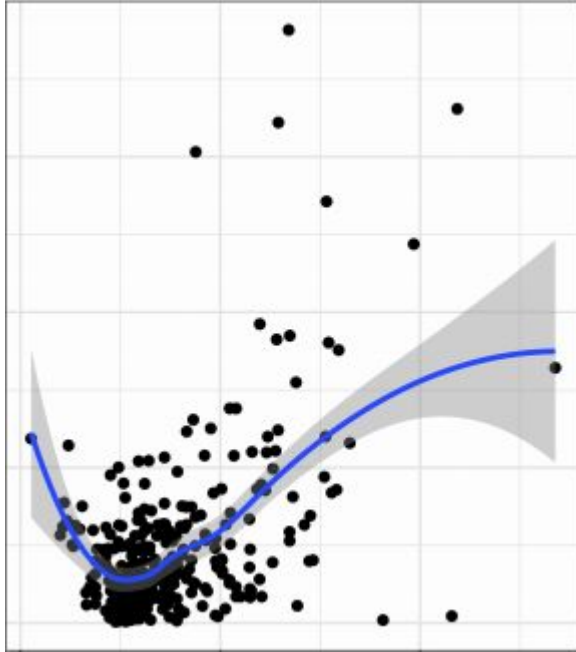
1. Split continuous predictor values to categories (based on ranges)
2. Calculating weights of factors/categories in occurred and non-occured transitions
3. Forecast based on weights

This approach works only if there is very straightforward connection between factors and their subranges and transitions

$$WOE = \ln \left(\frac{\text{Event\%}}{\text{Non Event\%}} \right)$$

Major limitations

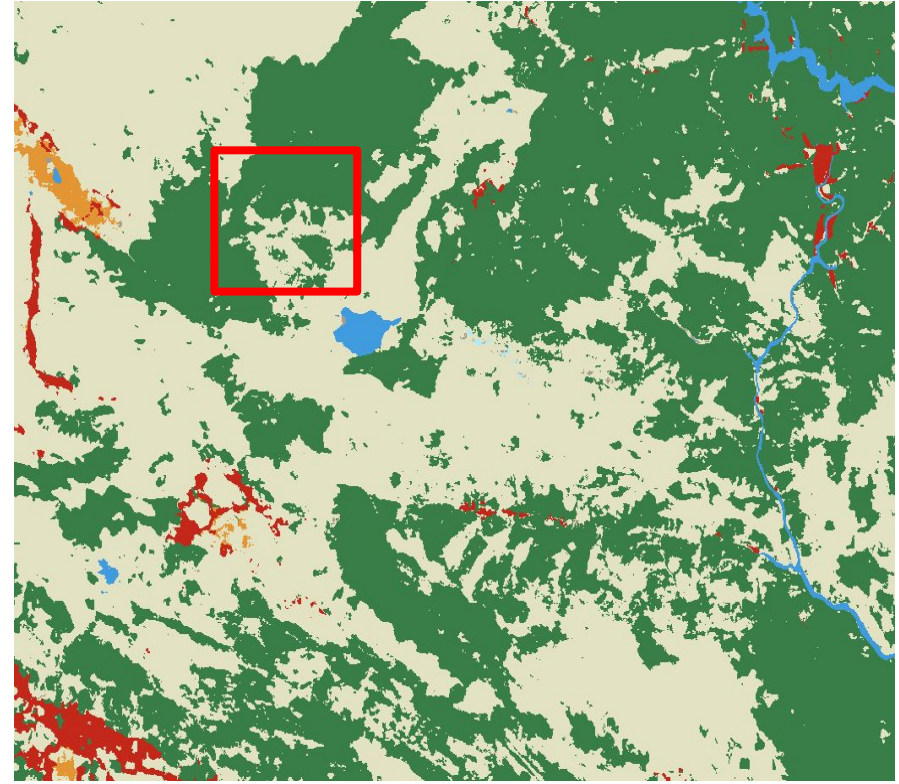
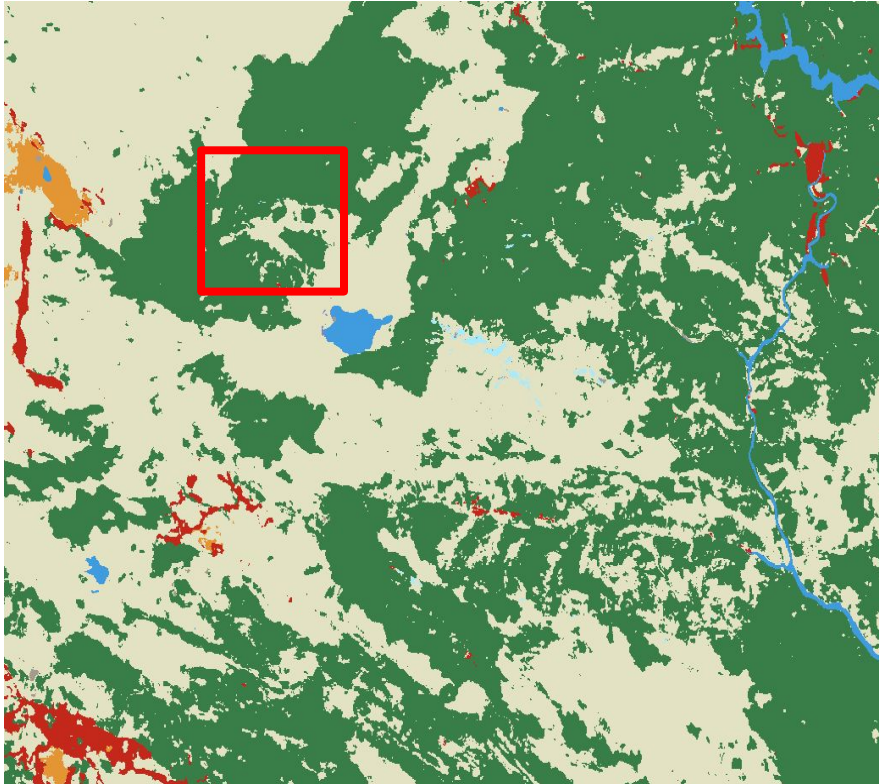
Conceptual – it's just statistics



