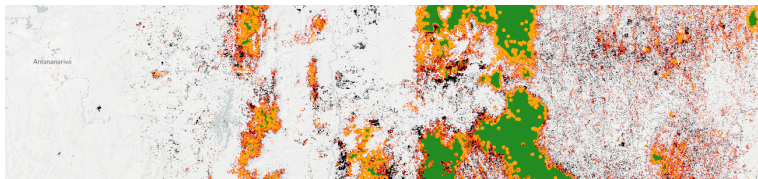


Computing the annual deforestation rate



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Observations of deforestation

- Historical deforestation maps are often derived from the analysis of satellite images (eg. Landsat).
- Deforestation is a rare event ($< 1\%/yr$) and is very variable from one year to another.
- Deforestation is often observed and estimated for a period of time T of several years (eg. 5 or 10 years).



Figure – Deforestation 2000–2010–2020 in Guadeloupe.

Annual deforestation rate

- To be able to compare deforestation intensity between regions (eg. countries) and time periods of different lengths (eg. 5 or 10 years), we need to compute a **mean annual deforestation rate** d in %/yr (also denoted $\%.\text{yr}^{-1}$).
- Several formulas have been proposed to compute d from the observed deforestation rate d' on a given period of time T .
- $d' = (A_0 - A_T)/A_0$, with A_0 : initial forest cover at time $t = 0$, and A_T : forest cover at time $t = T$ with $T > 1$.

Objectives

- Compare the different formulas used to compute the **mean annual deforestation rate** d in %/yr.
- Propose an appropriate formula for the JNR risk mapping tool.

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Notations

Areas and time

- A_t : forest area (in ha or km²) at time t with $t = 0, \dots, T$.
- $A_0 > A_1 > A_2 > \dots > A_T$.
- T : time-interval (in yr), $T > 1$.

Deforestation rates

- d' : observed deforestation rate for period of time T .
 $d' = (A_0 - A_T)/A_0$, in %.
- d : **mean annual deforestation rate** over the period of time T .
e.g. $d = (A_0 - A_1)/A_0$, in %/yr.
- d must be constant over the period of time T .
 $d = (A_0 - A_1)/A_0 = (A_1 - A_2)/A_1 = \dots$

Formulas

How to compute d from A_0 , A_T and T (or from d' and T as $d' = (A_0 - A_T)/A_0$)?

Proposed formulas

- FAO formula
$$r = (A_T/A_0)^{(1/T)} - 1$$
- Clark U. formula (inverted ratio)
$$\delta = (A_0/A_T)^{(1/T)} - 1$$
- Puyravaud formula
$$\rho = (1/T) \ln(A_T/A_0)$$
- Cirad formula (after correction)
$$d = 1 - (1 - d')^{1/T}$$

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FAO formula

$$r = (A_T/A_0)^{(1/T)} - 1$$

- Following FAO definition, r is a mean **annual rate of change**, not a mean annual rate of **deforestation**.
- This rate is zero if $A_T = A_0$ (no change), positive if $A_T > A_0$ (increase in forest cover), and negative if $A_T < A_0$ (deforestation). This equation is perfectly OK when correctly interpreted.
- In the Verra document about JNR mapping risk methodology, there is a misinterpretation of r described as the deforestation or forest degradation rate (see p. 8 of the document).
- To obtain a deforestation rate (which is assumed positive), we need the opposite :

$$d = 1 - (A_T/A_0)^{1/T}$$

Cirad formula

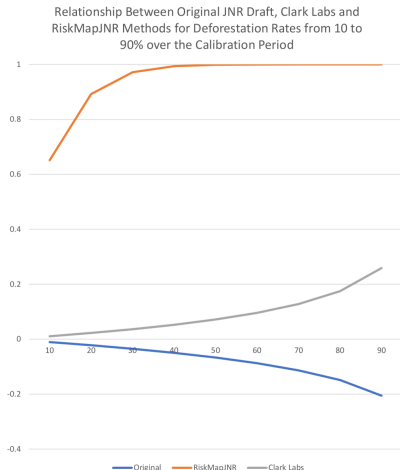
$$d = 1 - (1 - d')^{1/T}, \text{ with } d' = (A_0 - A_T)/A_0$$
$$d = 1 - (1 - (A_0 - A_T)/A_0)^{1/T} = 1 - (A_T/A_0)^{1/T}$$

- This formula is just the **opposite** of the FAO rate cited by Verra :
 $d = 1 - r$, with $r = (A_T/A_0)^{(1/T)} - 1$.
- Can be easily demonstrated mathematically.
- Note that $d = 1 - (1 - d')^{1/T} \Leftrightarrow d' = 1 - (1 - d)^T$
- This explains the error in the `riskmapjnr` Python package (there was a confusion between d and d' , now corrected).

