FAO workshop – Santa Marta (Colombia), July 2024

Jurisdictional risk maps for allocating deforestation

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

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

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cirad

AMAPlab

FAO FIAT PANIS

Outline

Outline

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

Several criticisms to project-based approach

Several criticisms were addressed to previous REDD+ methodologies for carbon credit certification accusing them to oversell credits.

- **Non-additionnality** : Emissions reductions would have happened anyway. Inflated project-level baselines. Jurisdictional reference levels are reasonably good predictors of future trends.
- **Leakage** : The larger the area covered by a REDD+ initiative, the lower the leakage risk.
- **Reversal** : Jurisdictions are less likely than projects to have their forest carbon stocks decimated by a disturbance event.

Frances Seymour (WRI) : 4 Reasons Why a Jurisdictional Approach for REDD+ Crediting Is Superior to a Project-Based Approach.

New jurisdictional approach

Deforestation intensity

- Baseline activity data or Forest Reference Emission Level at the jurisdictional level
- Amount of deforestation.
- Deforestation “quantity” or “intensity”.

Spatial deforestation risk

- Map of the deforestation risk at the jurisdictional level.
- Spatial relative probability of deforestation.
- Deforestation “location”.

Risk map at the jurisdictional level

Objectives

- Identifying hot-spots/cold-spots of deforestation.
- Classifying forest pixels by risk of being deforested.
- One unique model for the whole jurisdiction (no methodological discrepancies between projects).
- Use this map to allocate deforestation (estimated for the jurisdiction) per project.

Figure – Map of the deforestation risk for Perou.
Green : low, Red/**Black** : high.

Allocating deforestation to projects

- Jurisdictional risk map : a map with class of deforestation risk.
- Obtaining a deforestation density map :
  Class of defor. risk $[1, 2, \ldots, l] \rightarrow$ Defor. density (ha/yr/pixel).
- Can be used to allocate deforestation per project.

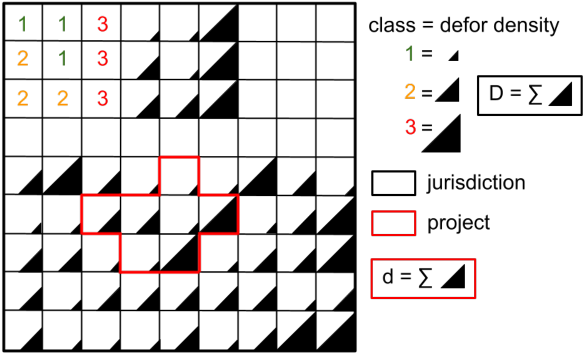


Figure – Allocating deforestation to projects within the jurisdiction.

Outline

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

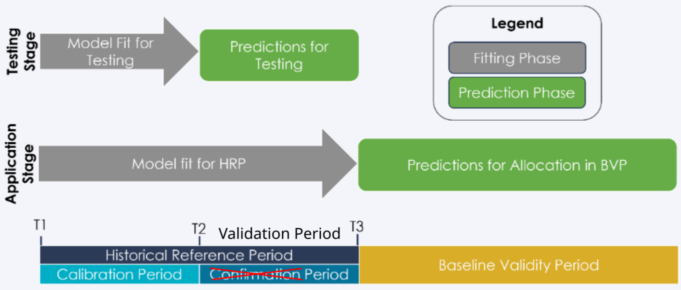
VT0007 tool

- Developed by Clark University (J. R. Eastman and R. G. Pontius Jr.) for Verra.
- **Aim** : Obtaining the best risk map possible at the jurisdictional level.

Basic steps

1. Use a reasonably good reference model to map the deforestation risk.
2. Let the user propose alternative maps from alternative models.
3. Validation step : check that alternative models are better than the benchmark model.
4. Use the best alternative map to allocate deforestation.

Modelling periods



- Three dates : t1, t2, t3.
- Four periods : calibration, validation, historical, (baseline validity period).
- Why different periods : model predictions must be compared with **independent data** (validation period).
- To forecast after t3, we want to use as much data as possible (historical period).

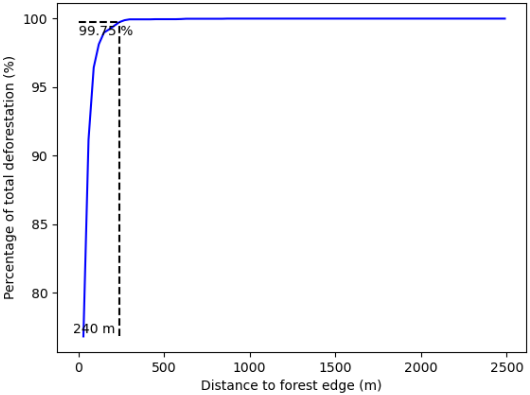
Benchmark model

- 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).

