# Quantitative interactions between forest and the water resources

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# 1. Introduction - Objectives

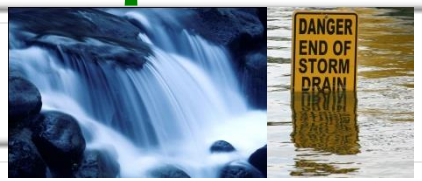
- A deeply entrenched « popular narrative » about the hydrological role of forest…
- … that sometimes  enters our scientific community
- A solid body of scientific information about the relationships between forest and water is existing: forest and the water cycle, soil erosion, stream sedimentation, water quality, landslides… and is worth to be mentioned
- This paper: to focus on **quantitative issues**
- See also Abstract N°2281 for qualitative issues (Lafforgue et al.)

# 1. A few brief basic hydrological reminds

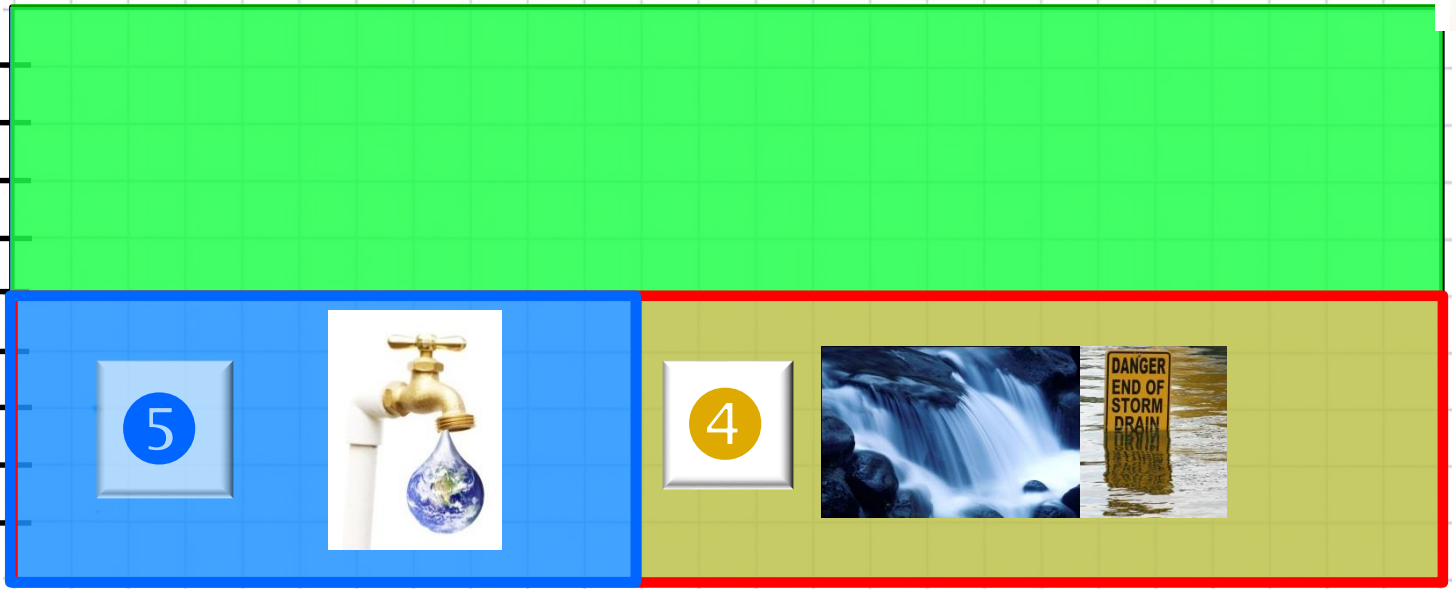
❶ Rainfall

❷ Interception & evapotranspiration

❹ Surface Runoff



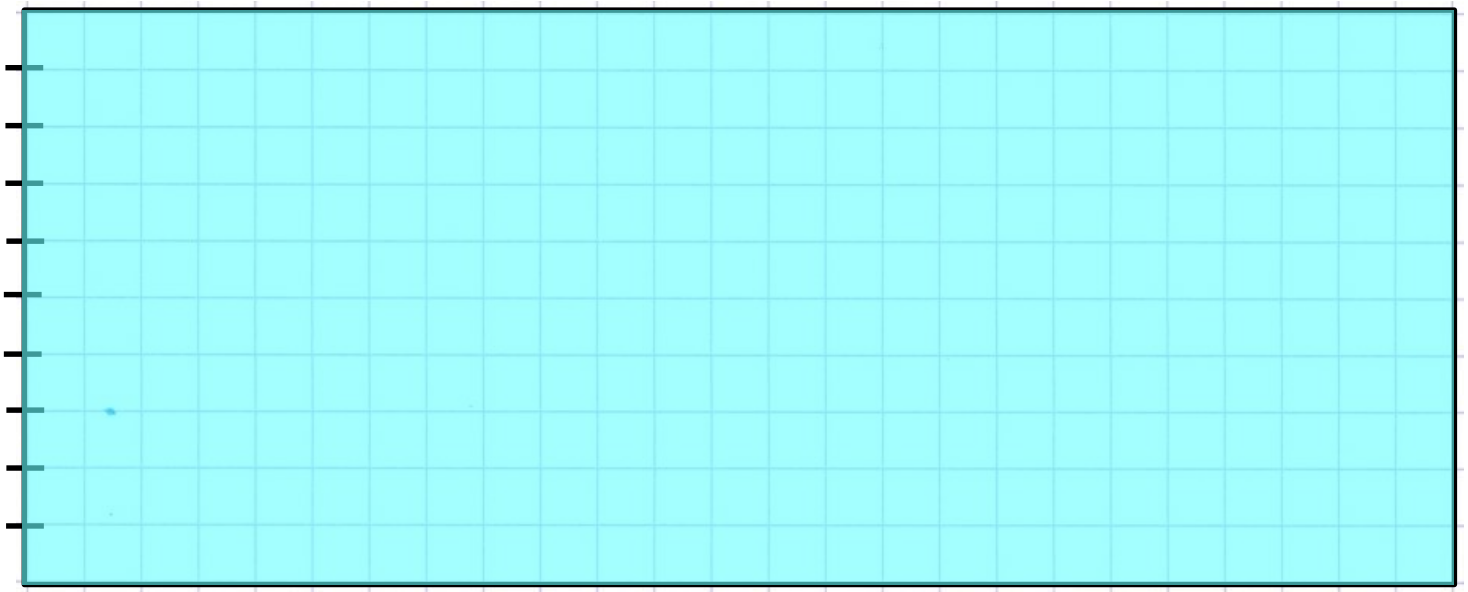

❺ Recharge – Low stage discharge