MOLUSCE does not know the nature of water or vegetation, it can not reason as geographer.

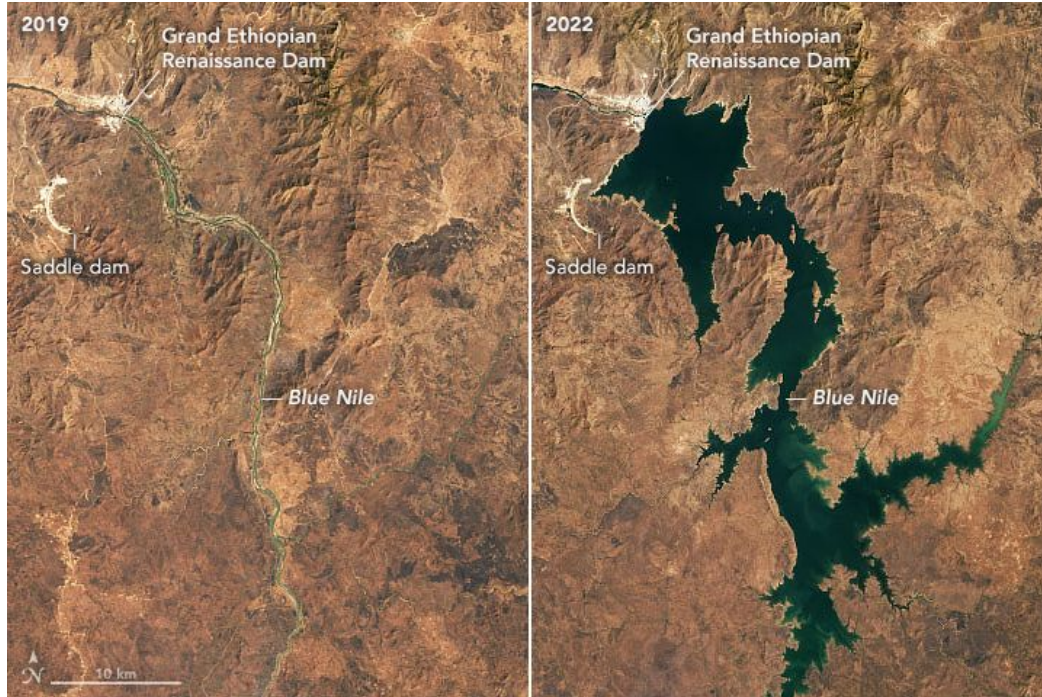
It sees complex patterns in numbers and continues them into the future.