Clark U. formula

$$\delta = (A_0/A_T)^{(1/T)} - 1$$

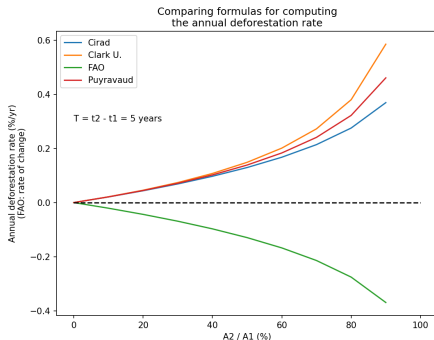
- Inverse ratio A_0/A_T in place of A_T/A_0 .
- Seems to provide reasonable estimates.



Problems with Clark U. formula

$$\delta = (A_0/A_T)^{(1/T)} - 1$$

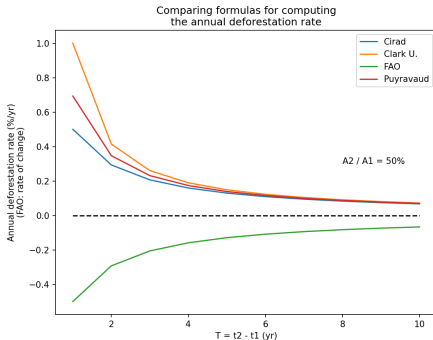
- Not defined when $A_T = 0$
- $A_T = 0$ is frequent (small window size or T is large).
- Difficult to interpret.
- Overestimation of the mean annual deforestation rate.



Problems with Clark U. formula

$$\delta = (A_0/A_T)^{(1/T)} - 1$$

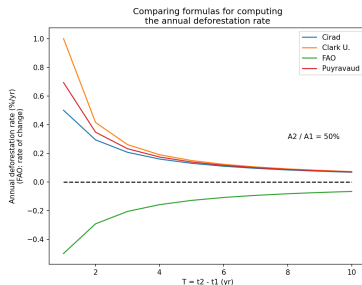
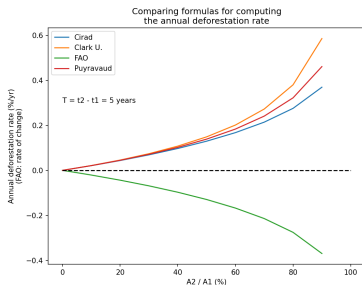
- Overestimation of the mean annual deforestation rate.



Puyravaud formula

$$\rho = (1/T) \ln(A_T/A_0)$$

- Derived from the instantaneous rate of change.
- Not defined when $A_T = 0$.
- Again, $A_T = 0$ is frequent (small window size or T is large).
- Overestimation of the mean annual deforestation rate.



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Recommendation

We recommend the use of the following formula to estimate the **mean annual deforestation rate** :

$$d = 1 - (1 - d')^{1/T} \text{ equivalent to } d = 1 - (A_T/A_0)^{1/T}$$

Demonstration

We demonstrate that $d = 1 - (1 - d')^{1/T}$:

We have : $A_0 > A_1 > A_2 > \dots > A_T$

Then, $A_1 = A_0 - d \times A_0 = A_0(1 - d)$

$A_2 = A_1 - d \times A_1 = A_1(1 - d) = A_0(1 - d)(1 - d) = A_0(1 - d)^2$

...

$A_T = A_0(1 - d)^T \Leftrightarrow A_T/A_0 = (1 - d)^T$ (1)

By definition, $d' = (A_0 - A_T)/A_0$ (2)

(1) and (2) $\Rightarrow d' = 1 - (1 - d)^T$ (3)

$(1 - d)^T = 1 - d'$

$1 - d = (1 - d')^{1/T}$

$d = 1 - (1 - d')^{1/T}$ (4)



... Thank you for attention ...

<https://ecology.ghislainv.fr/presentations>



AMAP