# 2. Forest and the water cycle: 2.1 Forest and rainfall

## ❶ Rainfall

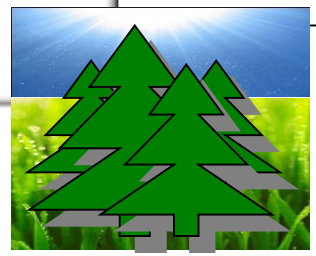
**➔ Forest does not make it rain**



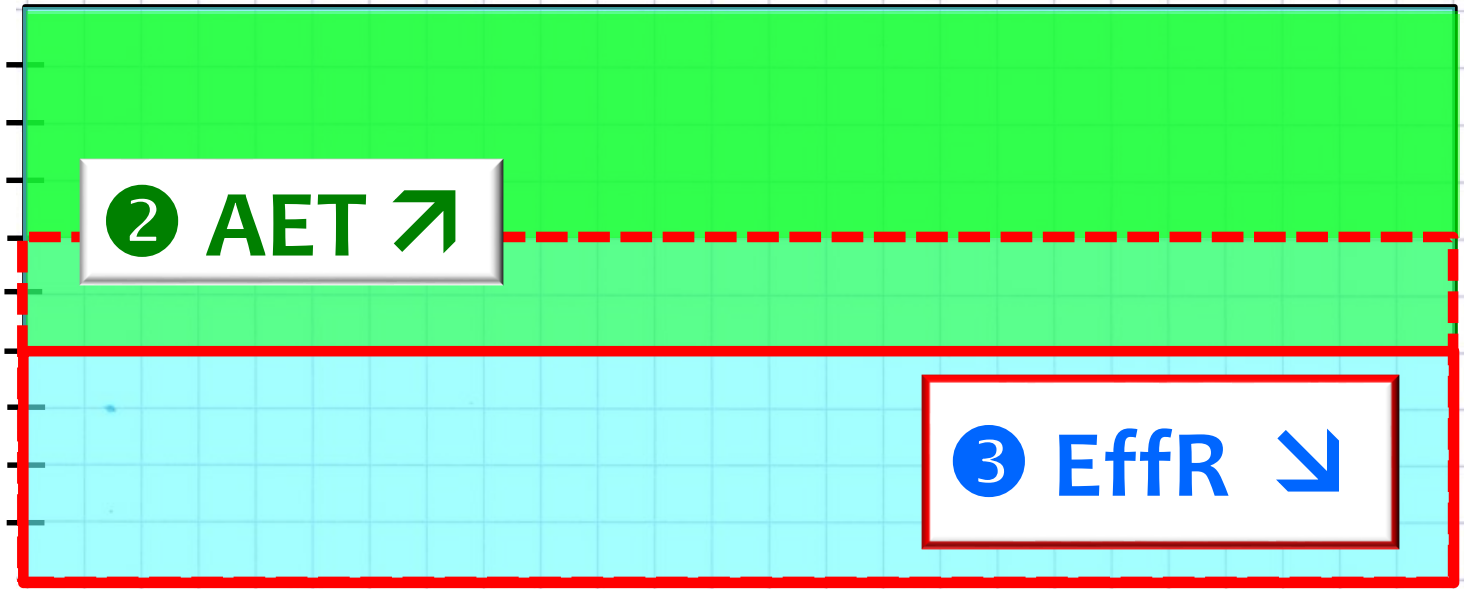
**Clearing forest doesn't reduce total rainfall, and conversely reforestation doesn't increase rainfall at the watershed scale**
**(at the scale of basins <= "Amazonia"!)**
**➔ At the exception of "occult precipitations" in cloud forests**

# 2.2 Forest and the water cycle
# AET & EffR

## ❷ Interception & evapotranspiration



## ❸ Efficient Rainfall




**Note that: - Interception = evapotranspiration = link with climate**
**- Interception is higher in forests than in most other landcovers**
**- And (and not as a consequence) evapotranspiration is higher there for 4 main reasons: (1) leaf development (higher than other plants), (2) roughness (air turbulence), (3) dark leaf color, and (4) deeper root exploration capacity (ETP↗)**

