FAO workshop – Santa Marta (Colombia), July 2024

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

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Outline

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Outline

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.

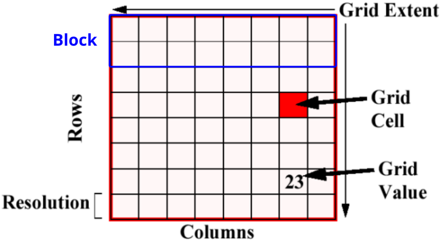
Python based

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.

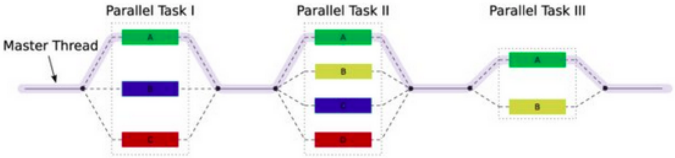
Processing raster by blocks

- 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.



Website and documentation

The website includes all the documentation to use the plugin :

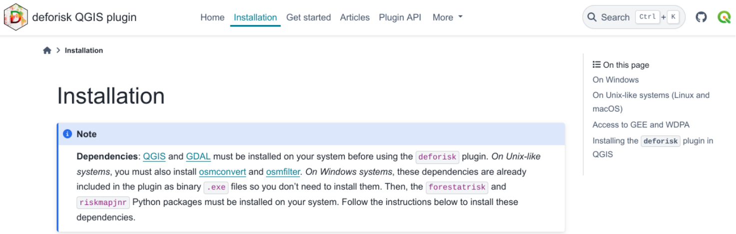
- Installation page : How to install the plugin ?
- Plugin API page : What is the meaning of each parameter ?
- Get started page. How to start using the plugin on a small area of interest ?
- Articles' page. How can I use the plugin for specific cases (subnational jurisdictions, user's data) ?
- References'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

https://deforisk-qgis-plugin.org

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).



deforisk QGIS plugin   Home   Installation   Get started   Articles   Plugin API   More   Search Ctrl + K

Installation

Installation

Note

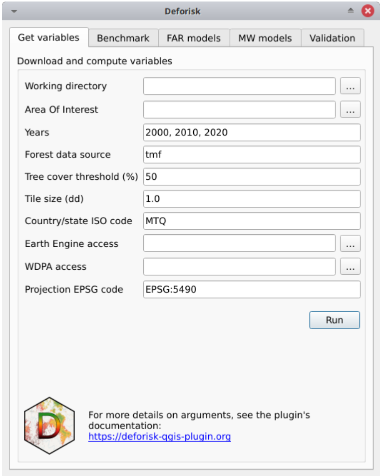
Dependencies: QGIS and GDAL must be installed on your system before using the `deforisk` plugin. *On Unix-like systems*, you must also install osmconvert and osmfilter. *On Windows systems*, these dependencies are already included in the plugin as binary `.exe` files so you don't need to install them. Then, the `forestatrisk` and `riskmapjnr` Python packages must be installed on your system. Follow the instructions below to install these dependencies.

On this page
- On Windows
- On Unix-like systems (Linux and macOS)
- Access to GEE and WDPA
- Installing the `deforisk` plugin in QGIS

Outline

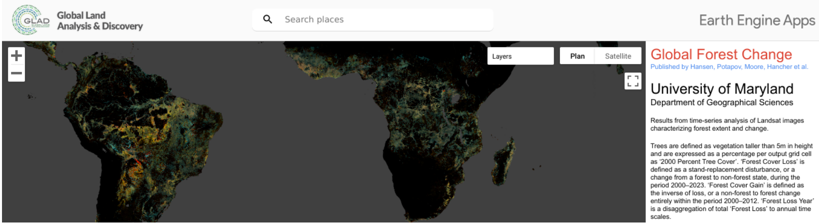
Get variables

- 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.).



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

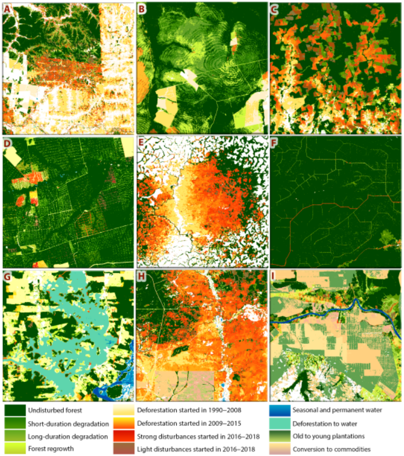


TMF dataset

- 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)

