FAO workshop – Santa Marta (Colombia), July 2024

Using the `deforisk` QGIS plugin for making and comparing deforestation risk maps

Ghislain VIEILLEDENT[1] Thomas ARSOUZE[1] FAO team[2]

[1] **Cirad** UMR AMAP, [2] **FAO** Rome and Latin America

Outline

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Aims

- Provide **a tool** to create and compare **deforestation risk maps**.
- At the **jurisdictional** level.
- Following **Verra's methodology** for certification.
- **Allocating deforestation** to projects within the jurisdiction.

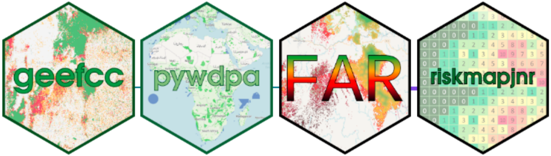
Specificities

- Open-source and Python based : transparency, reproducibility.
- Computationally efficient :
  - Processing raster by blocks.
  - Running tasks in parallel.
- OS independent : Windows, Linux, MacOS.
- Should run on any computer with average performance.
- Performant alternative statistical models (iCAR).
- Fully documented and translated (English, Spanish, French).
- Help with data preparation.
- Should be (relatively) easy to use.

Python based

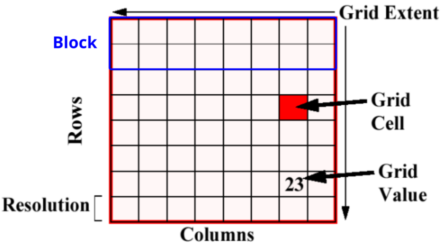
The `deforisk` plugin relies on four Python packages developed specifically for modelling deforestation :

- `geefcc` : make forest cover change maps from Google Earth Engine (GEE).
- `pywdpa` : downloading protected areas from the World Database on Protected Areas (WDPA).
- `forestatrisk` : model deforestation and predict the spatial deforestation.
- `riskmapjnr` : risk maps following Verra JNR methodologies.



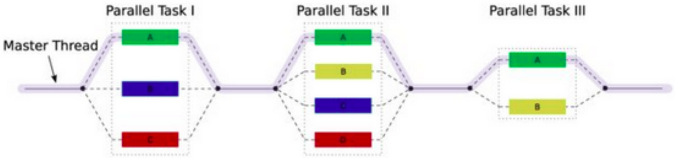
Processing raster by blocks

- Raster files of forest cover change and explanatory variables might occupy a space of several gigabytes on disk.
- Processing such large rasters in memory can be prohibitively intensive on computers with limited RAM.
- Functions used in the `deforisk` plugin process large rasters by blocks of pixels representing subsets of the raster data.
- This makes computation efficient, with low memory usage.



Running tasks in parallel

- State-of-the-art approach to select the best risk map implies repeating tasks (model, periods).
- To save computation time, the `deforisk` plugin use the QGIS task manager.
- Allows running several analysis in parallel.



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Website and documentation

The website includes all the documentation to use the plugin :

- Installation page : How to install the plugin ?
- Plugin API page : What is the meaning of each parameter ?
- Get started page. How to start using the plugin on a small area of interest ?
- Articles' page. How can I use the plugin for specific cases (subnational jurisdictions, user's data) ?
- References' page : A page with reference documents including presentations.

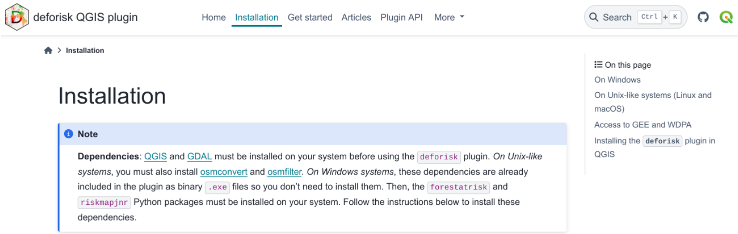
https://deforisk-qgis-plugin.org

Outline

Installation

Reduced number of steps for installing the plugin :

- Install QGIS and GDAL on you system (using `OSGeo4W` on Windows).
- Install the `forestatrisk` and `riskmapjnr` Python packages using pip.
- Download and install the `deforisk` plugin from QGIS.
- (Unix-like systems only : install OSM tools).