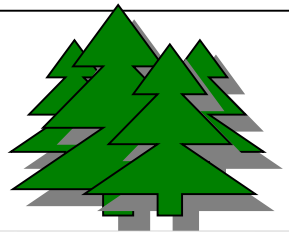
# 2.3 Forest and the water cycle
# Runoff/Floods

## ❹ Surface Runoff


## ➔ The forest can reduce surface runoff

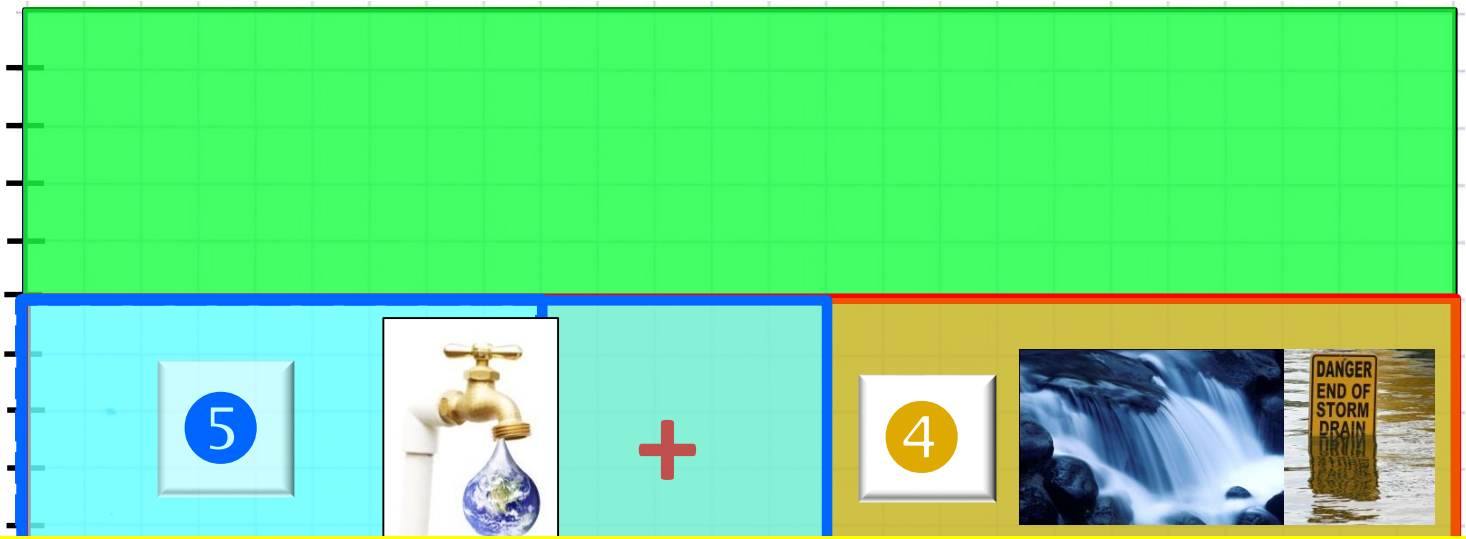
- Increases in peak (floods) flows as a result of cutting trees for small to medium-sized rainfall events in small catchments (<10 km$^2$)
- Major determinants of large scale flooding = rainfall amount & intensity, antecedent rainfall and geomophology, <u>not vegetation type</u>
- Trees do not prevent erosion = condition of soil surface & understory veg.