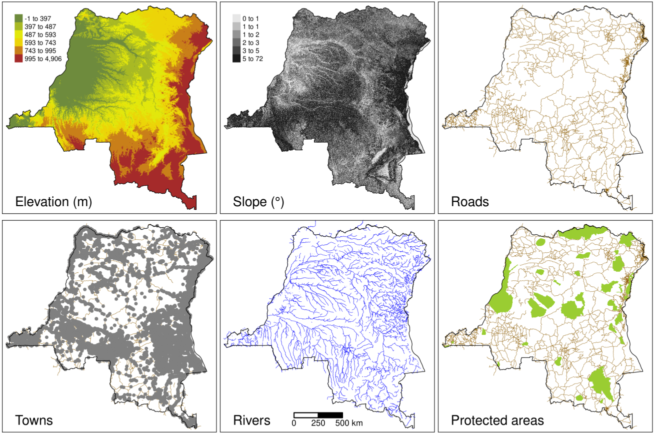


Spatial variables

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

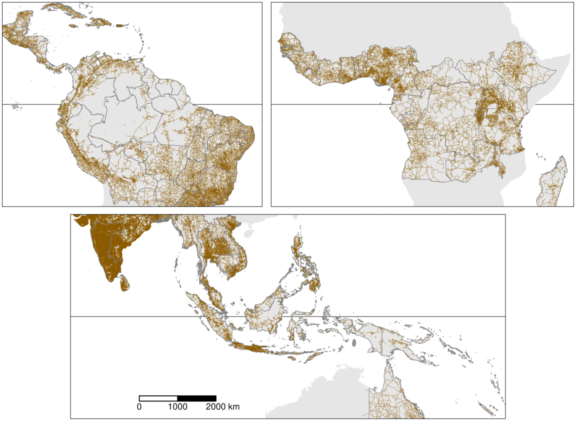
Spatial variables



Spatial explanatory variables in DRC

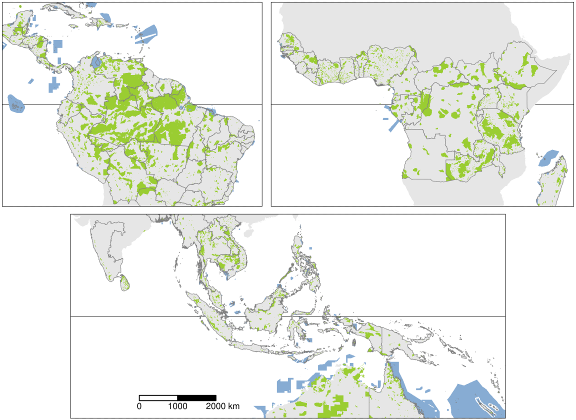
Roads

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



Protected areas

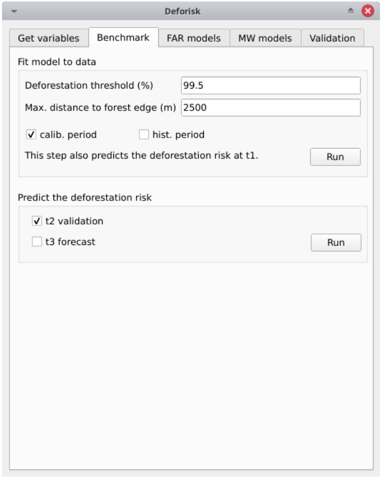
- PA status : “Designated”, “Inscribed”, “Established”, or “Proposed”.
- 85,000 protected areas from WDPA.



Outline

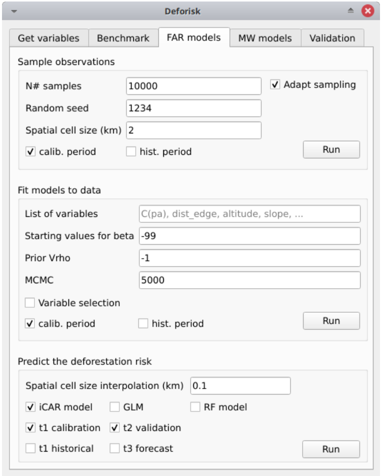
Benchmark model

- 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.



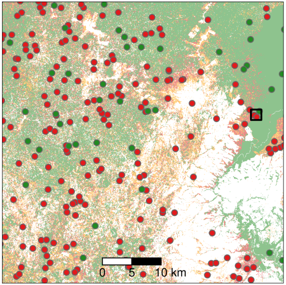
Forestatrisk models

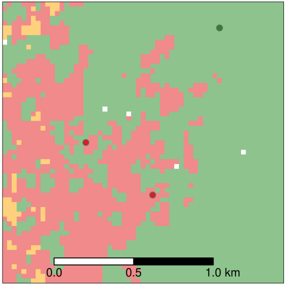
- Three statistical models : iCAR, GLM, RF.
- iCAR : Logistic regression with spatial random effects (iCAR process).
- GLM : Generalized Linear Model, simple logistic regression (no random effects).
- Random Forest model : random regression trees.
- Statistical models based on a sample of the observations.