Figure – Subjurisdictions in Martinique (MTQ)

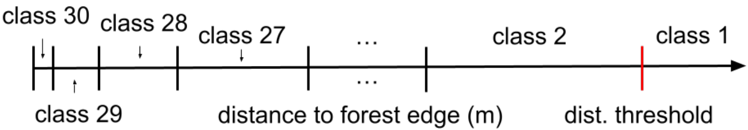
Distance threshold

- Identify the distance to forest edge below which **99.5%** of the deforestation occur.
- Use this distance to define the first class of risk (class 1).



From distance to risk class

- Distances below the threshold are transformed into classes of deforestation risk.
- A geometric series is used for that, ensuring that classes have a wider range for bigger distances.
- We define 29 additional classes of risk from 2 to 30 (class 1 has already been defined).

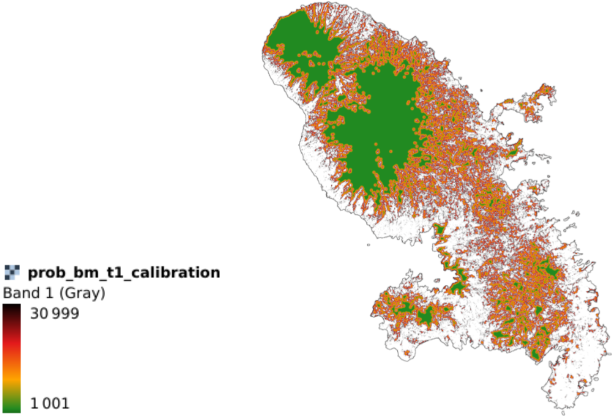


Classes from subjurisdictions

- Each subjurisdiction get a number from 1 to (potentially) 999.
- We combine classes derived from distance with subjurisdictions in the following way : **DD**SSS, with **DD** the distance class and SSS the subjurisdiction number.
- We obtain classes going from 01001 to potentially 30999 if there are 999 subjurisdictions.
- So for 10 subjurisdictions, we obtain ∼300 classes (but some distance classes might be missing).

Classes from subjurisdictions

- Following these steps, we obtain a map at the jurisdictional level where each forest pixel belongs to a given class of deforestation risk.
- Area in dark green : classes **1**SSS, beyond the deforestation threshold.



Deforestation density

- Each class i has an associated **deforestation probability** : $\theta_{m,i} = d_i/n_i$ (unitless), with d_i the number of deforested pixels during the period, and n_i the number of forest pixels at the beginning of the period.
- **Quantity adjustment** ρ : $\theta_{a,i} = \rho\theta_{m,i}$, so that total predicted deforestation = observed (or expected) deforestation. For the benchmark model for the calibration and historical periods, $\rho = 1$.
- **Deforestation density (in ha/yr per pixel)** computed as $\delta_i = \theta_{a,i} \times A/T$. A : pixel area (in ha), T : time-interval of the period (in yr).
- The deforestation density is used to predict the amount of deforestation for each pixel belonging to a given class of deforestation risk.

Deforestation density

Table – Deforestation rates 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
1001	33433	0	0.0	0.0	10	0.09	0.0
1002	12965	0	0.0	0.0	10	0.09	0.0
1003	91686	19	2.072e-04	2.072e-04	10	0.09	1.865e-06
1004	82279	5	6.076e-05	6.076e-05	10	0.09	5.469e-07
2001	1373	0	0.0	0.0	10	0.09	0.0

Deforestation density (in ha/yr per pixel) computed as $\delta_i = \theta_{a,i} \times A/T$

Deforestation density

Deforestation density can be used to allocate deforestation to projects within a jurisdiction.

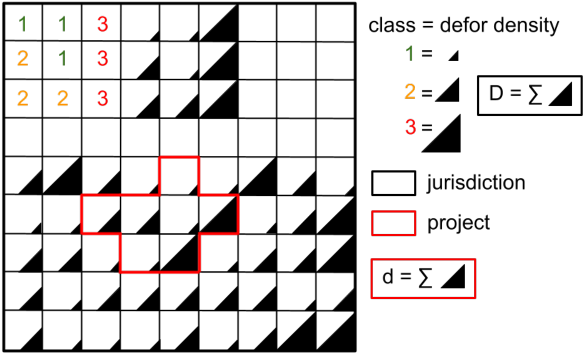


Figure – Allocating deforestation to projects within the jurisdiction.