# 2.4 Forest and the water cycle
# Low flows/Recharge/W. Resource



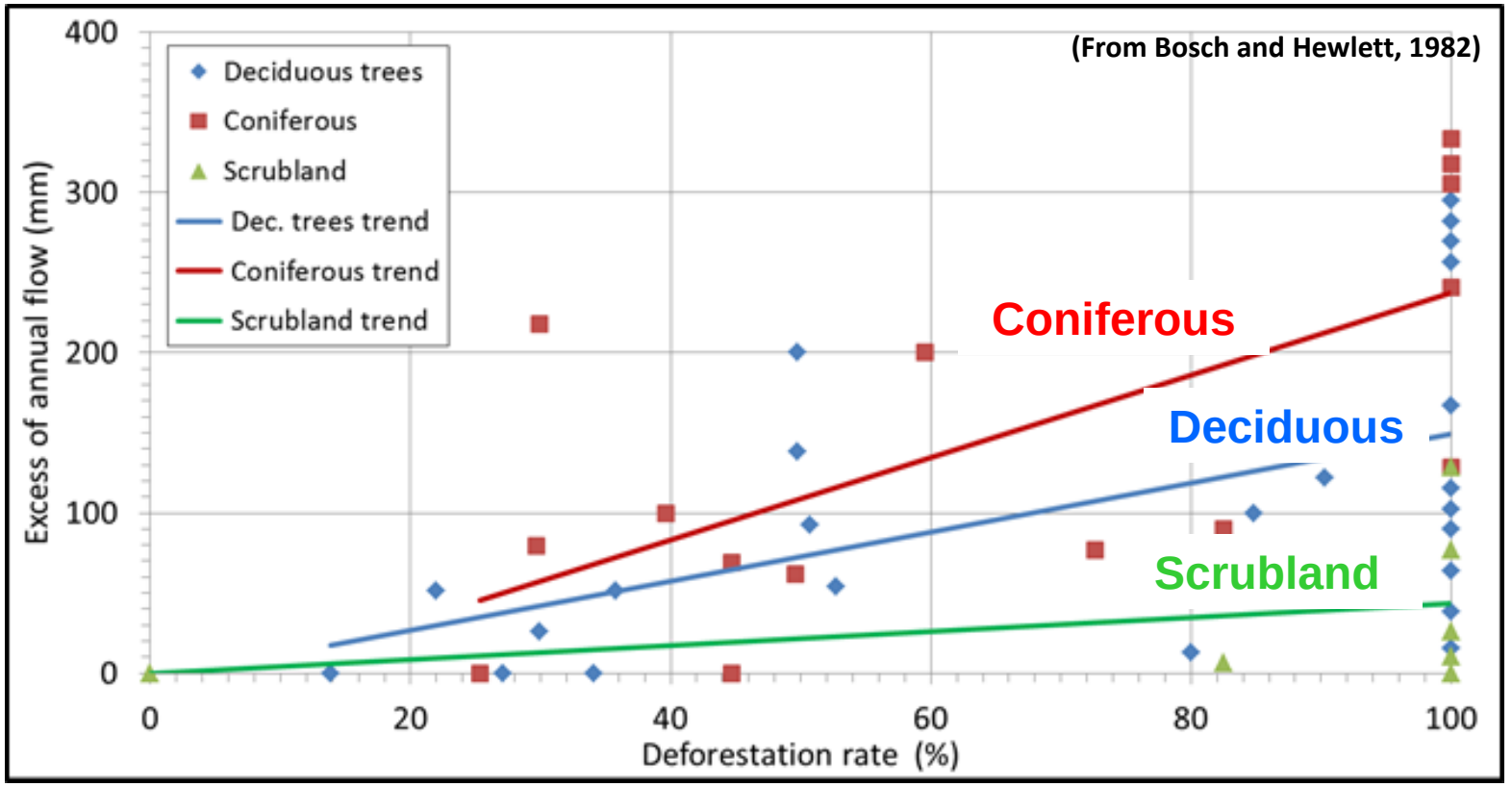
## ❹ Surface Runoff

## ❺ And may (or not) increase recharge



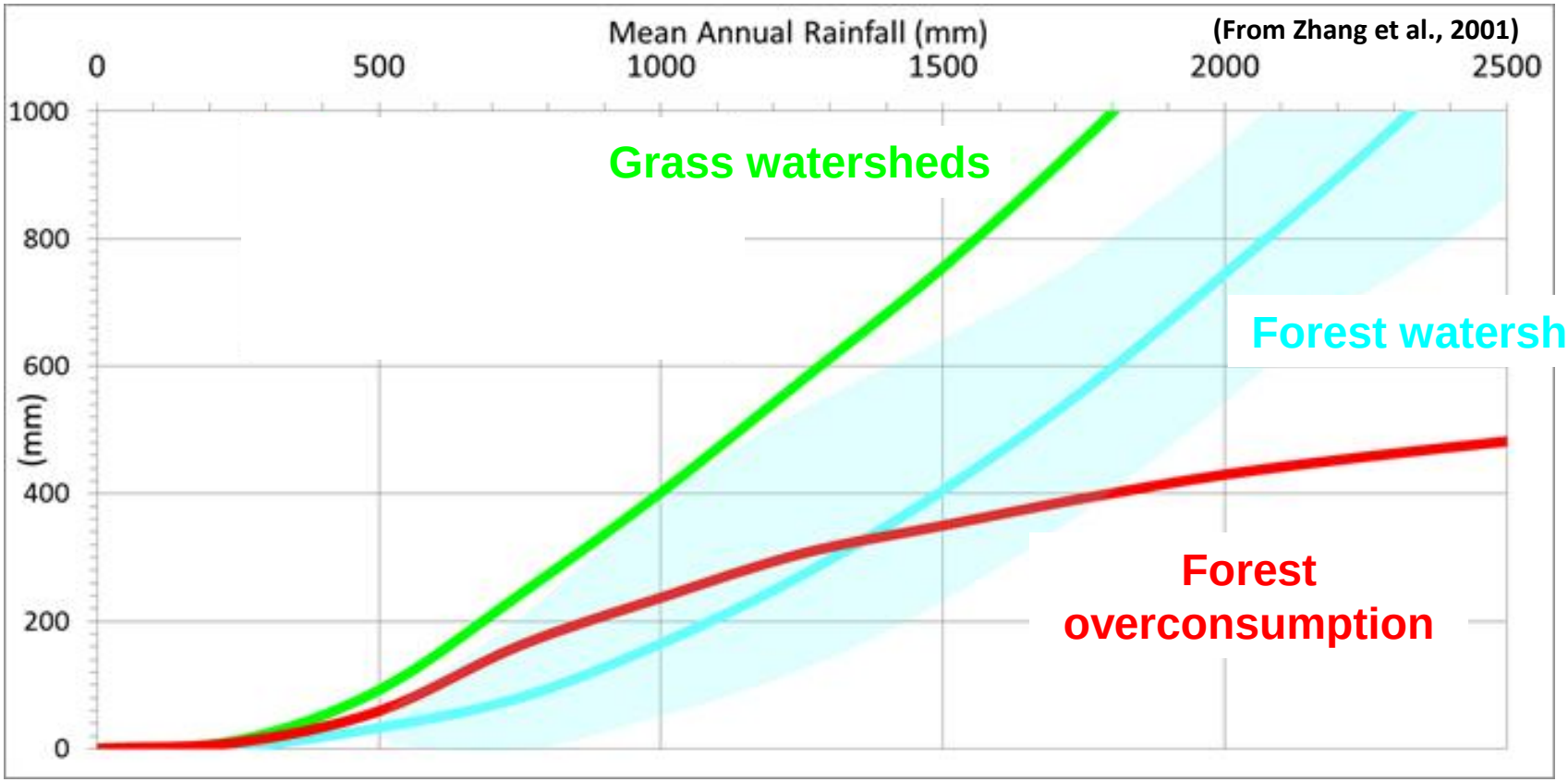

- Forest may increase recharge to the soil but ≠ aquifer recharge/Water resource
- Reforestation decreases base (low) flow. Mostly noticeable in small basins
- Impact of reforestation of catchments with heavily compacted soils depends on the trade-off between the increase in rainwater infiltrated and increase in evapotranspiration