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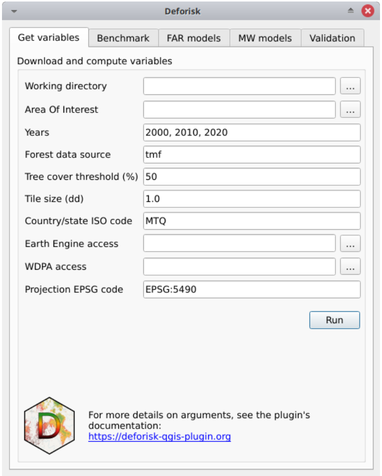
Get variables

- Functions to help prepare the data for modelling deforestation.
- Two different sources for **forest cover change** (GFC or TMF).
- Spatial explanatory variables describing **forest accessibility** and **land tenure** (altitude, slope, distance to roads, protected areas, etc.).



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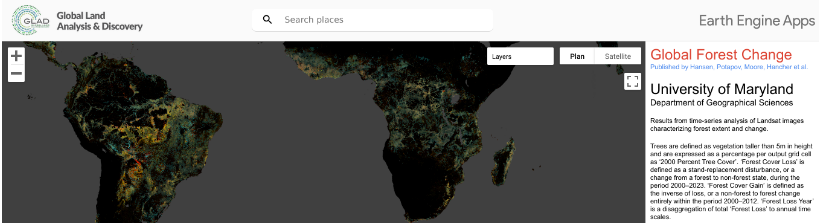
GFC dataset

- Hansen et al. 2013.
- Global dataset encompassing all forest types.
- Tree cover and annual tree cover loss.
- 30m resolution, from 2000 on.
- Data : https://glad.earthengine.app/view/global-forest-change

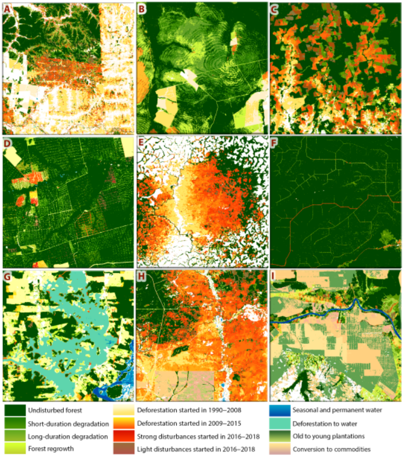


TMF dataset

- Vancutsem et al. 2021. Tropical Moist Forests (evergreen forest, no dry deciduous forests).
- 30m resolution, from 1990 on.
- Tropical deforestation was underestimated (-33% in 2000–2012, Hansen et al. 2013), especially in Africa.
- Data : https://forobs.jrc.ec.europa.eu/TMF/.

TMF dataset

- Precise enough to visually identify the causes of deforestation (logging, fires, agriculture)



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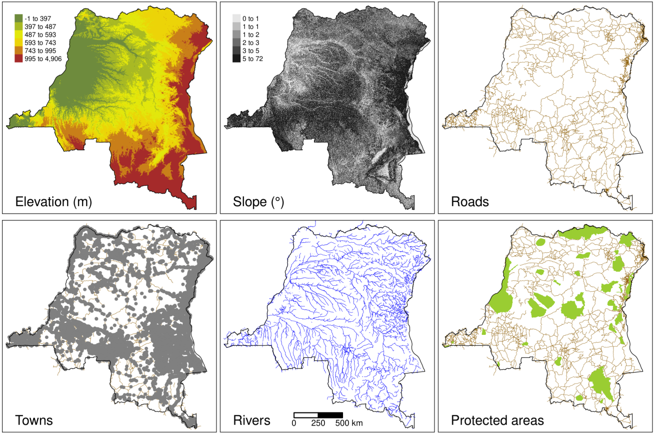
Spatial variables

The plugin helps computing eight explanatory variables.

