From Precipitation Recycling to the Cooling Power of Forests: New Roles for Nature-Based Solutions

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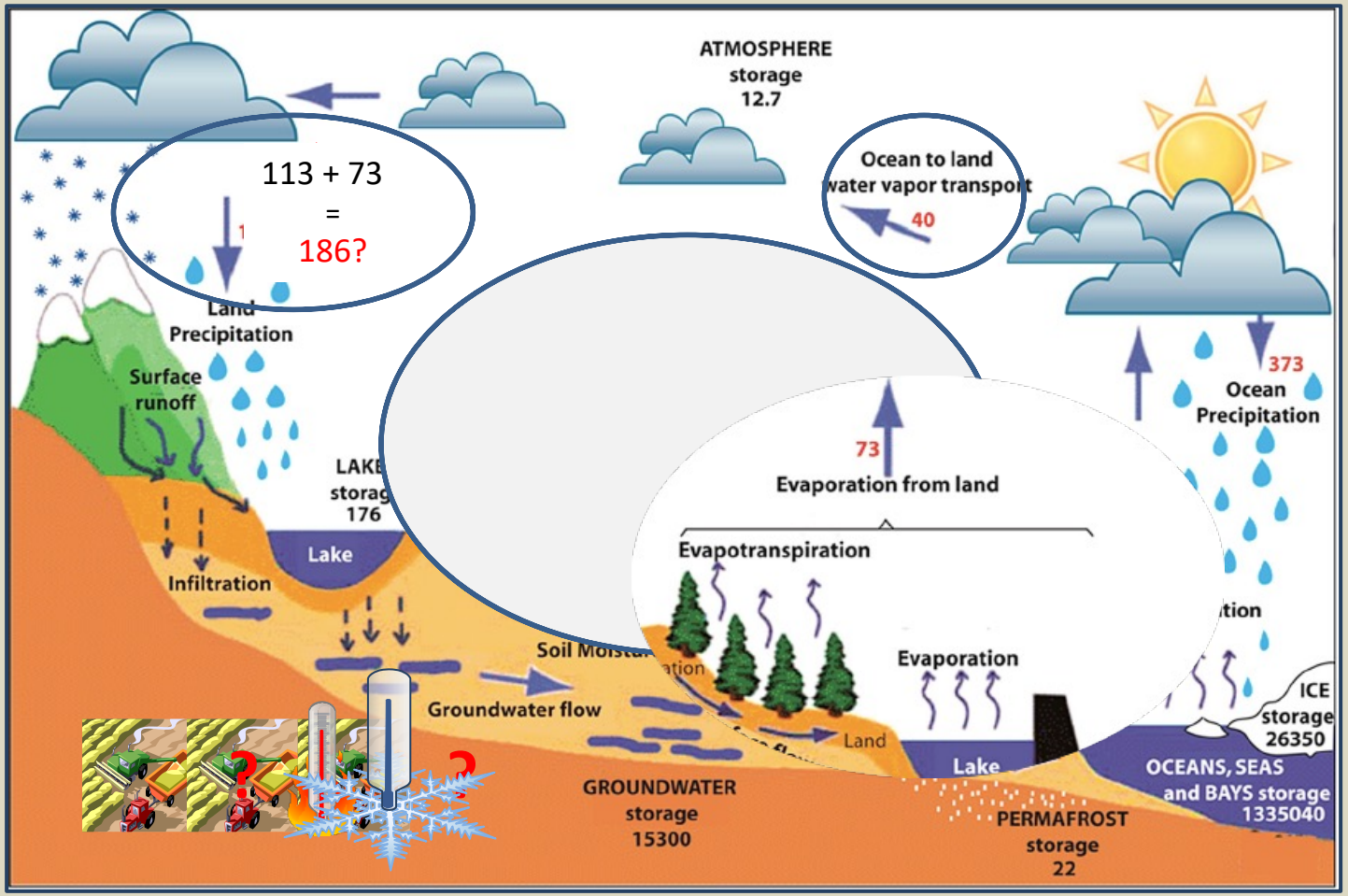
Global Hydrologic Cycle and Variations in Land Cover



(Gimeno et al 2012)

Precipitation Recycling: Large and important benefits from increased wetland and forest cover!

Debate on the Advantages of Forests for Cooling/Warming

Principal causal pathways by which wetlands and TFVC (tree, forest and vegetation cover) influence temperature and the climate

- Carbon sequestration (& respiration)
- Surface albedo effects
- Latent heat production (ET)
- Cloud production

Principal focus of UNFCCC

Largely ignored by UNFCCC

⇒ Different studies focus on different causal pathways, little consistency across studies

⇒ Almost no studies integrate cloud production with all the other causal pathways

- However, many of these studies are frequently sold as “net effects” models?