Alternative models

- Alternative maps from alternative models must be compared with the benchmark model.
- The alternative model can be of different forms : geoprocessing model (moving window), statistical model (iCAR, GLM, RF).
- E.g. Clark Labs propose the MLP (Multi-Layer Perceptron) statistical model in the Land Change Modeller module of the TerrSet software.

Alternative models

- A risk map with deforestation densities derived from the alternative model must be provided.

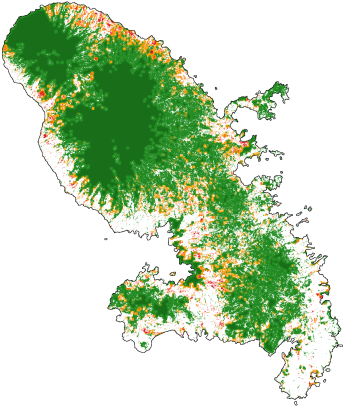


Figure – Risk map obtained with a moving window model.

Validation procedure

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

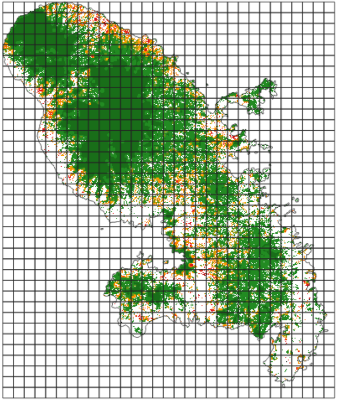
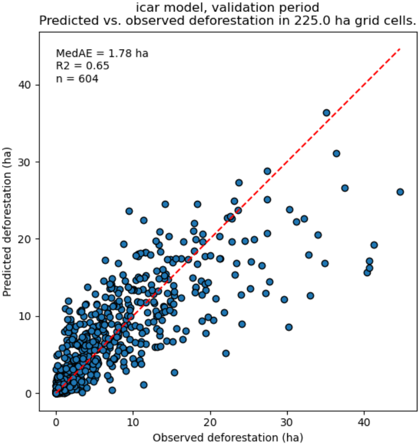


Figure – Coarse grid covering the area of interest.

Validation procedure

- Comparing predicted vs. observed deforestation.
- Performance indices : R^2, and median of absolute error (MedAE).



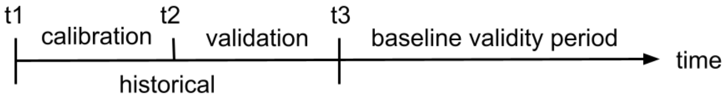
Validation procedure

- Performance indices are computed for each model.
- The model with the higher R^2 and the lower MedAE is selected.

Table – Performance indices.

ncell	period	model	MedAE	R2	RMSE	wRMSE
604	validation	bm	2.71	0.43	6.08	6.22
604	validation	icar	1.78	0.65	4.79	4.59
604	validation	glm	2.39	0.38	6.39	6.52
604	validation	rf	2.09	0.50	5.69	5.74
604	validation	mw_11	2.34	0.56	7.66	6.83
604	validation	mw_21	2.51	0.56	7.54	6.66

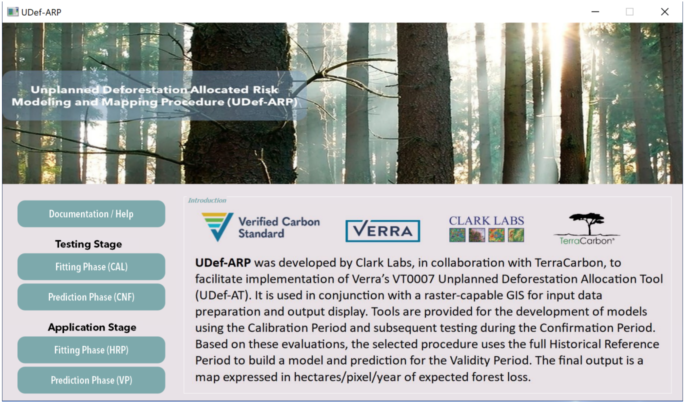
Validation procedure



- We can compare predicted vs. observed deforestation for three time periods : **calibration**, **validation**, and **historical period**.
- To estimate model performance at forecasting deforestation in the future : **predicted vs. observed deforestation** for the **validation period** with a model fitted over the **calibration period**.
- This way, we use **independent observations** of deforestation for model validation (observed deforestation over the validation period have not be used to calibrate the model).
- Verra's methodology : the alternative model must be better for both the calibration and validation periods.

