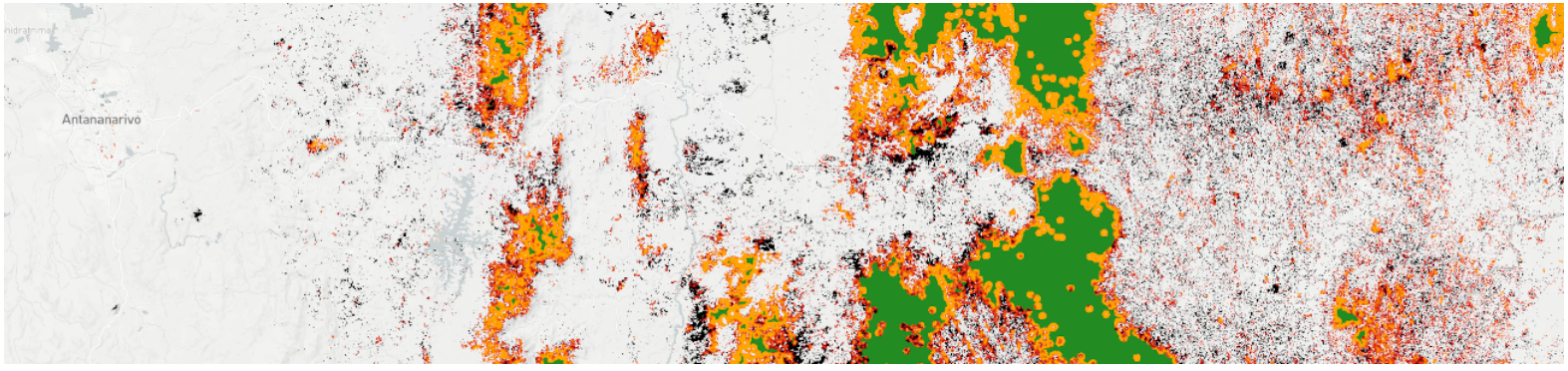
Clark University – JNR risk mapping meeting – September 16th 2022

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 ($< 1\%/\text{yr}$) 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).

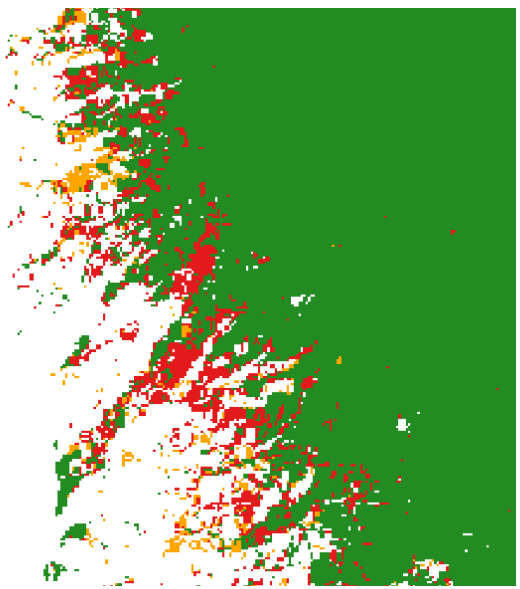

Figure – Deforestation 2000–2010–2020 in Guadeloupe.

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 $\%.\mathrm{yr}^{-1}$).
- 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 km^2) at time t with $t = 0, \ldots, T$.
- $A_0 > A_1 > A_2 > \ldots > A_T$.
- 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.
  $d = (A_0 - A_1)/A_0 = (A_1 - A_2)/A_1 = \ldots$.