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).



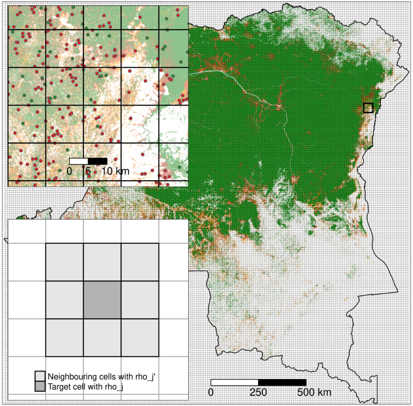


iCAR model

A logistic regression model with iCAR process :

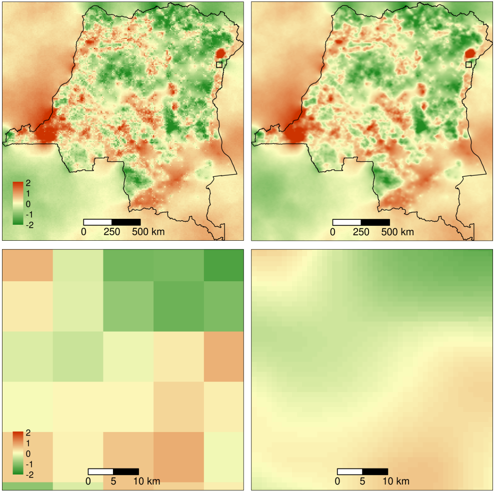
$$y_i \sim \mathcal{B}ernoulli(\theta_i)$$
$$\text{logit}(\theta_i) = \alpha + X_i\beta + \rho_{j(i)}$$
$$\rho_{j(i)} \sim \mathcal{N}ormal(\sum_{j'} \rho_{j'}/n_j, V_\rho/n_j)$$

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

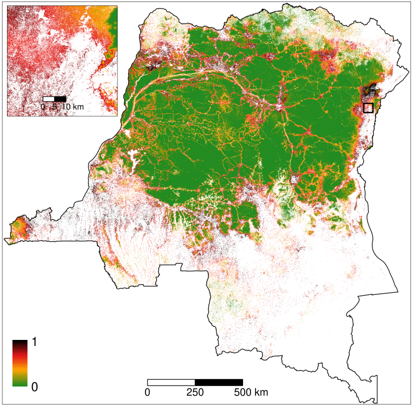
Spatial random effects



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

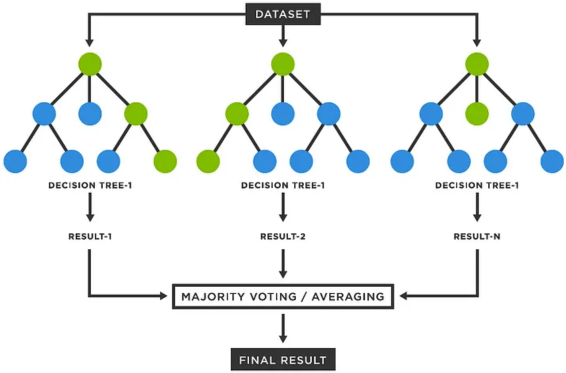
A simple logistic regression model without random effects :

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

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

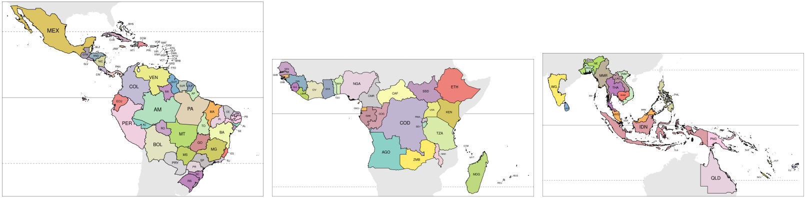
Random Forest model

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



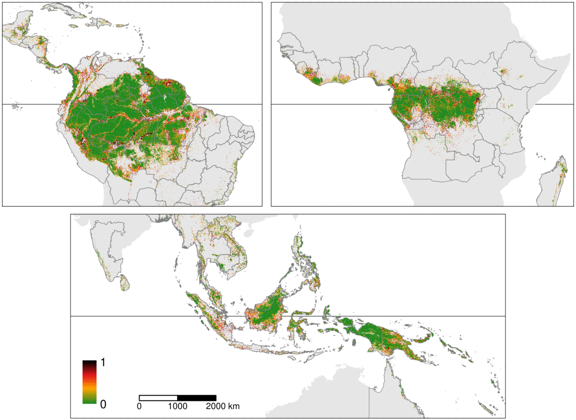
ForestAtRisk in the tropics

- **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

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).