# 3. Some quantitative facts
# Catchment flow/Water resource




- Deforestation = increase in annual surface flow, proportional to the rate of deforestation
- Conifers evapotranspiration > deciduous trees > scrubland
- Extra flows increases with rainfall: a few % up to about 20%

# 4. Some quantitative facts
## Explorating Zhang et al. curves

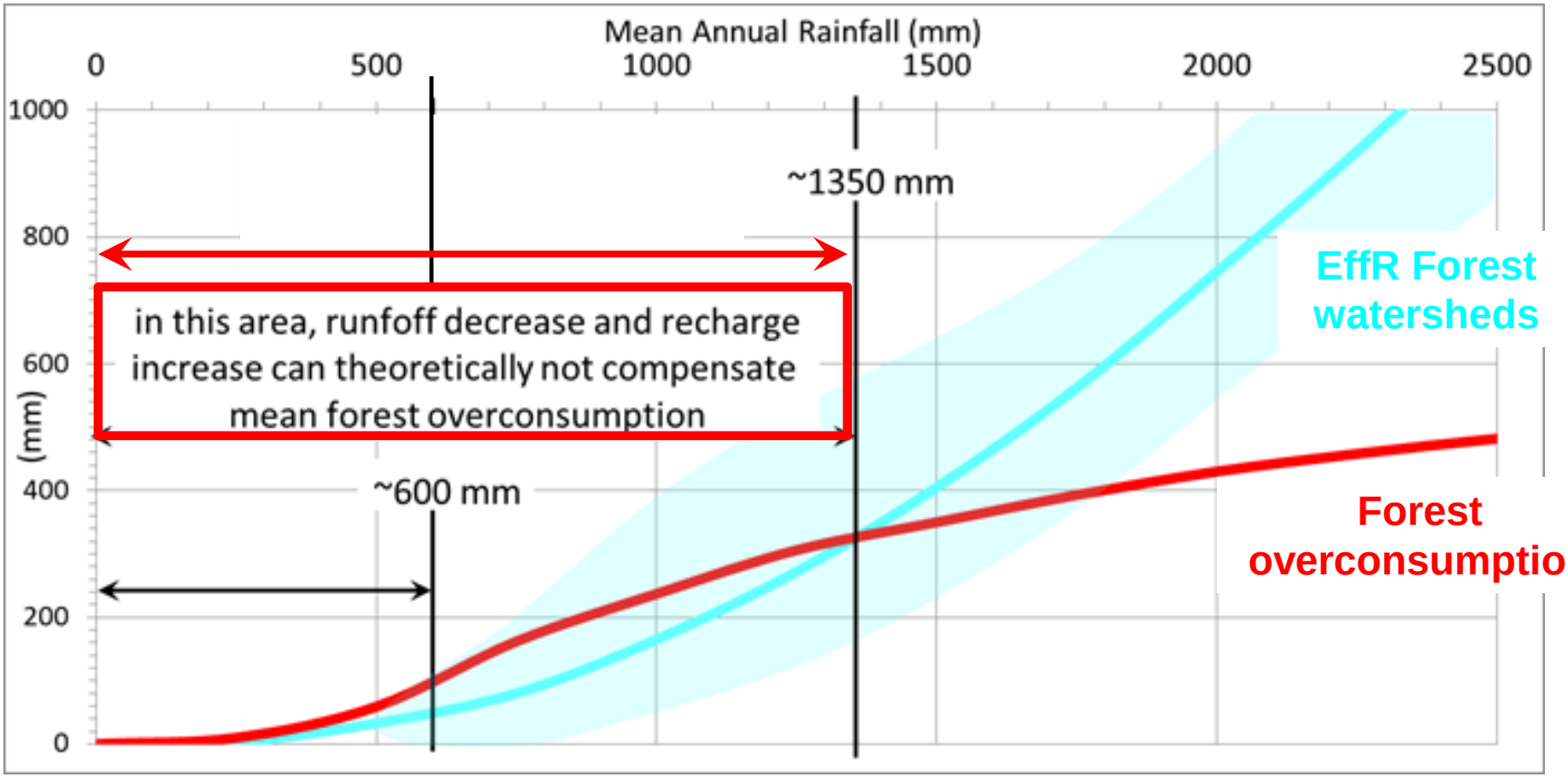



**Efficient rainfall curves**

- Uncertainty due to the worldwide dispersion of forest annual evapotranspiration
- The impact is hopefully lower for low rainfall areas
- However, the impact is always negative