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

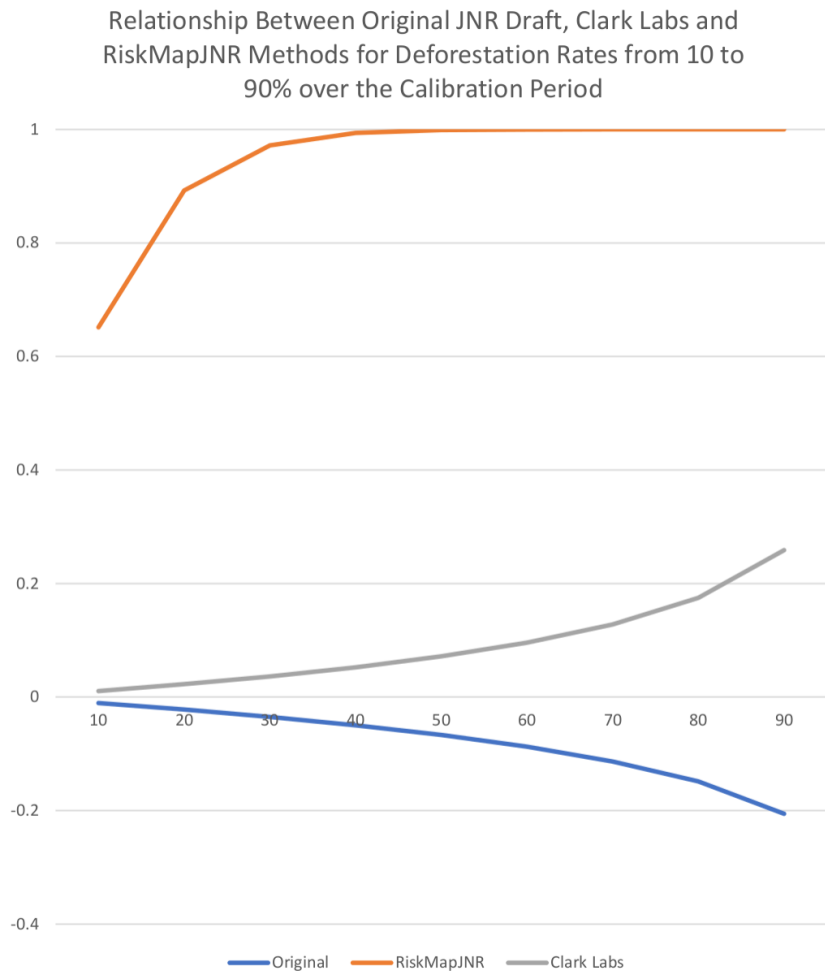
$$d = 1 - (1 - d')^{1/T}, \text{ with } d' = (A_0 - A_T)/A_0$$
$$d = 1 - (1 - (A_0 - A_T)/A_0)^{1/T} = 1 - (A_T/A_0)^{1/T}$$