Direct causal effects of CO2 Emissions/Removals

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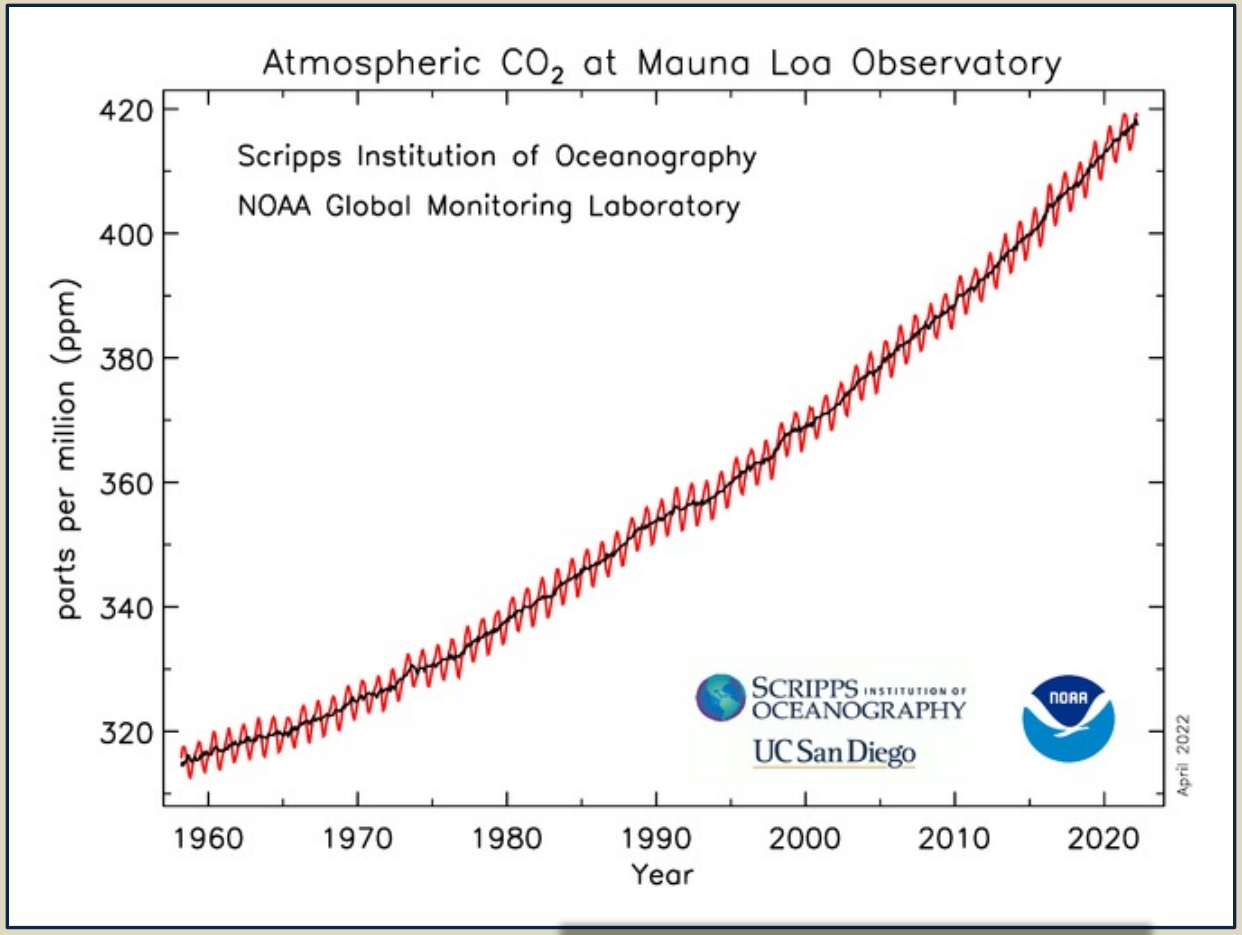
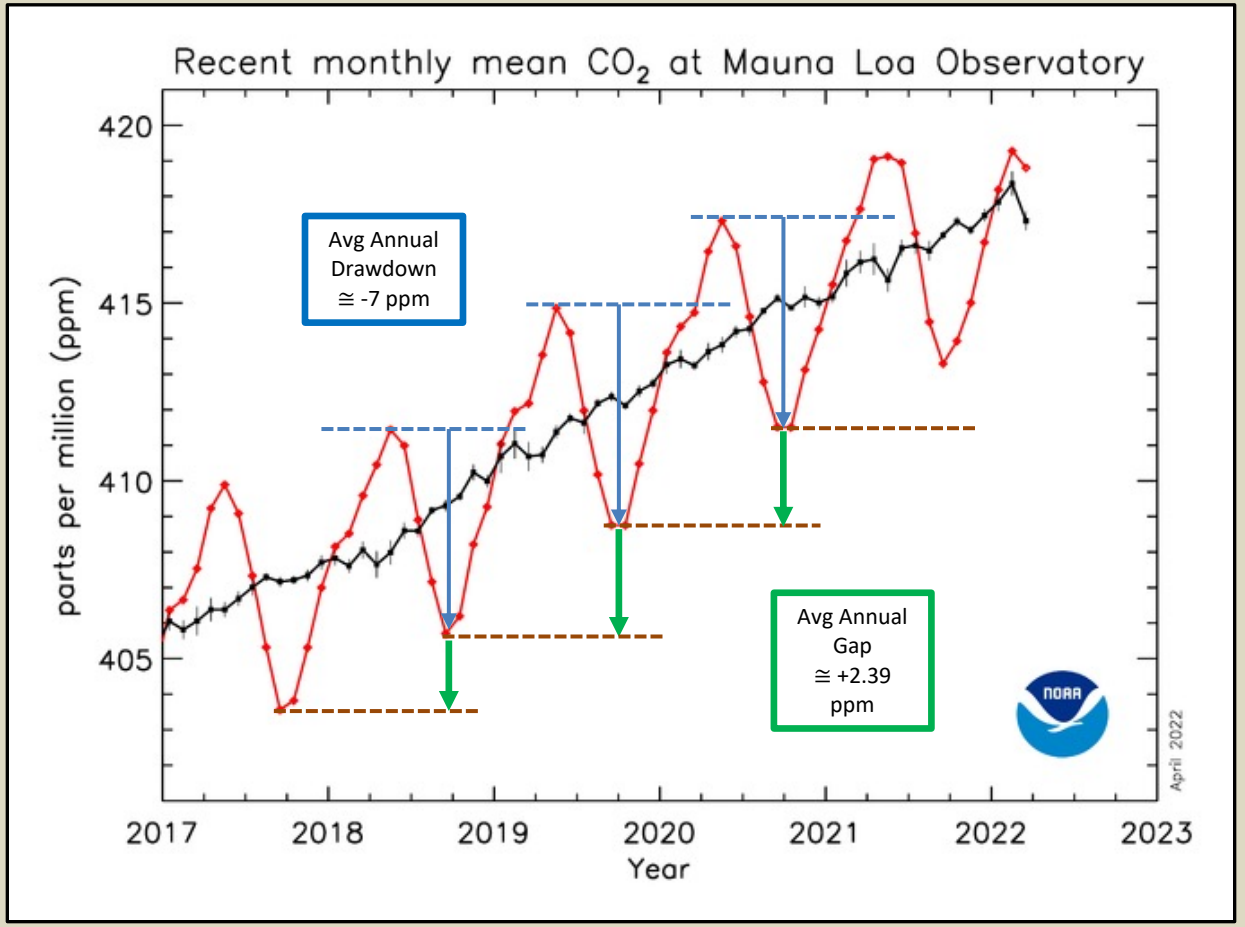
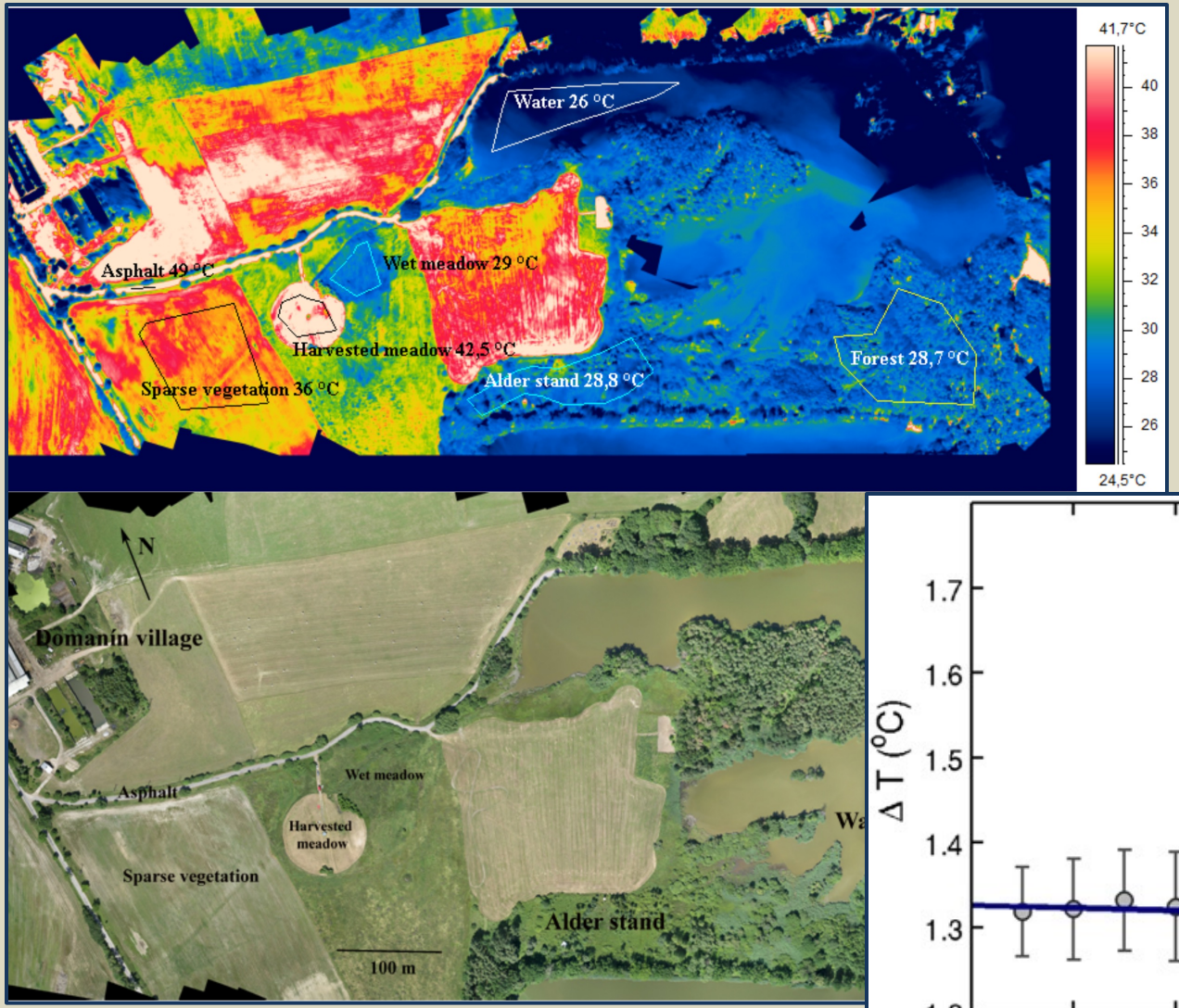