Product	Source	Variable derived	Unit	Resolution (m)	Date
Forest maps (2000-2010-2020)	Vancutsem et al. 2021	distance to forest edge	m	30	–
		distance to past deforestation	m	30	–
Digital Elevation Model	SRTM v4.1 CSI-CGIAR	elevation	m	90	–
		slope	degree	90	–
Highways	OSM-Geofabrik	distance to road	m	150	March 2021
Places		distance to town	m	150	March 2021
Waterways		distance to river	m	150	March 2021
Protected areas	WDPA	presence of protected area	–	30	March 2021

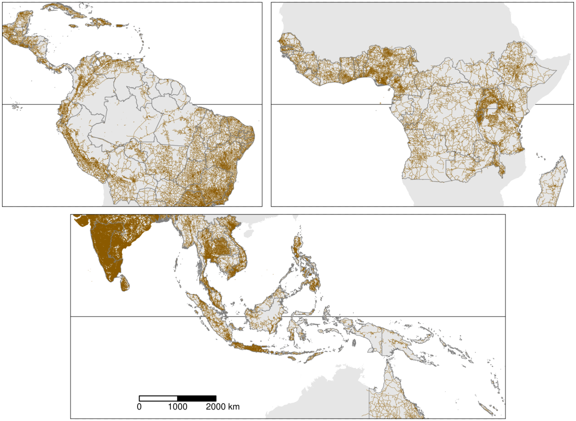
Spatial variables



Spatial explanatory variables in DRC

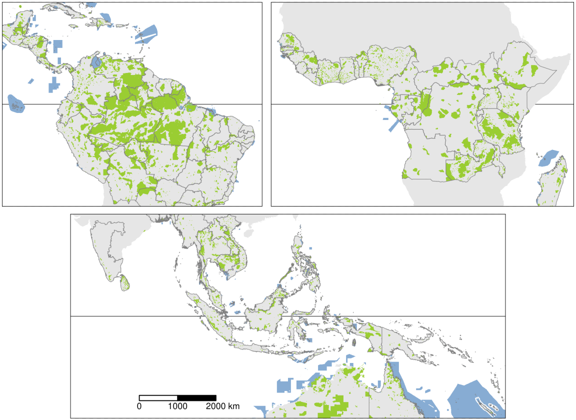
Roads

- OpenStreetMap (OSM)
- “motorway”, “trunk”, “primary”, “secondary” and “tertiary” roads
- 3.6 million roads from OSM



Protected areas

- PA status : “Designated”, “Inscribed”, “Established”, or “Proposed”.
- 85,000 protected areas from WDPA.



Outline

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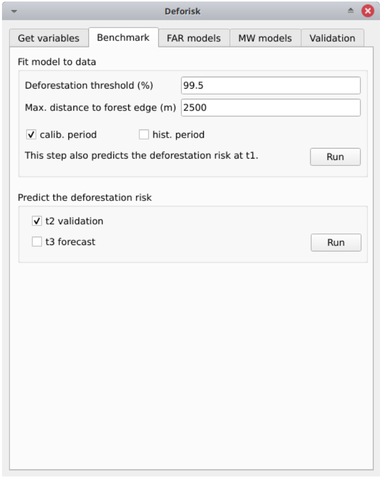
Benchmark model

- Benchmark model or reference model.
- A reasonably good deforestation model (better than a null model).
- Assuming a *decrease of deforestation with distance to forest edge* (commonly admitted).
- And a *different model between subjurisdictions* (regional variability).
- See presentation **Cirad and FAO**. 2024. Jurisdictional risk maps for allocating deforestation.