Conceptual — events out of pattern could not be predicted



<https://n1info.ba/english/news/fire-in-bosnias-blidinje-nature-park-getting-out-of-control-firefighters-warn/>

Engineering constructions



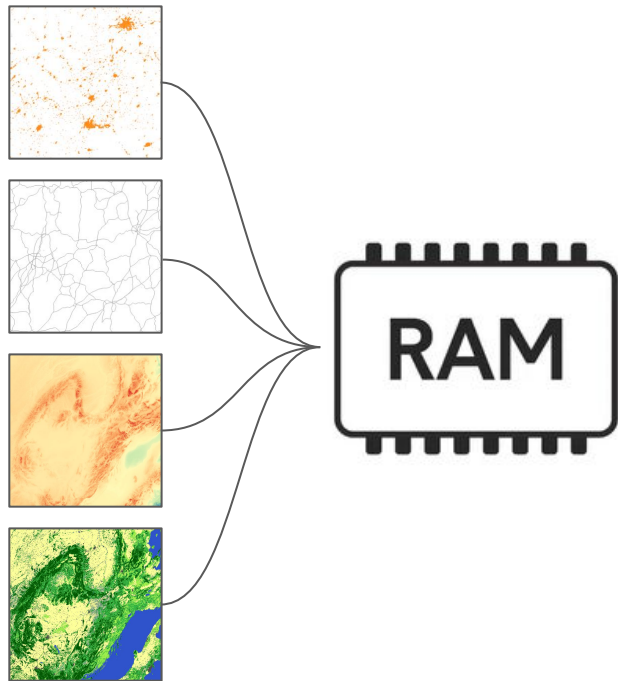
May 15, 2006



July 17, 2000

source: earthobservatory.nasa.gov

Technical — all data is uploaded to RAM



Experiments are limited by workstations RAM.

Effective for millions of pixels per input dataset, but not billions

Technical — same set of classes in both source LULCs

First LULC map unique values:

10	20	30	40	70	80	90
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Second LULC map unique values:

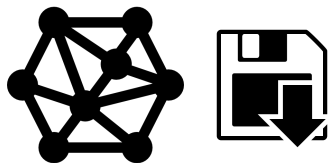
10	20	30	40	70	80	100
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Couldn't be processed