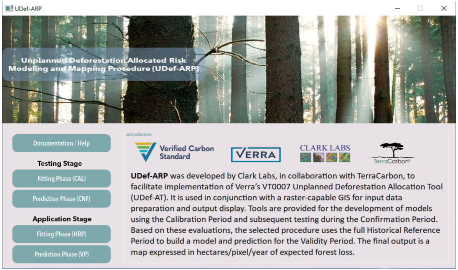
Outline

Verra/Clark Labs software



Standalone app : https://github.com/ClarkCGA/UDef-ARP
QGIS plugin : https://github.com/ClarkCGA/UDef-ARP-Plugin

Verra/Clark Labs software



- User must provide rasters : forest cover change, distance to forest edge at several dates, subjurisdictional borders, alternative risk maps at several dates.
- Using this data, the UDef-ARP provides the basis :
  - for developing a benchmark model.
  - for comparing the benchmark and alternative models.

Limitations

- No tool to help prepare the data.
- No tool to help develop the **alternative models**.
- Windows only (at the moment).
- Require a computer with high RAM for large jurisdiction : all rasters are stored in RAM during processing. Therefore, large jurisdictions will **require substantial RAM allocations** (e.g., 64Gb).
- Use of Float data for risk maps with deforestation density (ha/pixel/yr) : **large space on disk**.
- Documentation in English only, **no translations available**.
- Recent tool, some feedbacks from users (e.g. Fronterra) : Post 1, Post 2, Post 3.

Existing software for alternative models

- Dinamica EGO : Universidade Federal de Minas Gerais, Brazil.
- Land Change Modeler : Clark Labs, Clark University, Worcester, USA.
- CLUE : Institute for Environmental Studies, Vrije Universiteit, Amsterdam, Netherlands .

Great programs with many applications. Many scientific studies, published in a large number of scientific articles, have used these programs.

Limitations

- Not all are open source (e.g. Dinamica EGO and LCM) : **transparency**.
- Not all are free (e.g. LCM) : but discount for student and developing countries.
- Not all allow scripting (e.g. LCM, CLUE) : **reproducibility**.
- Might not work with high resolution ($<=$ 30 m) rasters on large jurisdictions (country scale).
- Limited number of statistical models for modelling land use change : limited accuracy and over-fitting.

See **Vieilledent et al.** 2021, *JOSS*, doi : 10.21105/joss.02975 for more details.

Limitations

- Verra's methodology includes **several steps** (calibration, validation, forecast), which must be **repeated** (model, period).
- It must be possible to follow Verra's methodology with one of these programs (given some requirements, such as high RAM computer).
- But it would require a lot of work for the user to adapt the use of the program to Verra's methodology (e.g. validation step with coarse grid).
- **Note** : in the documentation for UDef-ARP, Clark Labs indicates plans to offer a utility to facilitate the creation of vulnerability maps for alternative models in the near future.

Outline

Summary

- We need a **map of the deforestation risk** at the **jurisdictional level**.
- Deforestation risk : **deforestation density** in ha/pixel/yr.
- This map should be better than the map derived from the benchmark model.
- The best map will be used to **allocate deforestation** to projects within the jurisdiction.

A not so simple methodology

- Risk map must be obtained following Verra/Clark Labs methodology.
- The methodology was developed with simplicity in mind.
- But modelling deforestation is inherently complicated and model comparison and validation require a minimal number of steps.
- This makes hard to develop an alternative model better than the benchmark model using existing tools.

Need for an integrative tool : the deforisk QGIS plugin

- A utility to facilitate the creation of risk maps for alternative models is needed.
- Specificities :
  - **Integrative** : all the steps of Verra's methodology (benchmark model, alternative models, validation, allocation).
  - **Accuracy** : high accuracy for forecasting deforestation.
  - **Easy to use** : simple interface with documentation.
  - **Transparent and reproducible** : using open-source software (important for carbon/biodiversity credit certification).

- Cirad and FAO have worked at developing the `deforisk` QGIS plugin to meet these objectives : https://ecology.ghislainv.fr/deforisk-qgis-plugin

. . . Thank you for attention . . .

https://ecology.ghislainv.fr/deforisk-qgis-plugin

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

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cirad

AMAPlab

FAO
FIAT PANIS