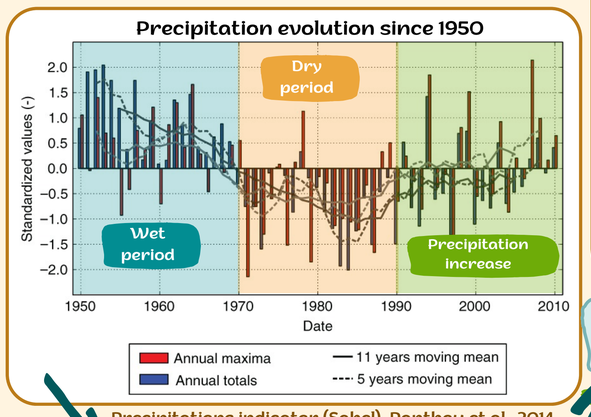
Eco-hydrology modelling in arid areas : Study of root density impact on water fluxes in the Sahelian region

Context



Precipitations indicator (Sahel). Panthou et al., 2014

1 Precipitation increased with extreme events frequence rise :
- More intense drougths
- More intense precipitations
- Degraded land due to the drougths

Aerian pictures of land degradation (Sahel).

Massaza et al., 2021

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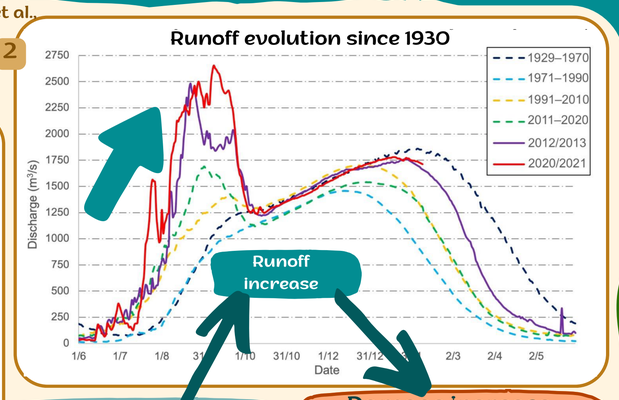
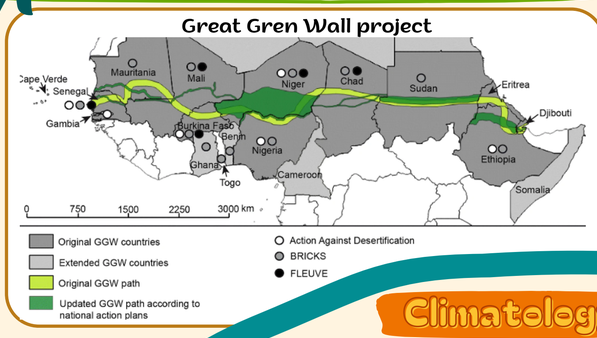


Decrease of the soil infiltration capacity

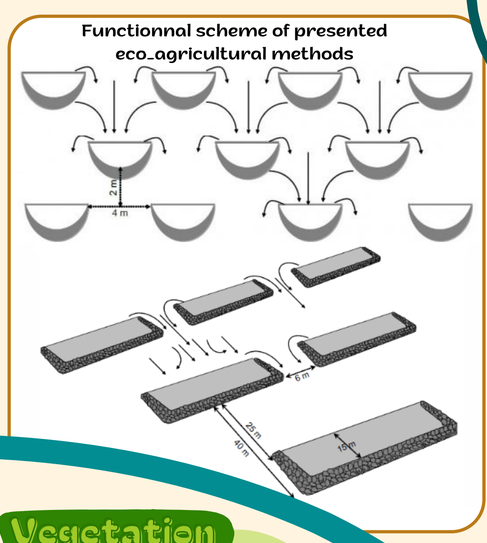
- Damage increase
- Difficulty for vegetation to recover

How to fight against desertification?

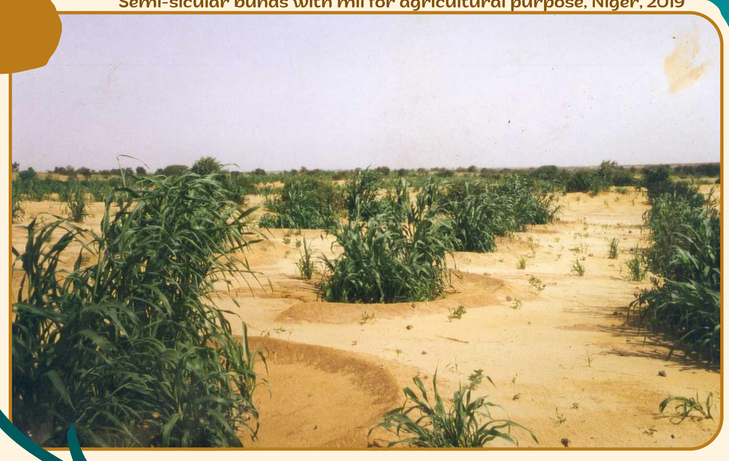


Study Area

Coordinated soil restoration strategies (semi-circular bunds or benchs) :
- embankments to slow down runoff and favor water infiltration
- planting species adapted to the climate and requiring little water