The annual drawdown/re-emission gap (imbalance) is growing:
1960: +0.82 ppm
2020: +2.39 ppm
(IPCC AR6 WGI Ch5).

We Know ET Cools the Land Surface, But What does Albedo Tell Us?

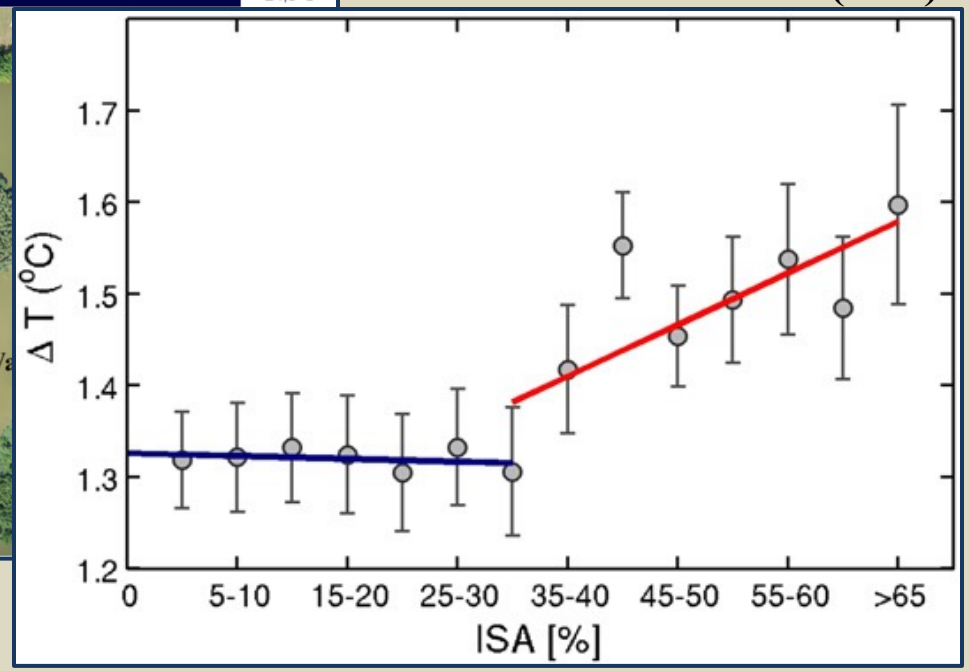
EVAPOTRANSPIRATION (ET)



(Pokorny, Hesslerova et al., 2013)

- Forest-water interactions ***dissipate solar energy***
- ***Transpiration and Evaporation*** require energy
- ***Reduced Surface Warming*** is the result.

Urban Areas above/below 35% Impervious Surface Area (ISA)