- 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

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

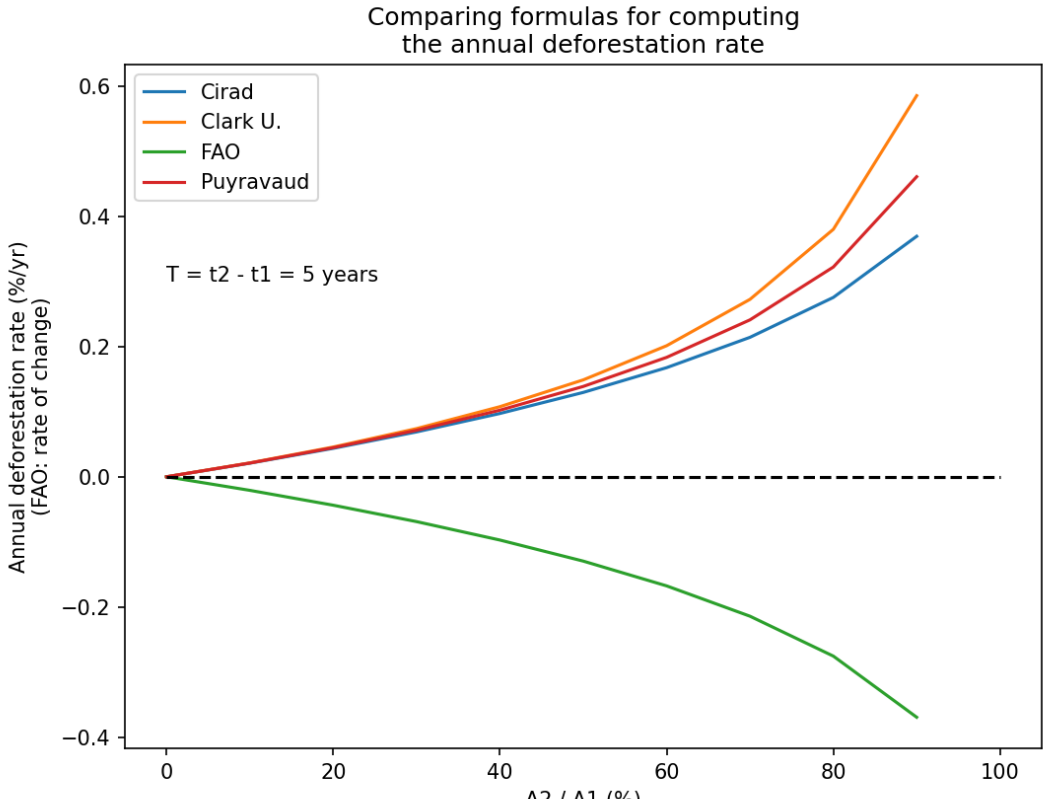
- Inverse ratio A_0/A_T in place of A_T/A_0.
- Seems to provide reasonable estimates.



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.