But there is a simple workaround — manually add single pixels with Serval tool

Technical – save/load mechanism is for single context



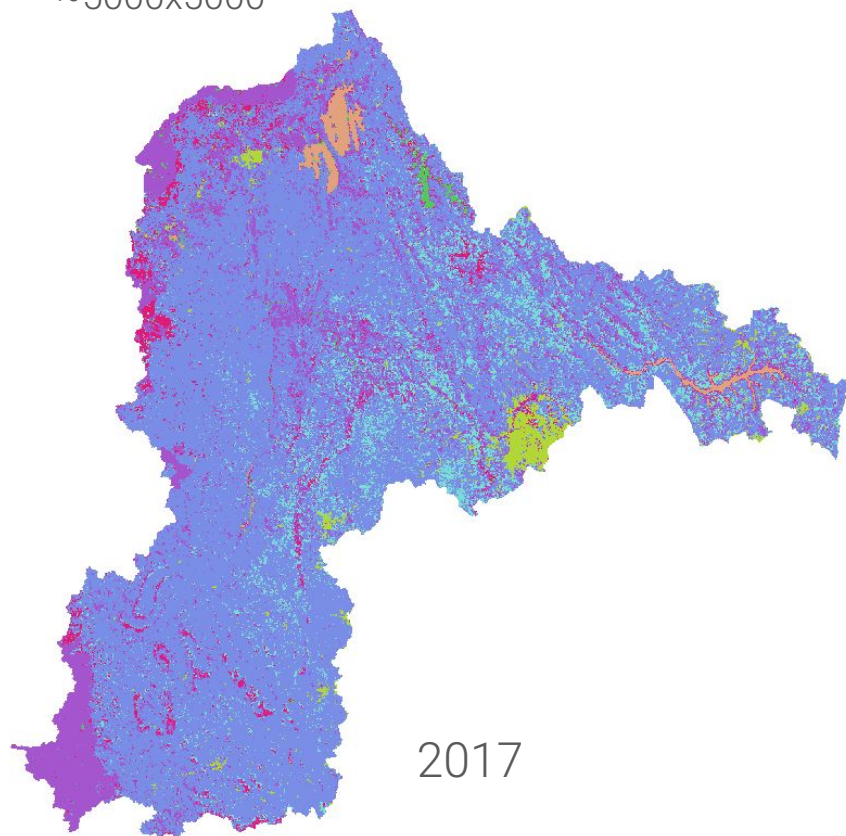
Model uses information about extent and dimensions of input data, and could not be applied to datasets with different domain

Save/load currently is for multi-iteration predictions, allowing to use same model with different versions of environmental factors