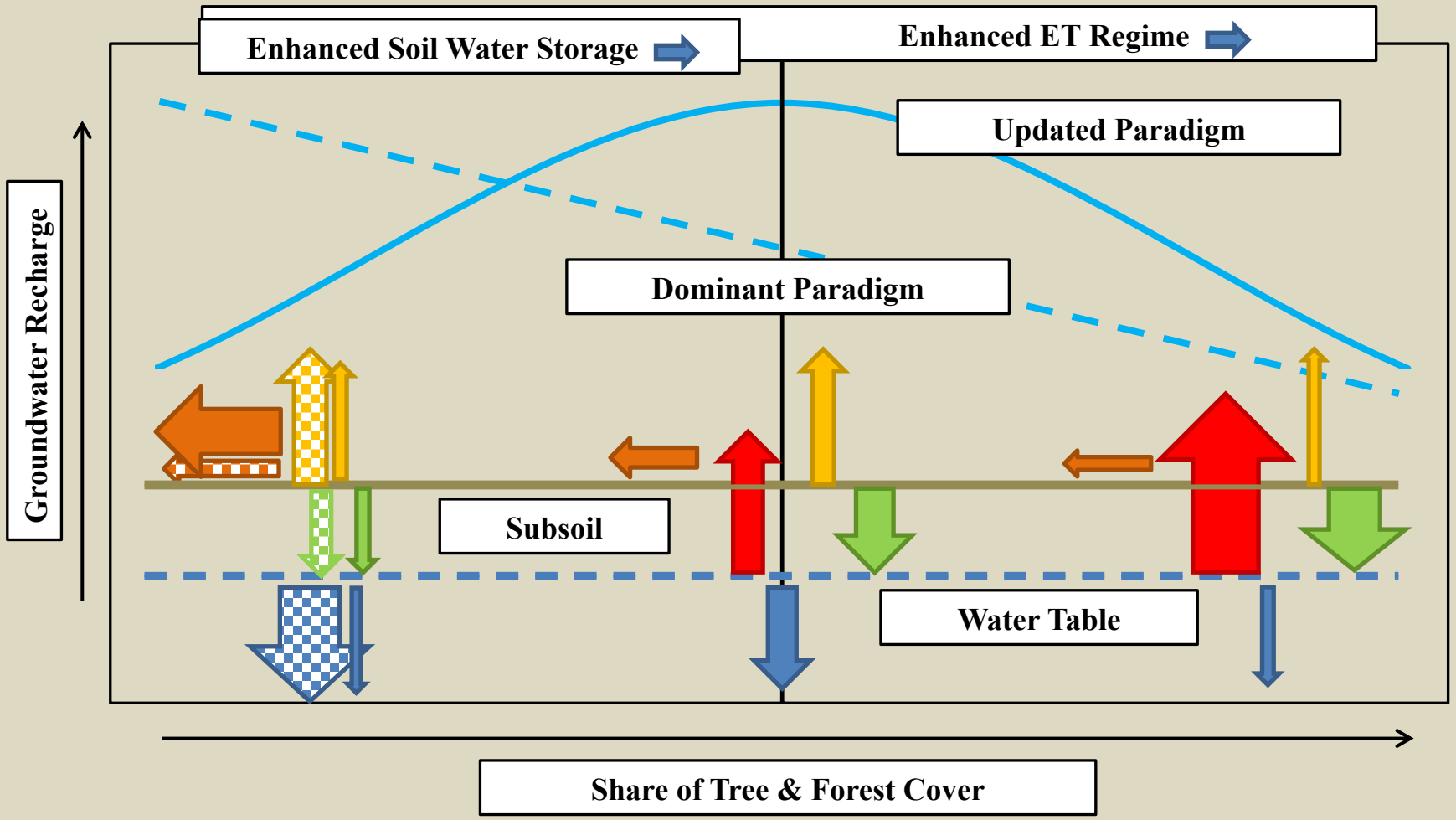


(Bounoua et al., 2015)

Transpiration Overland flow Soil evaporation Infiltration Groundwater recharge

Storage, Soil Water Infiltration, the ET Regime and Vegetation Dependence

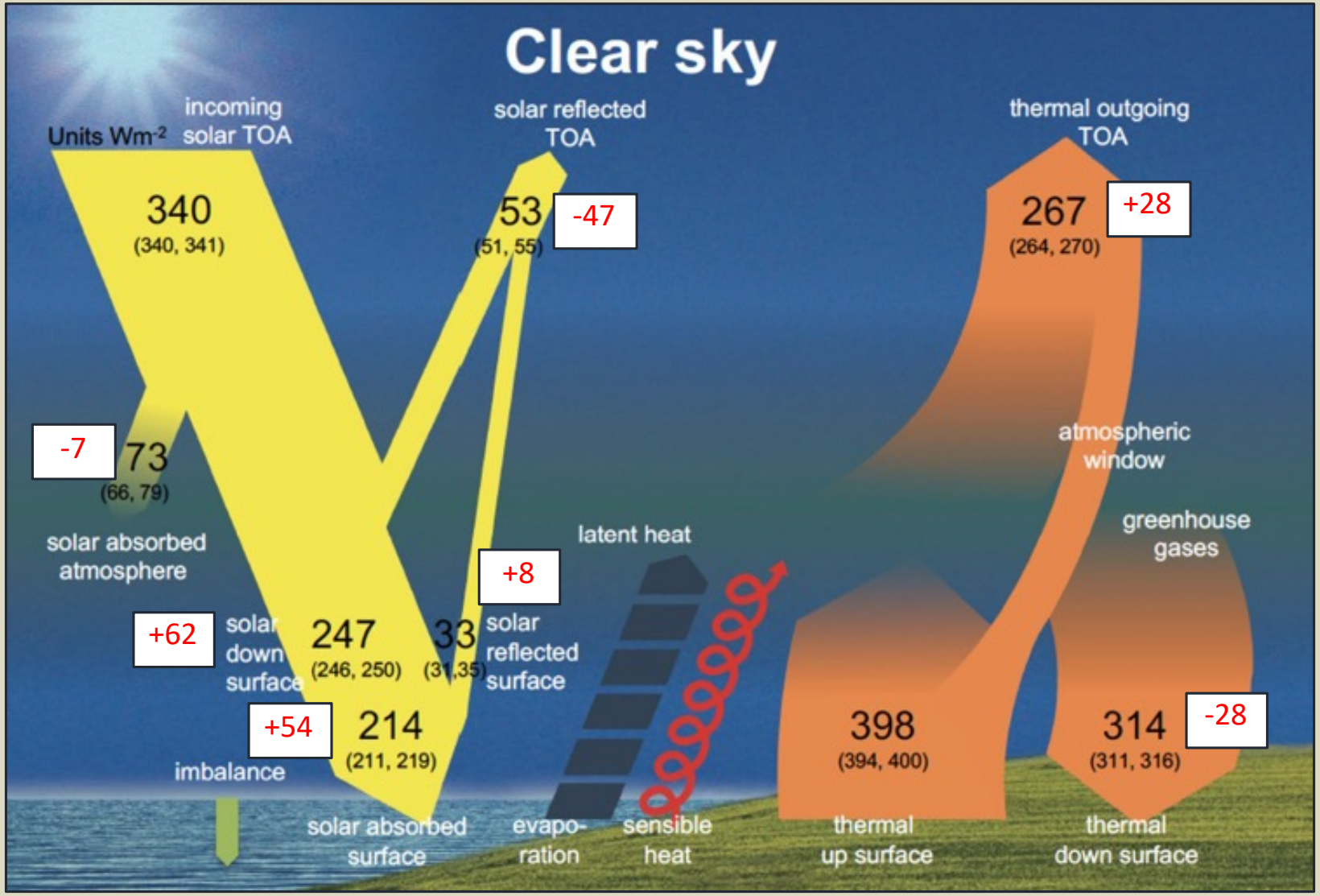
EVAPOTRANSPIRATION (ET)