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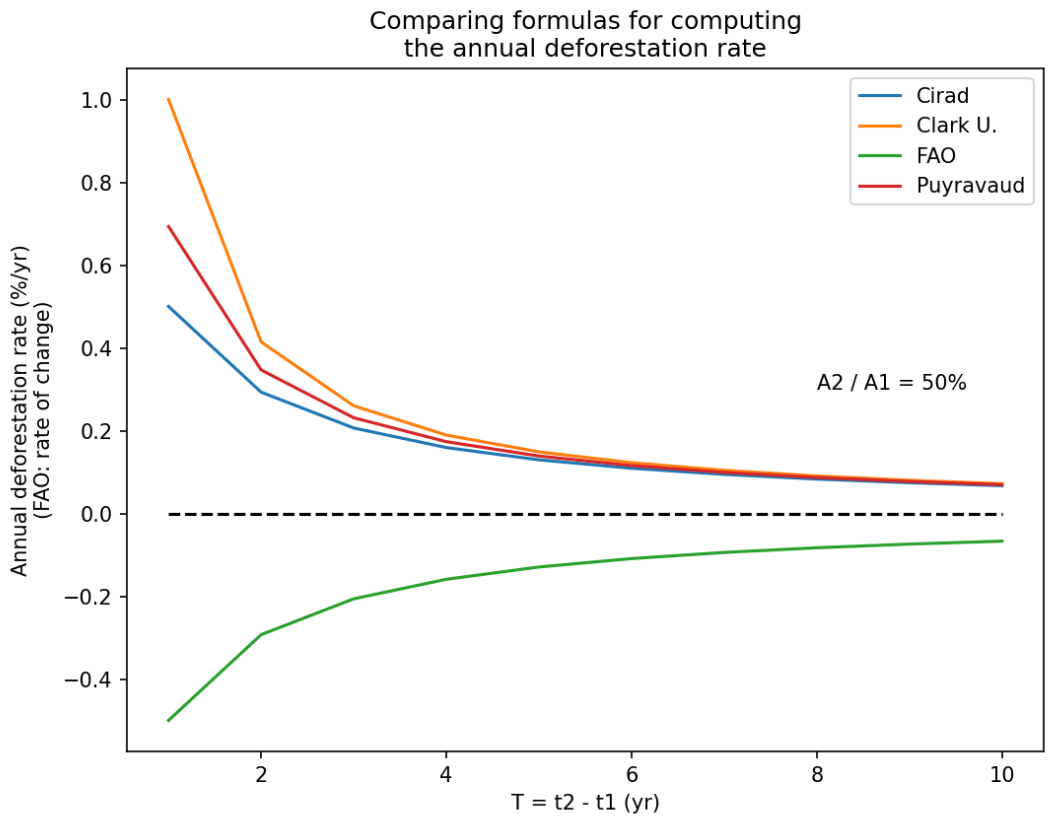
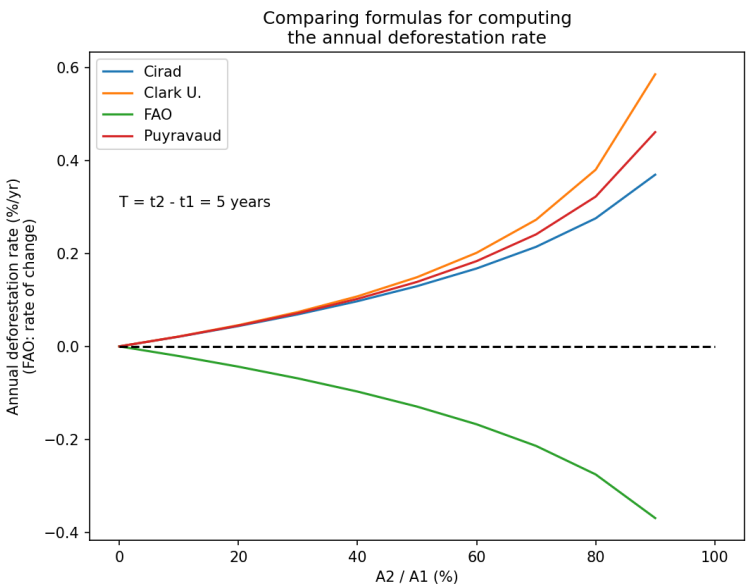
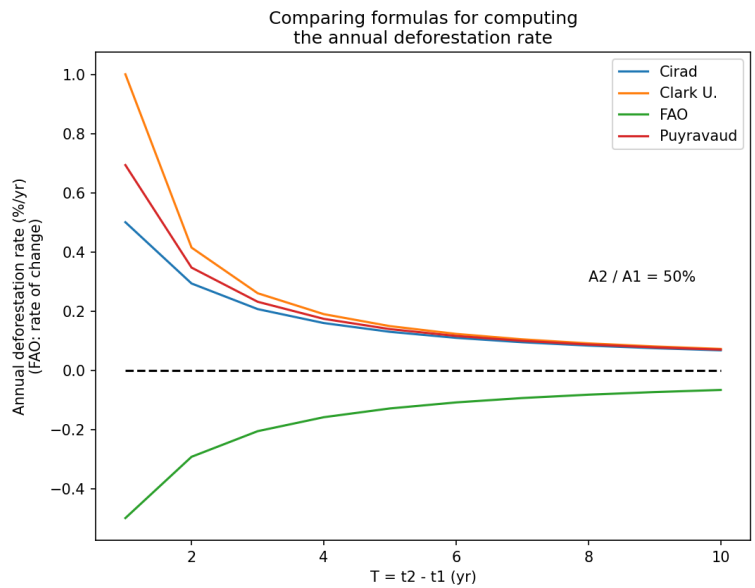


Puyravaud formula

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

- 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 : $A_0 > A_1 > A_2 > \ldots > A_T$
Then, $A_1 = A_0 - d \times A_0 = A_0(1 - d)$
$A_2 = A_1 - d \times A_1 = A_1(1 - d) = A_0(1 - d)(1 - d) = A_0(1 - d)^2$
...
$A_T = A_0(1 - d)^T \Leftrightarrow A_T/A_0 = (1\text{-}d)^T$ (1)

By definition, $d' = (A_0\text{-}A_T)/A_0$ (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 . . .

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