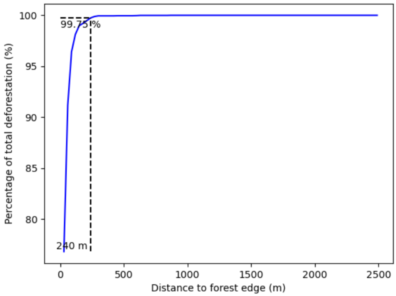
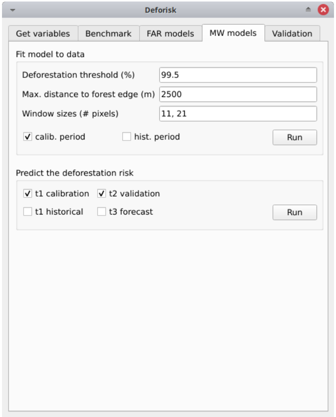


Figure – Cumulative deforestation as a function of the distance to forest edge.



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].

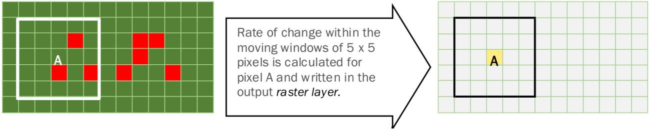
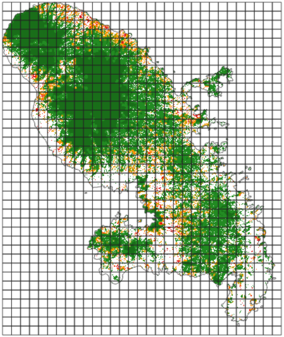
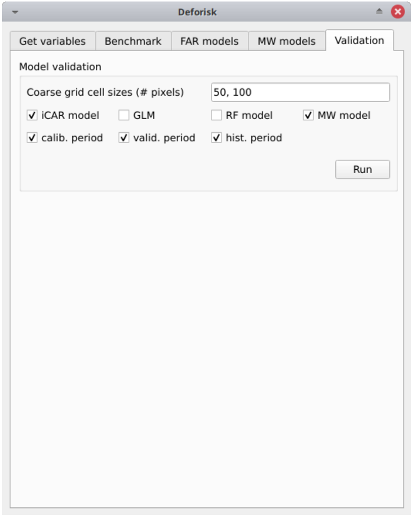


Figure – Moving window.

Validation

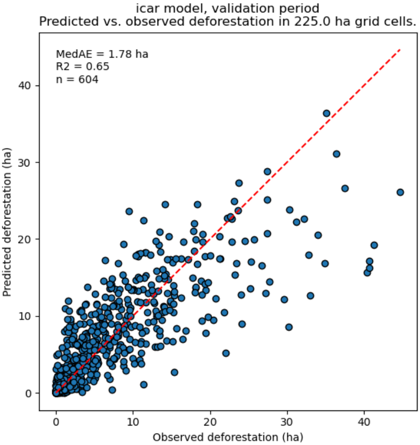
- Comparing predicted vs. observed deforestation (in ha) for each cell in a coarse grid.
- For a given period of time.





Validation

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



Outline

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.

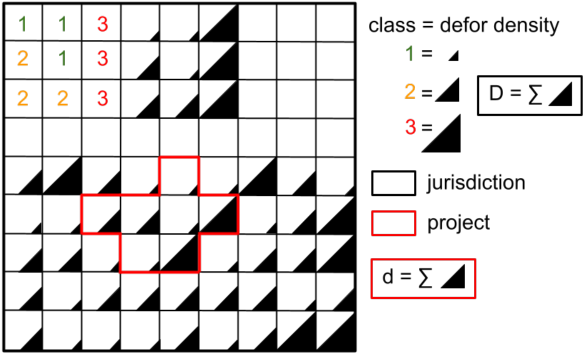
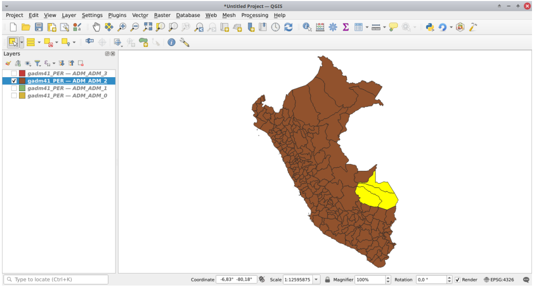


Figure – Allocating deforestation to projects within the jurisdiction.

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.



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

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.

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