- Minimum tree cover requirement (restoration)
- Optimal tree cover density? (may be much higher)
- Think about the implications here of models like the Palmer Drought Severity Index (PDSI) for land cover?
- Which is better for improving soil moisture storage and water availability across space?

Global Energy Budget under Clear Skies

CLOUD FORMATION



- **This may be about as close as we can get to an estimation of the deforested state (i.e., without clouds).**
- The net result of the increase in the downward solar radiation flux and the increase in the upward thermal heat flux is equivalent to about **+20 Wm² (+5.8 Wm² over the land surface)**
- Suggests deforestation brings significant warming (not cooling)
- The loss of cloud cover matters!

Numbers in red compare the clear sky to the energy budget with clouds.

Wild et al., (2019)

How much of an impact could increased cloud cover have?

CLOUD FORMATION

Estimated Effect of Increased Forest Cover on the Net Radiative Balance (EEI) and TFVC Drawdown	Estimated Historical Forest Cover Loss (FCL)		Formulas	Logic
	-40%	-50%	(FAO estimate)	cropland + urban settlement conversions
Land Latent Heat Flux (LHF, Wm^2)	38.0	38.0	(Wild, 2015)	Terrestrial Latent Heat Flux
Current Annual TFVC CO_2 Drawdown ($GtCO_2$ -eq yr-1)	-12.5	-12.5	IPCC AR6 WGIII Ch7	Annual TFVC Drawdown
Lost Latent Heat Flux (compared to 100% Forest Cover, Wm^2)	-25.3	-38.0	= (LHF/FC) * (1-FC)	Lost terrestrial latent heat flux (assuming all land can be converted)
Potential LHF (PLHF) with cropland conversion to forest (Wm^2)	10.1	15.2	= (x * .80) * (1 - 0.5)	Potential additional terrestrial latent heat flux assuming only agricultural land (80% of total loss) can be converted - Cropland LHF = 50% * forest LHF)
% Increase in Latent Heat Flux (assume 100% cropland conversion to forest, minus cropland ET Flux)	21%	29%	= PLHF/LHF	Potential % increase in LHF
Change in top-of-cloud OLW (assuming initial 28 Wm^2 OLW flux)	1.7	2.3	= (28 * (PLHF/LHF)) * .29	Estimated change in outgoing LW flux (adj. for 29% land cover) - increases in cloud cover reduce the OLW flux
Change in top-of-cloud OSW (assuming 64 Wm^2 outward reflectivity)	-3.9	-5.3	= -(64* (PLHF/LHF)) *.29	Estimated change in outgoing SW flux (adj. for 29% land cover) - increases in cloud cover increase the OSW flux
Estimated Change in EEI from change in cloud cover (Wm^2)	-2.2	-3.0	= SUM (ΔOLW + ΔOSW)	Potential Change in EEI from Increased Cloud Cover
Estimated Change in Total Annual TFVC Drawdown ($GtCO_2$-eq yr^{-1})	-8.3	-12.5	= (DD/FC) * (1-FC)	Potential Change in TFVC Drawdown from Increased TFVC

IPCC AR6 WGI Ch7: the EEI is estimated at 0.5 □ .185 Wm^2 (for the period 1971-2006), and 0.79 □ .27 Wm^2 for the period 2006-2018

These back-of-the-envelope calculations presumably overestimate factors such as reduced temperatures (with more TFVC), E over water bodies, magnitude, etc.

Some Conclusions:

Wetland, tree, forest, and vegetation cover play an important role in providing the potential for increased ET production and thus hydrologic intensity across land surfaces.

Increased wetland, tree, forest and vegetation cover contributes dramatically to many significant and beneficial outcomes:

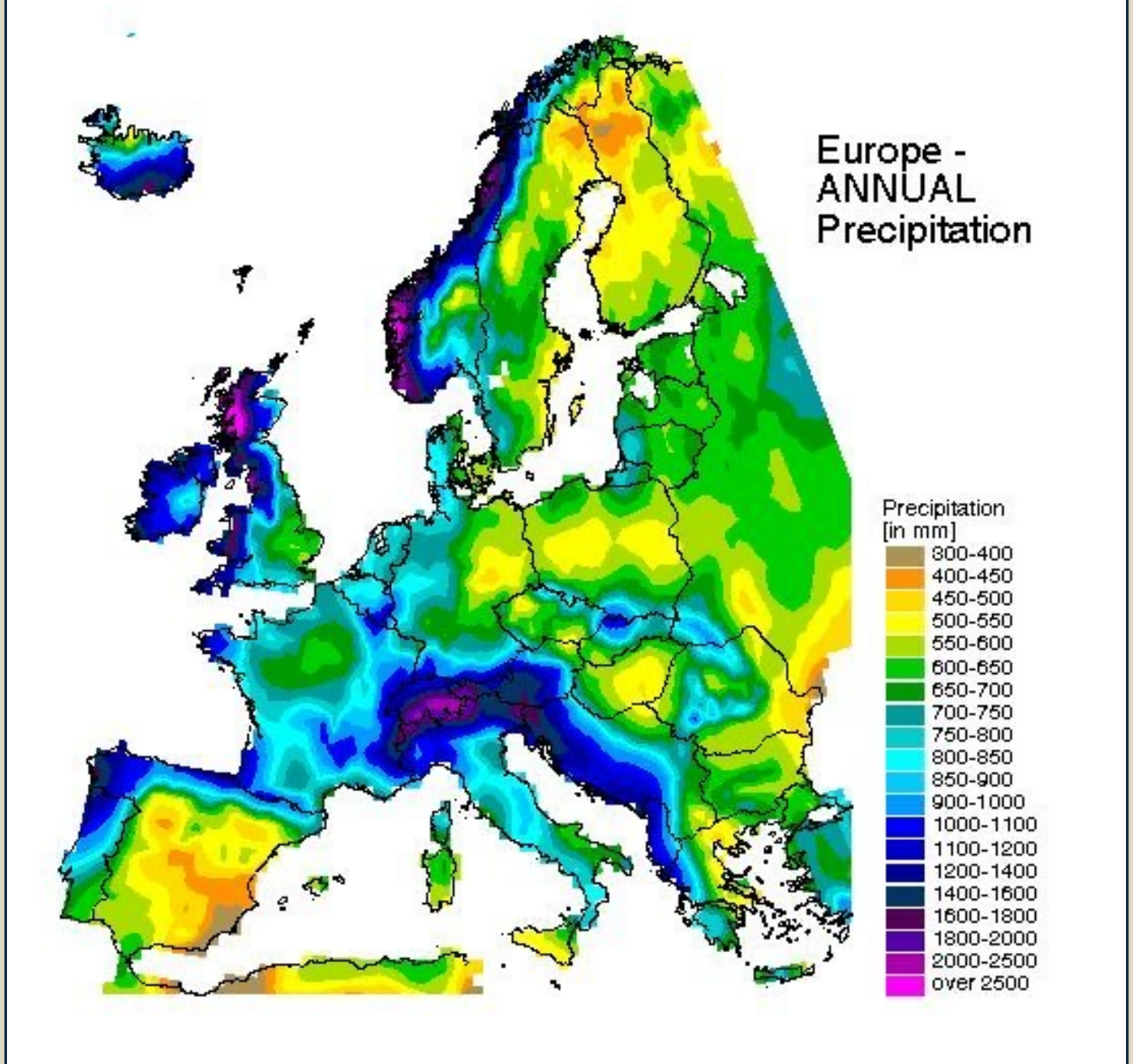
- The cross-continental transport and recycling of water and atmospheric moisture
- The cooling of terrestrial surfaces (lowering of surface temperatures) requires TFVC!
- More wetlands and forests can also bring extensive global cooling:
    - Reduction of atmospheric CO2 (carbon sequestration).
    - Increase in cloud cover and top-of-atmosphere reflectivity.

➢ The benefits of increased wetland, tree, forest and vegetation cover, irrespective of where they occur, should not be ignored.

➢ Each tree is a carbon sink, each tree is a cooling tower.

Thanks for Listening!

Comments Welcome
(EllisonDL@Gmail.com)