# 4. Some quantitative facts

## Can an Increase in Recharge (a Decrease in Runoff) = Compensate Forest "Overconsumption"?




- Even if <u>100% runoff</u> before planting is transformed into <u>100% recharge</u> after planting…
- Below 600 mm, even in the most favorable cases

# 4. Some quantitative facts

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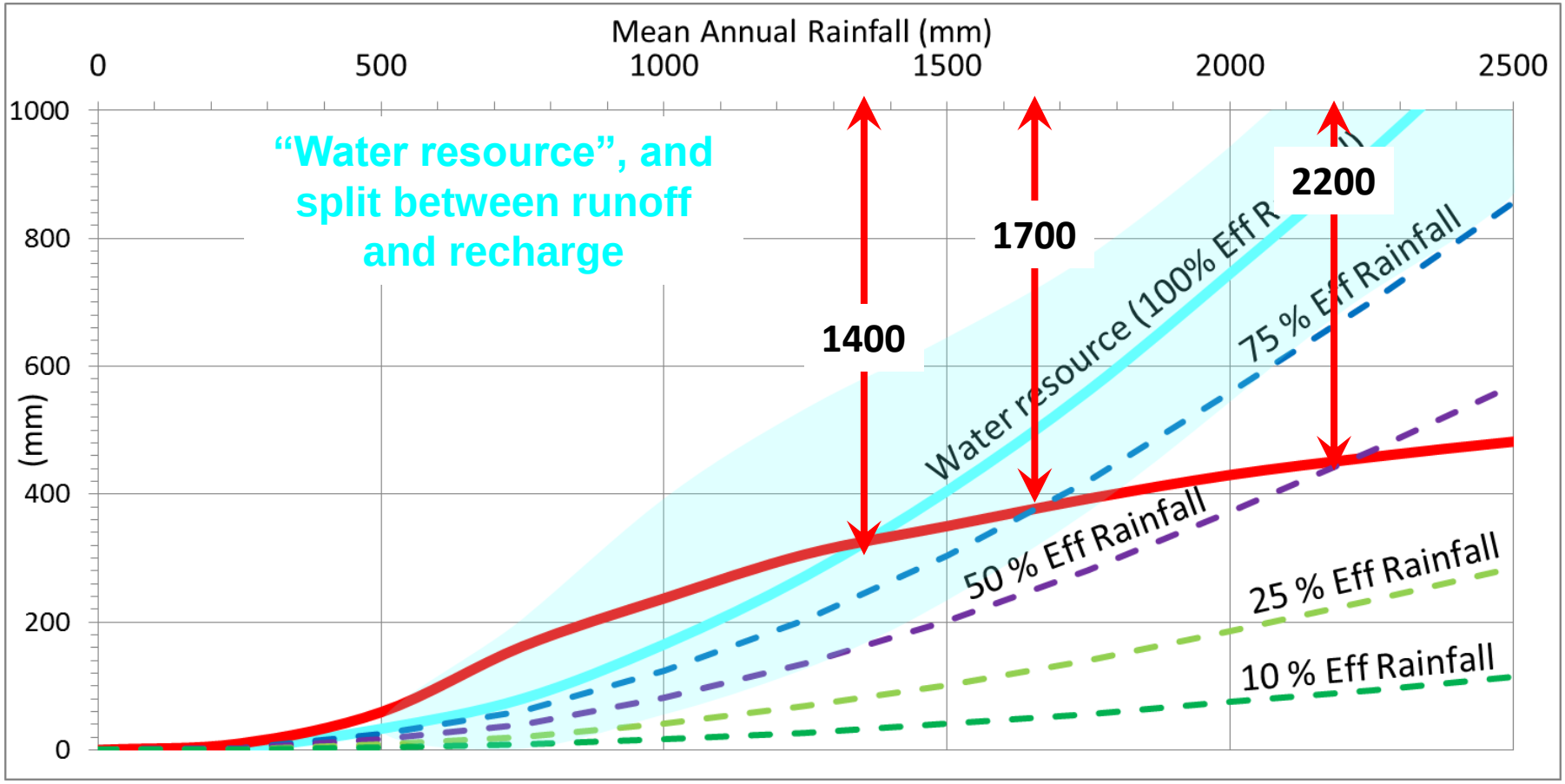
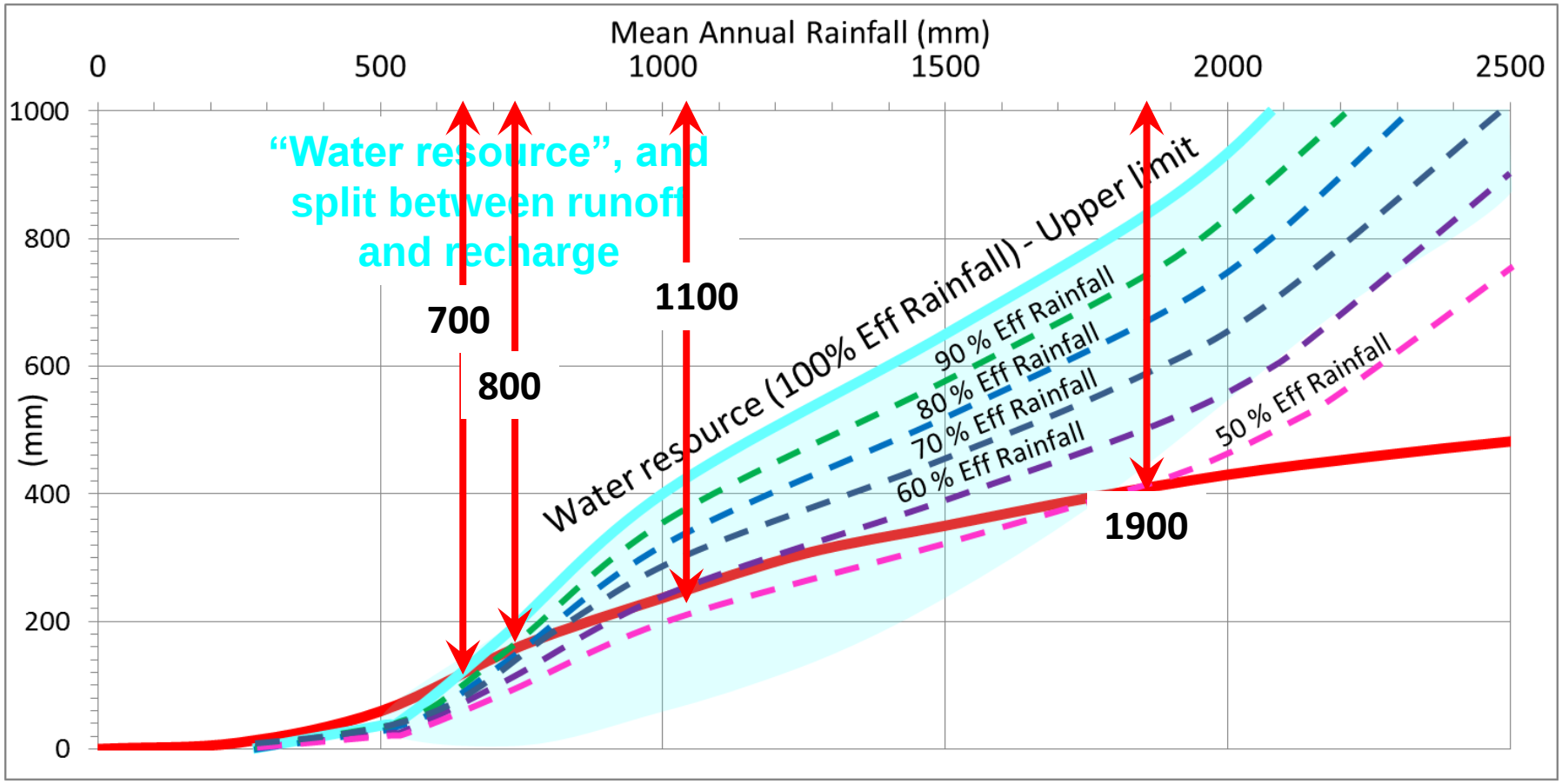