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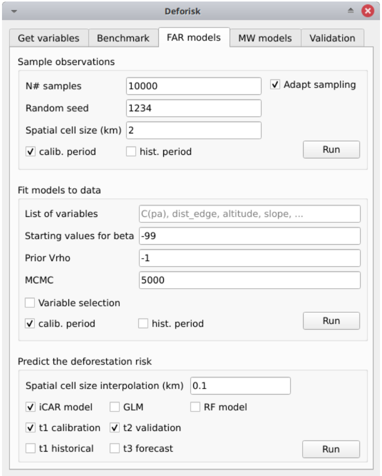
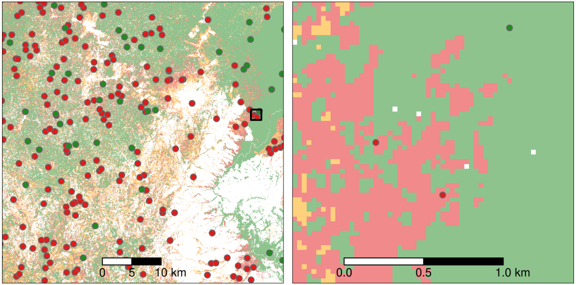
Forestatrisk models

- Three statistical models : iCAR, GLM, RF.
- iCAR : Logistic regression with spatial random effects (iCAR process).
- GLM : Generalized Linear Model, simple logistic regression (no random effects).
- Random Forest model : random regression trees.
- Statistical models based on a sample of the observations.



Sampling for FAR models

- We consider the forest cover change between t and $t+1$.
- Stratified sampling between deforested/non-deforested pixels.
- Total number of points proportional to the forest cover (from 20,000 to 100,000 points per study area).

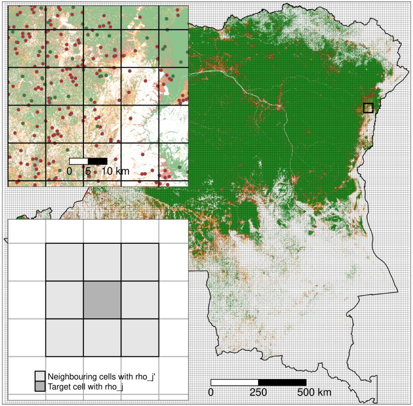


iCAR model

A logistic regression model with iCAR process :

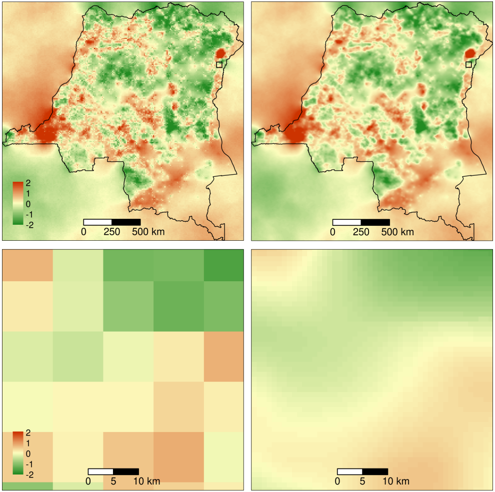
$$y_i \sim \mathcal{B}ernoulli(\theta_i)$$
$$\text{logit}(\theta_i) = \alpha + X_i\beta + \rho_{j(i)}$$
$$\rho_{j(i)} \sim \mathcal{N}ormal\Big(\sum_{j'} \rho_{j'}/n_j, V_\rho/n_j\Big)$$

Random effects $\rho_{j(i)}$ allows accounting for residual spatial variation not taken into account by model variables X_i.