Europe -
ANNUAL
Precipitation
Precipitation
[in mm]
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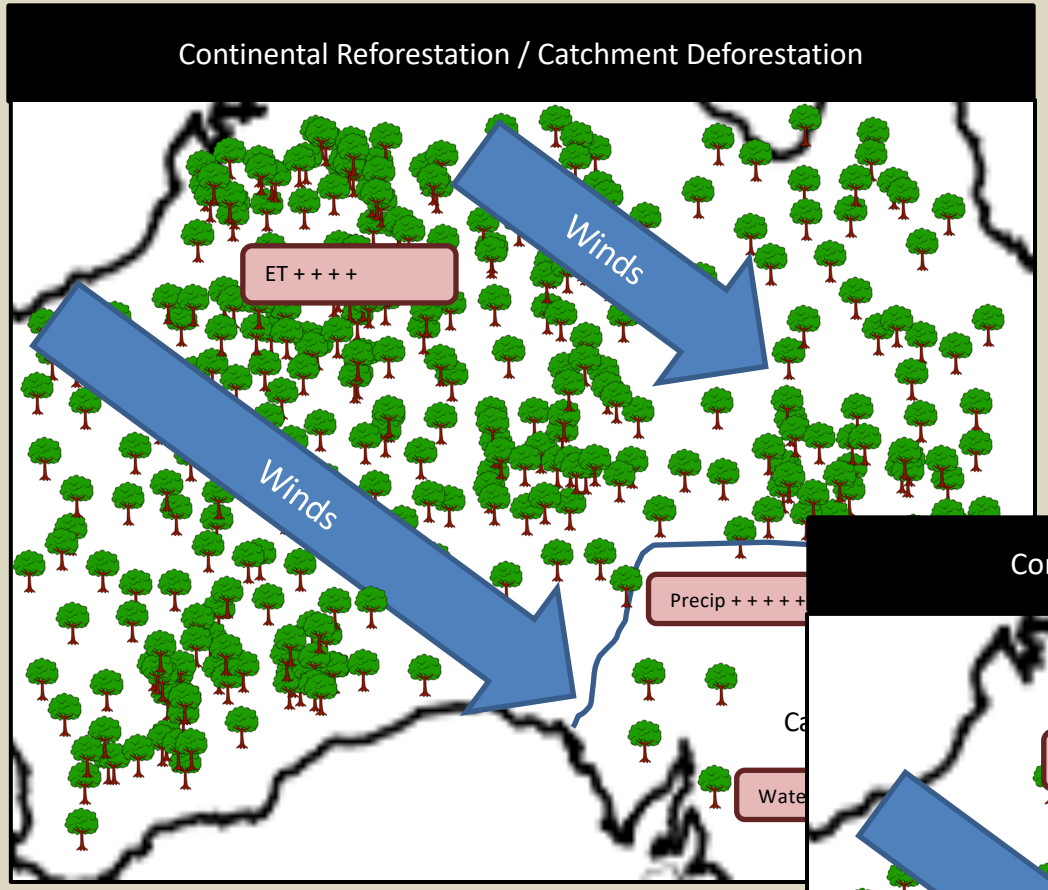
Continental Reforestation / Catchment Deforestation
ET + + + +
Winds
Winds
Precip + + + + +
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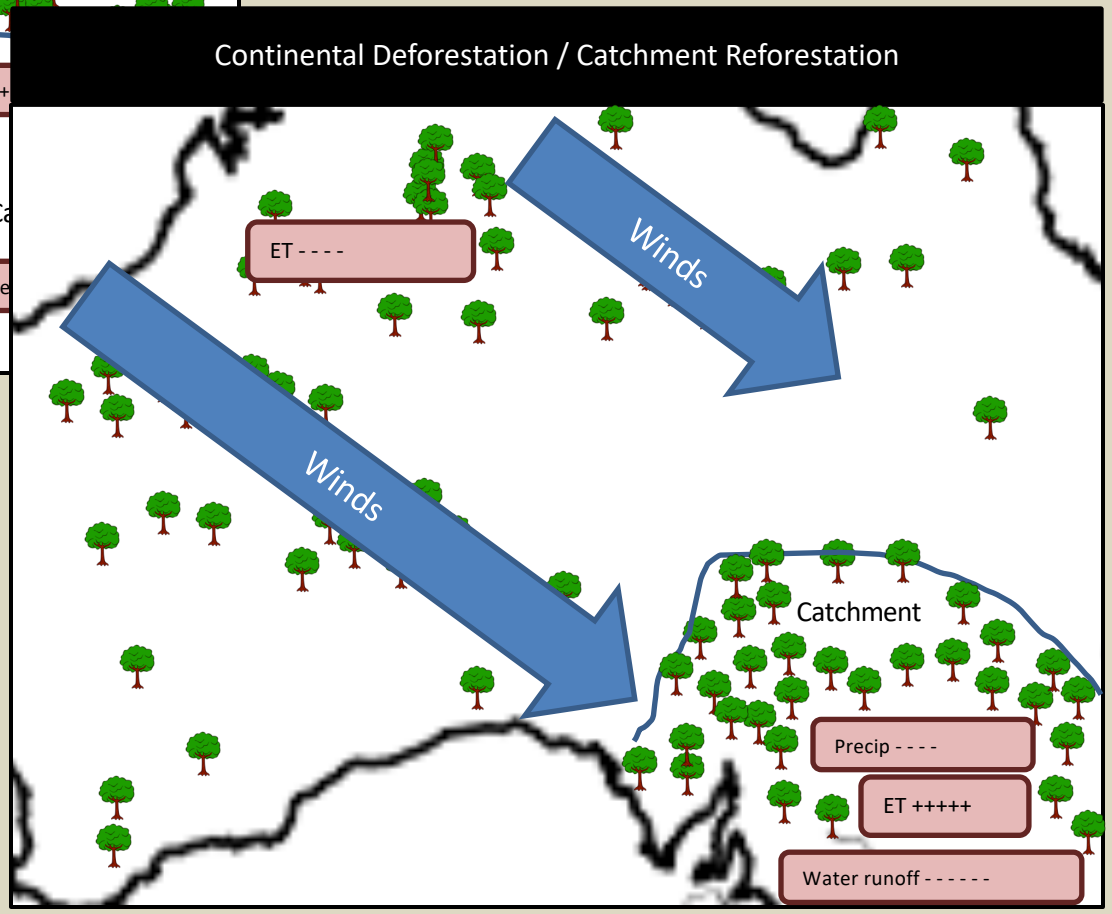
Continental Deforestation / Catchment Reforestation
ET - - - -
Winds
Winds
Catchment
Precip - - - -
ET +++++
Water runoff - - - - - -