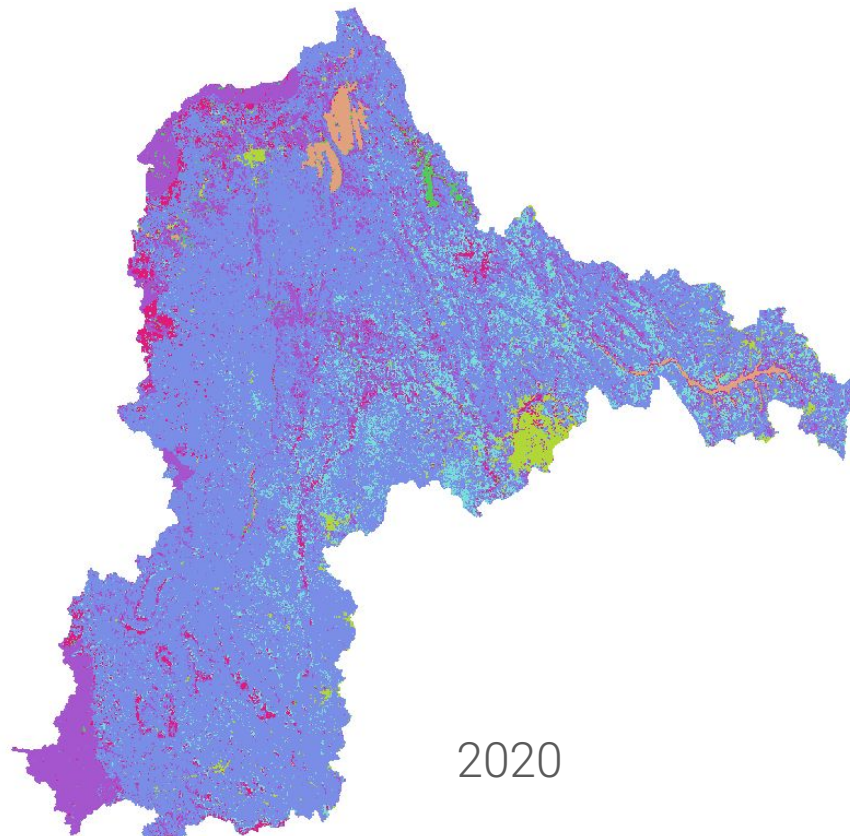
Common problems

Too little change over too much territory

~5000x5000

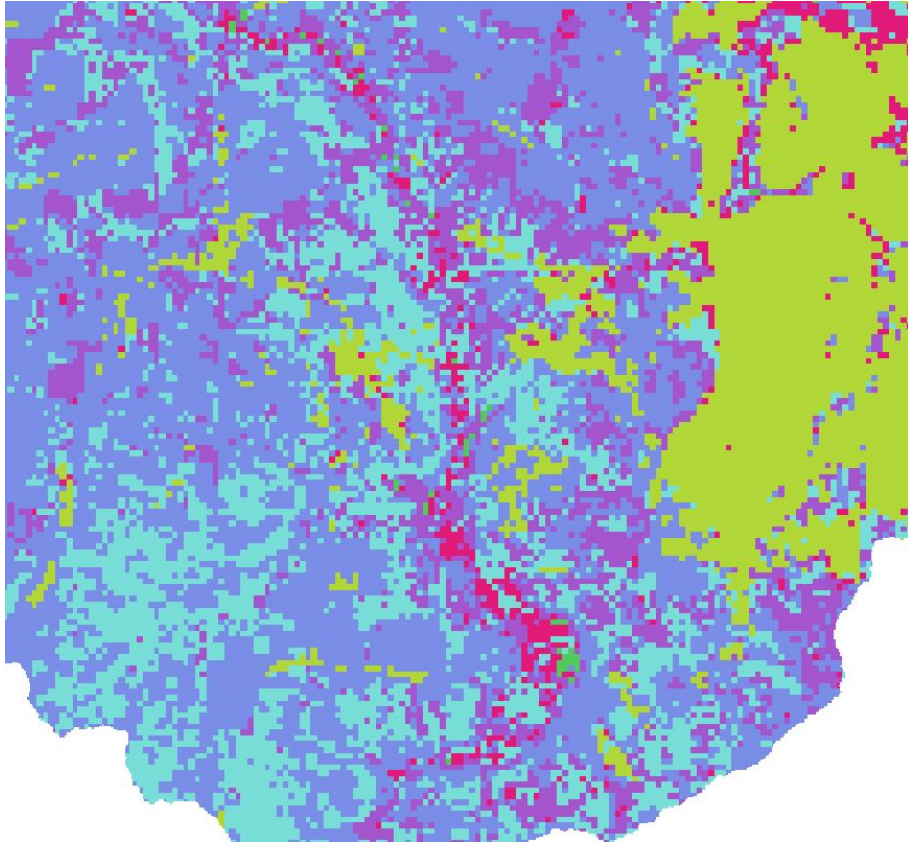


2017

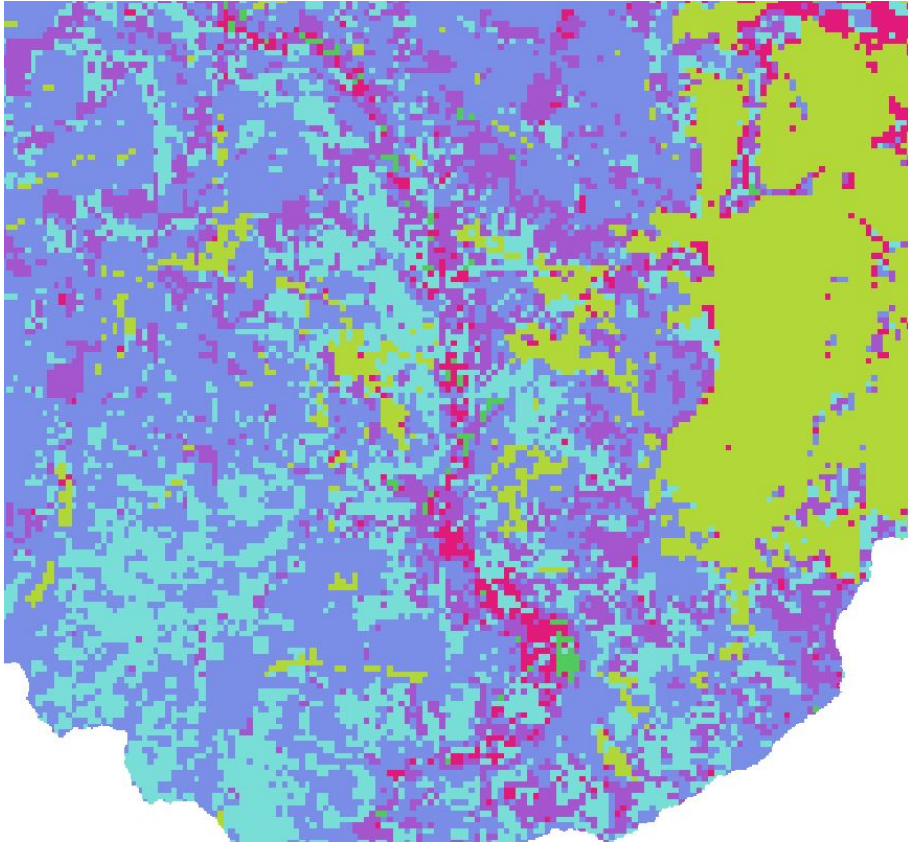


2020

Too little change over too much territory



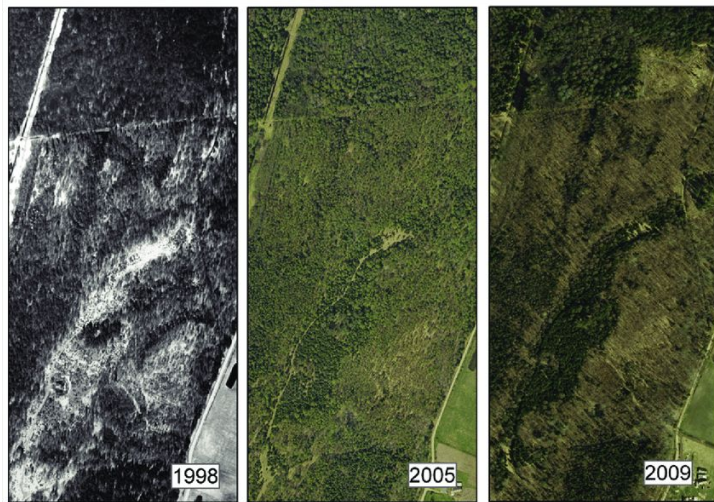
Too little change over too much territory



For model statistically it is much safer to predict no change at all. So it does.

It could work only if you have environmental factors really highlighting these alone changed pixels

Wrong hypothesis / set of variables not explaining the change



Source: Veteikis, Darius & Šabanovas, Simonas & Jankauskaitė, Margarita. (2011). Landscape structure changes on the coastal plain of Lithuania during 1998–2009. *Baltica*. 24.