**- Compensation of overconsumption only for very high annual rainfall (if runoff was 100% rainfall before reforestation… Rather unlikely)**

# 4. Some quantitative facts

## Can an Increase in Recharge (a Decrease in Runoff) Compensate Forest "Overconsumption"?

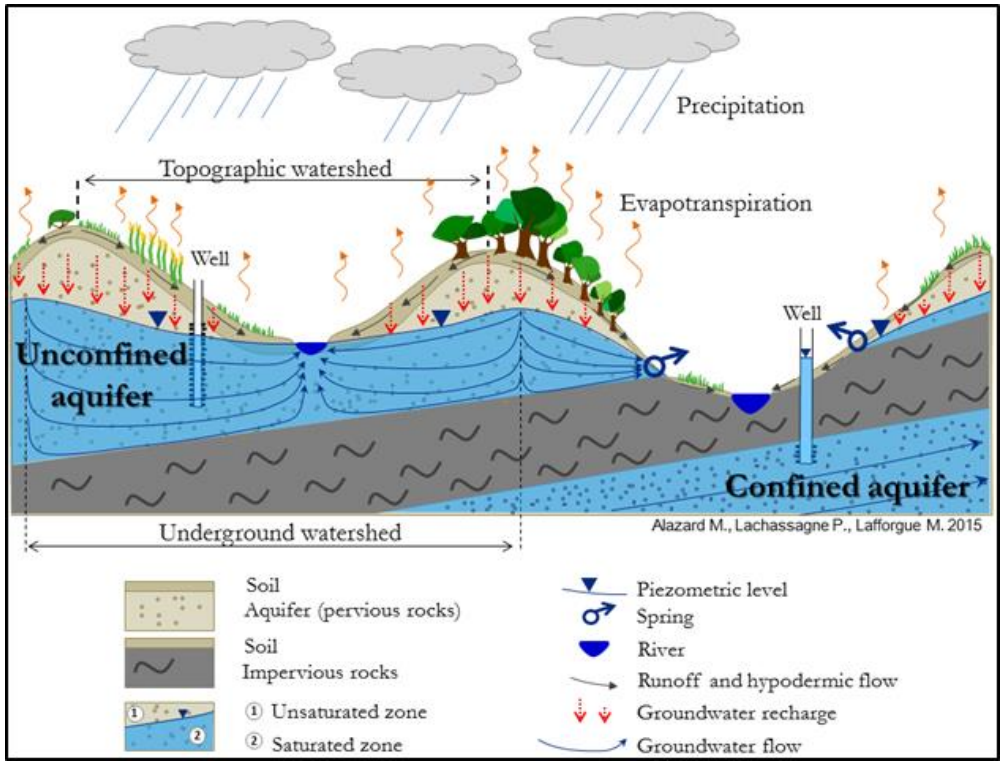


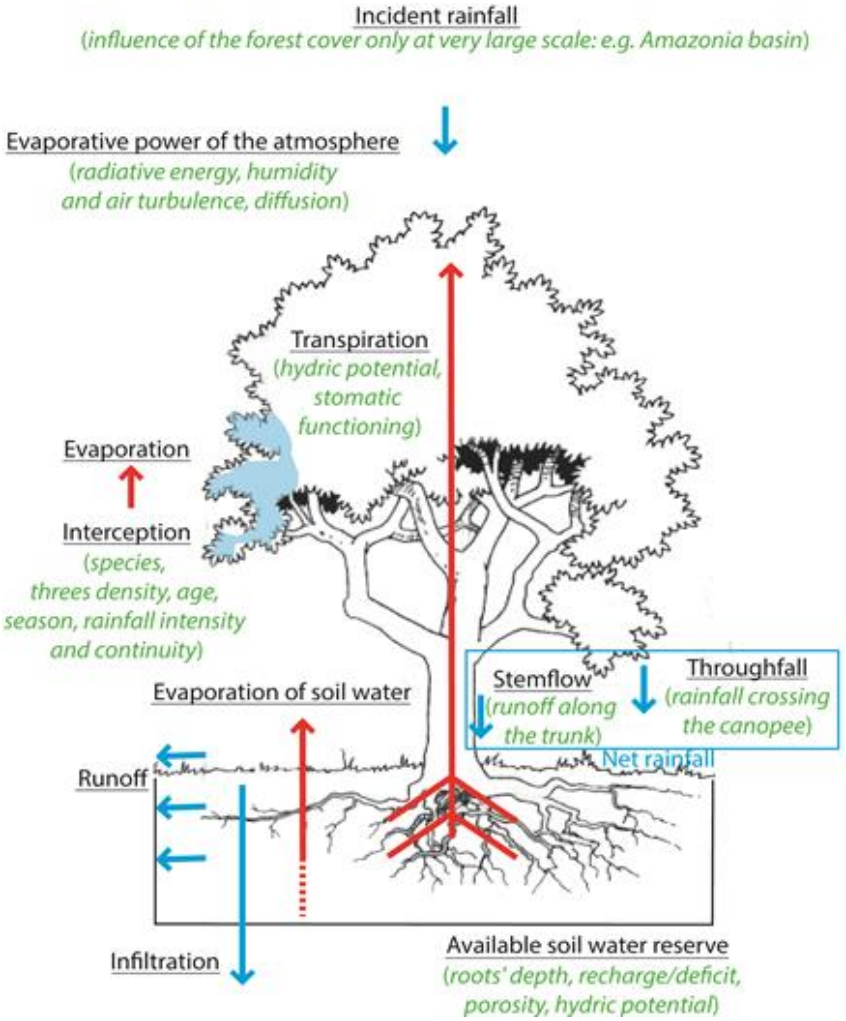

- The results are similar even in the most favorable cases
- and again, if runoff was 100% rainfall before reforestation…

# 5. Conclusions

- Increase in recharge (decrease in runoff) rarely compensates forest “overconsumption”
- A case by case study is required, and precise computation of the impact of forest requires a hydrological modelling approach:
  - impact higher in tropical countries (year long ET)
  - impact overgreen trees > deciduous (LAI)
  - groundwater fed trees: higher ET
- Main hydrological and hydrogeological configurations that favor or impede recharge:
  - high reserves/deep soils: higher ET
  - watersheds with significant runoff before reforestation – partial compensation of forest impact: granites, schists with no storage capacity
  - watersheds with low runoff – no compensation of forest impact: gentle slopes, permeable subsoil (sandy, volcanic…)

# Back-Up


Precipitation
Topographic watershed
Evapotranspiration
Well
Well
Unconfined aquifer
Confined aquifer
Underground watershed
Alazard M., Lachassagne P., Lafforgue M. 2015
Soil
Aquifer (pervious rocks)
Soil
Impervious rocks
① Unsaturated zone
② Saturated zone
Piezometric level
Spring
River
Runoff and hypodermic flow
Groundwater recharge
Groundwater flow


Incident rainfall
(influence of the forest cover only at very large scale: e.g. Amazonia basin)
Evaporative power of the atmosphere
(radiative energy, humidity and air turbulence, diffusion)
Transpiration
(hydric potential, stomatic functioning)
Evaporation
Interception
(species, threes density, age, season, rainfall intensity and continuity)
Stemflow
(runoff along the trunk)
Throughfall
(rainfall crossing the canopee)
Net rainfall
Evaporation of soil water
Runoff
Infiltration
Available soil water reserve
(roots' depth, recharge/deficit, porosity, hydric potential)