Square grid of 10km cells over DRC

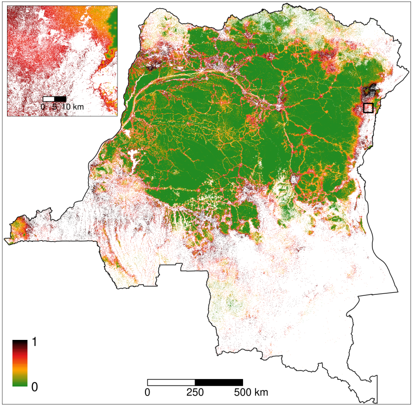
Spatial random effects



Interpolation of spatial random effects at 1km in DRC

Spatial probability of deforestation

- We use the fitted model to compute the spatial probability of deforestation.
- Probabilities in [0, 1] are transformed into classes in [1, 65535].



Relative spatial probability of deforestation in DRC

GLM model

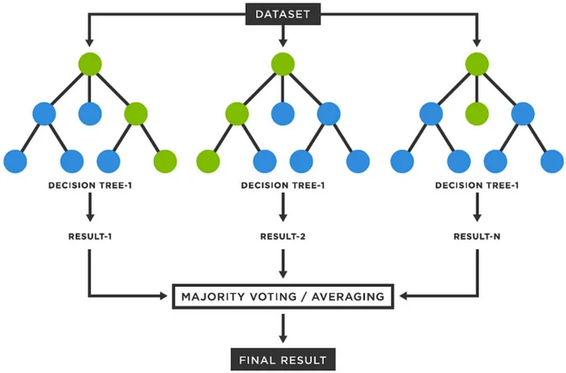
A simple logistic regression model without random effects :

$$y_i \sim \mathcal{B}ernoulli(\theta_i)$$
$$\text{logit}(\theta_i) = \alpha + X_i\beta$$

Easy to compare with iCAR to see the impact of spatial random effects.

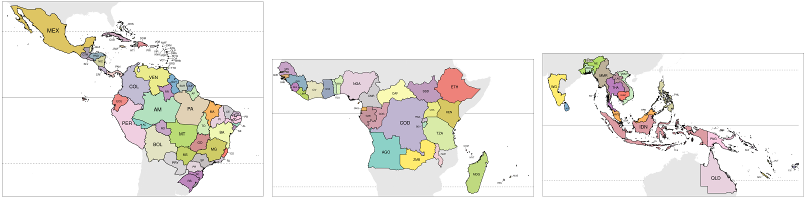
Random Forest model

- Random Forest is an ensemble machine learning algorithm.
- Combines multiple decision trees to create a more robust and accurate predictive model.



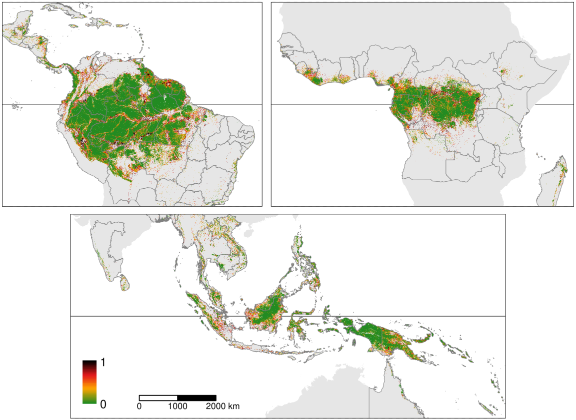
ForestAtRisk in the tropics

- **i.** Consider tropical moist forest in **92** countries (119 study areas)
- **ii.** Estimate the current deforestation rate and uncertainty in each country
- **iii.** Model the spatial risk of deforestation from environmental factors
- **iv.** Forecast the deforestation assuming a business-as-usual scenario
- **v.** Consequences in terms of carbon emissions



The 119 study areas in the 3 continents

ForestAtRisk in the tropics



Pantropical map of the spatial probability of deforestation
Article in review : 10.1101/2022.03.22.485306
https://forestatrisk.cirad.fr/maps.html

Outline

Moving window models

- Model proposed by previous Verra's methodology.
- Find a distance threshold to define class 1 for the deforestation risk (same thing as for the benchmark model).