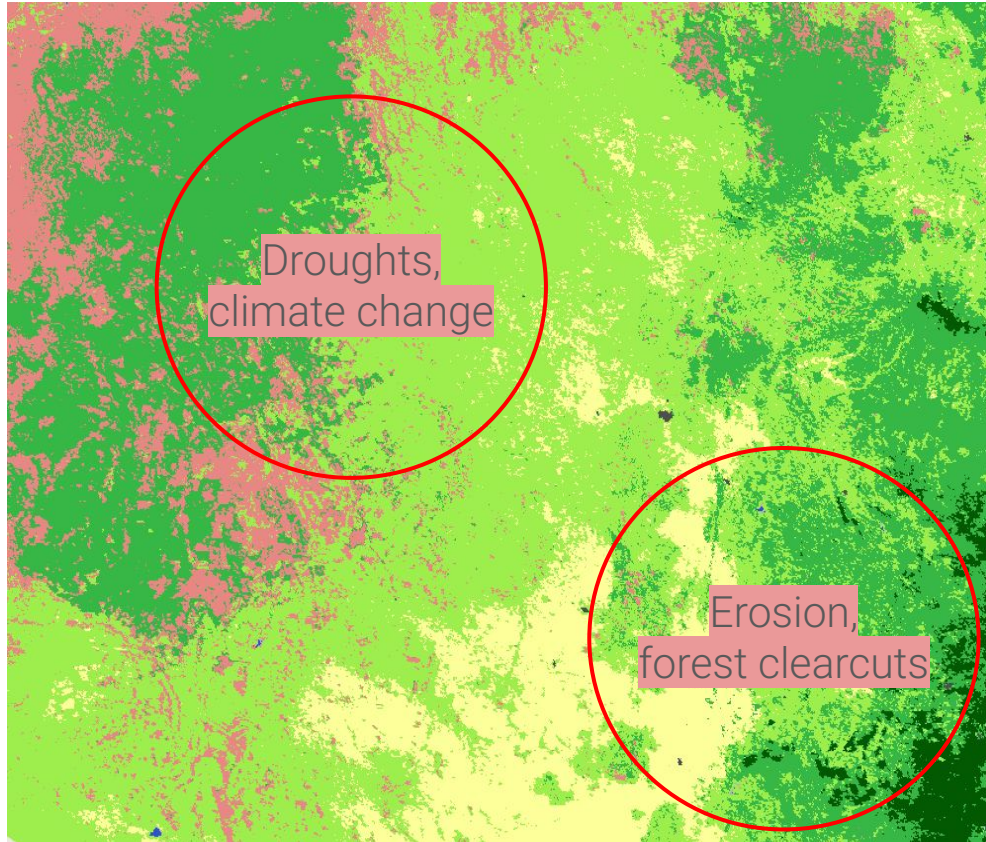
People often use “standard” set of predictors: infrastructure proximity, NDVI, slope etc.

But real factors in particular case could be **very different**, including “exotic” ones:

- Beavers activity
- Tree parasites
- Anything else

It's your task as a researcher to find out the real drivers.

Different patterns and factors in different subregions



Single model could fail predicting change in areas with different nature of transformation

Better to split region to several subregions, different experiments/models

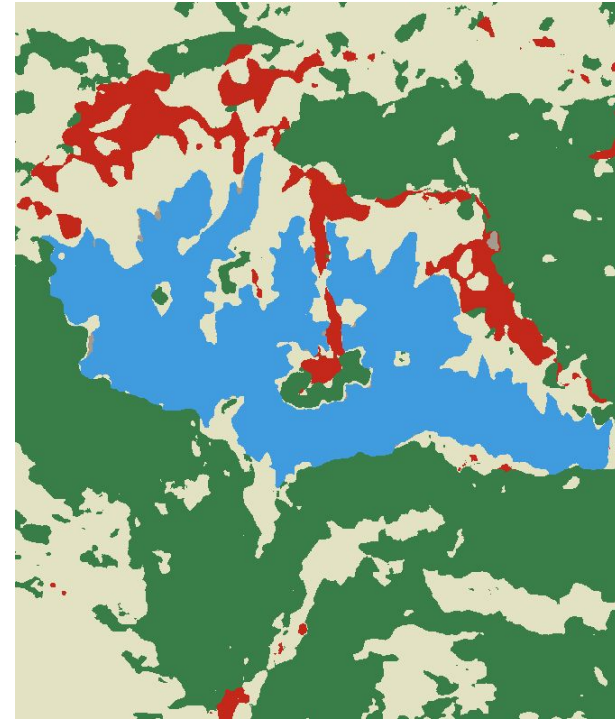
Pattern change over time, hard to explain with variables



2017



2019



2021



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