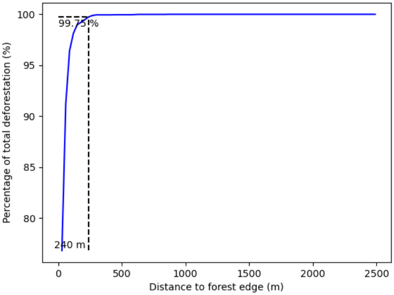
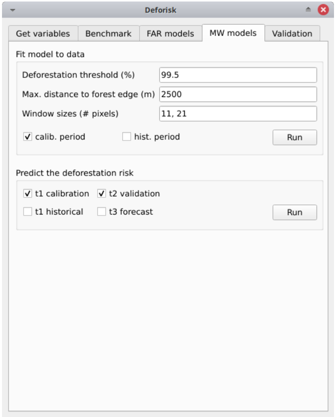


Figure – Cumulative deforestation as a function of the distance to forest edge.



Moving window models

- Compute a local risk of deforestation at the pixel level using a moving window.
- The moving window can be of different sizes.
- Deforestation rates in [0, 1] are converted to [2, 65535].

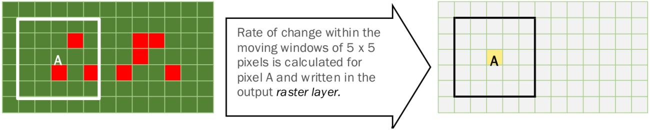
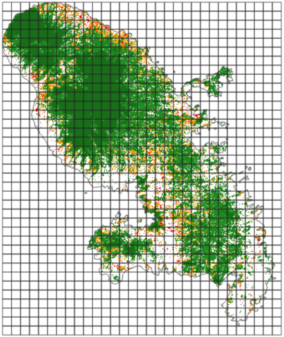


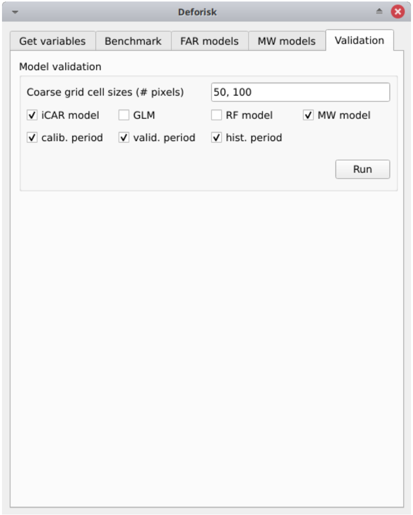
Figure – Moving window.

Outline

Validation

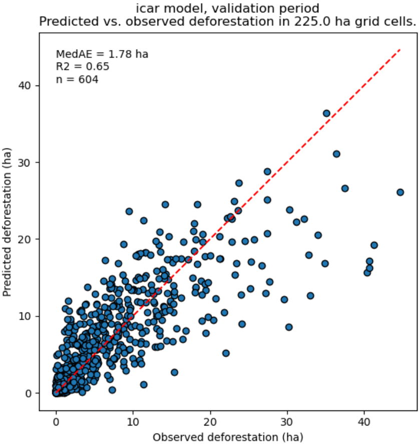
- Comparing predicted vs. observed deforestation (in ha) for each cell in a coarse grid.
- For a given period of time.





Validation

- Performance indices : R^2, and median of absolute error (MedAE).
- Computed for each model and each period (calibration, validation, historical).



Outline

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Allocating deforestation

For the best model, we obtain at t3 :

- A jurisdictional map with classes of deforestation risk.
- A table with relative deforestation rates for each class.

Table – Deforestation rates at t3 for each class of deforestation risk (numbers truncated to three decimal digits).

cat	n_i	d_i	$\theta_{m,i}$	$\theta_{a,i}$	T	A	δ_i
1	137575	–	1.000e-06	–	–	0.09	–
2	5425	–	1.625e-05	–	–	0.09	–
3	3523	–	3.151e-05	–	–	0.09	–
4	2458	–	4.677e-05	–	–	0.09	–
5	2078	–	6.203	–	–	0.09	–

Allocating deforestation

Table – Deforestation rates at t3 for each class of deforestation risk (numbers truncated to three decimal digits).

cat	n_i	d_i	$\theta_{m,i}$	$\theta_{a,i}$	T	A	δ_i
1	137575	–	1.000e-06	–	–	0.09	–

- Considering a total **deforestation** D (in ha) for the next Y **years** at the jurisdictional level.
- **Adjustment factor** is $\rho = D/(A \sum_i n_i \theta_{m,i})$, with A the pixel area in ha.
- **Absolute rate** is $\theta_{a,i} = \rho\theta_{m,i}$: so that total predicted deforestation $=$ expected deforestation.
- **Deforestation density** is $\delta_i = \theta_{a,i} \times A/Y$. Used to predict the amount of deforestation (in ha/yr) for each forest pixel.

Allocating deforestation

Deforestation density is δ_i (in ha/yr) is used to predict the amount of deforestation for each forest pixel.

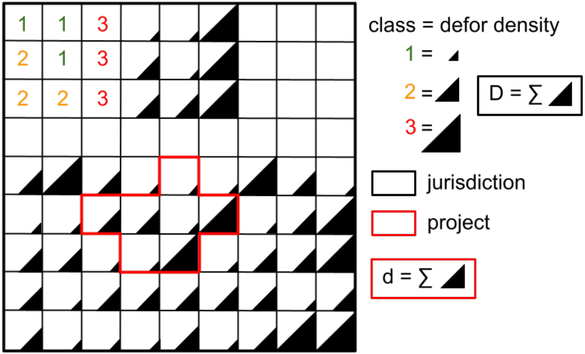

Figure – Allocating deforestation to projects within the jurisdiction.

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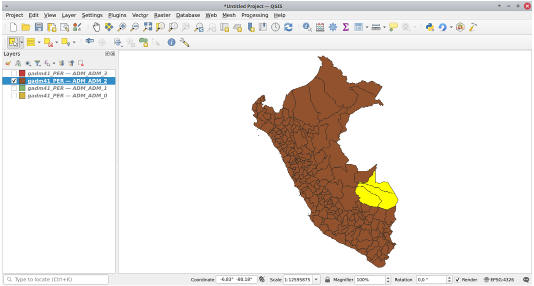
Subnational jurisdictions

- Possibility to work with subnational jurisdictions.
- GPKG file named `aoi_latlon.gpkg` with two layers named `aoi` for the jurisdiction and `subj` for the subjurisdictions.
- This file can then be used with the `deforisk` plugin to define the area of interest (AOI).
- More details on the website page Subnational jurisdictions.



Outline

User's data

- Possibility to use user's data : national forest cover change map, other explanatory variables (e.g. mining concessions).
- Manual steps at the moment.
- Files in the `data` folder must be replaced with user's data.
- Additional raster variables can be added to the `data` folder.
- Symbolic links in `data_*` folders must exist.
- More details on the website page User's data.

Outline

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Workshop agenda

Four practical sessions :

- Installing the software and run the `Get Started` tutorial.
- Chose a small subnational jurisdiction and select the best risk map.
- Derive the best risk map for a large jurisdiction (e.g. country scale).
- Exercices :
    - Change model parameters to see models' behavior (e.g. size of spatial cells for iCAR model).
    - Use country data (e.g. national forest cover change map).
    - Allocate future deforestation to a project.

Outline

Perspectives

- Recent plugin (first version in July 2024).
- Improvements are expected :
  - Increase computational speed (for predictions on large areas).
  - Adding more alternative models (MLP).
- Modifications from users' feedback.

... Thank you for attention ...

https://deforisk-qgis-plugin.org

> **Articles** > **References** > **Presentations**