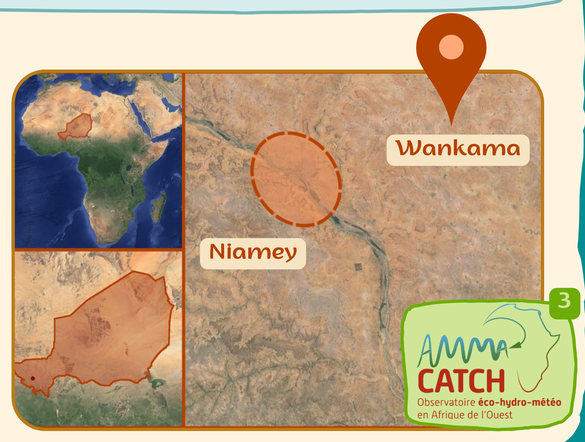


Semi-sicular bunds with mil for agricultural purpose, Niger, 2019



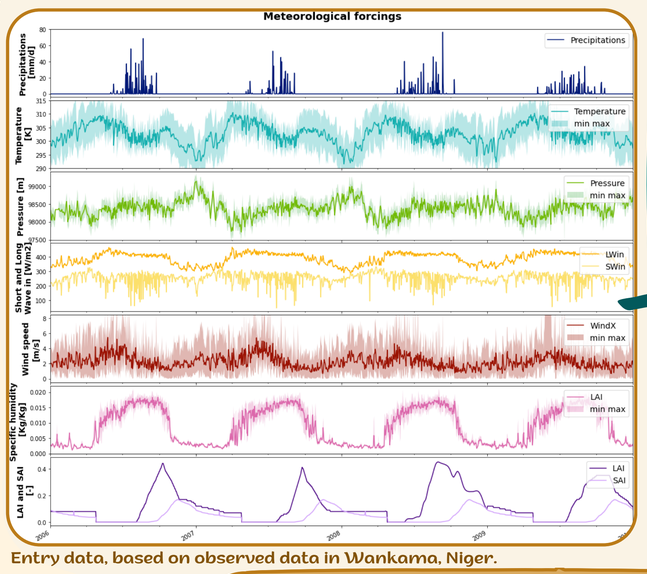
Need of an evaluation of these techniques :
comparison between simulation results and fields data

Case study near Niamey (Western Niger) in the Sahelian region. There, soil restoration strategy projects are implemented by NGOs



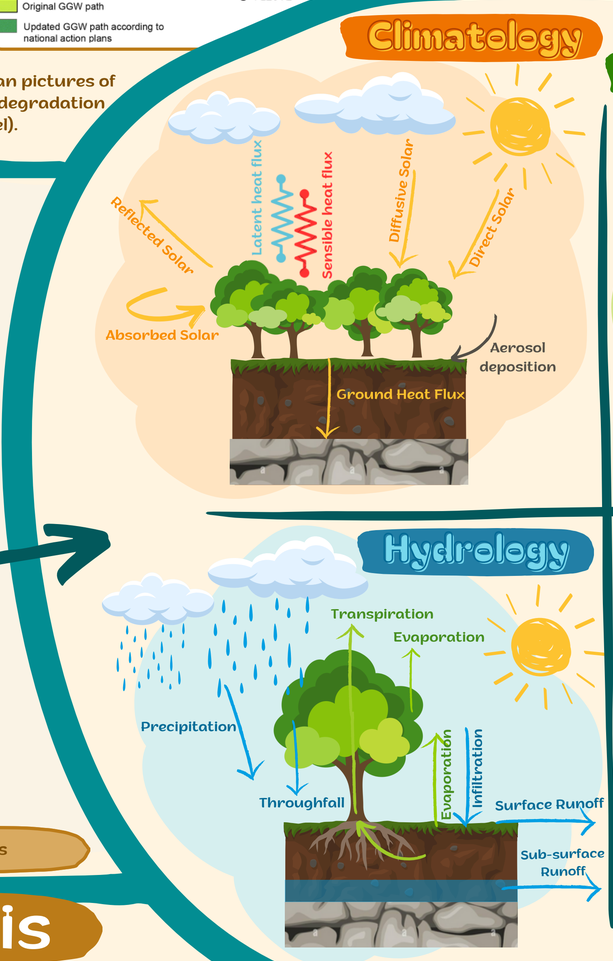
Location of Data collecting station, Wankama, west Niger

Entry data



Entry data, based on observed data in Wankama, Niger.

+ Soil parameters and vegetation parameters



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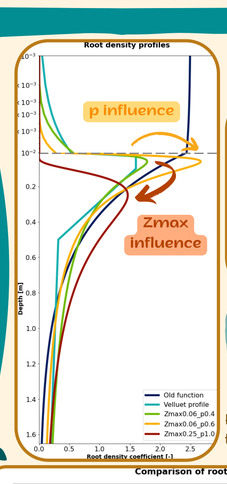
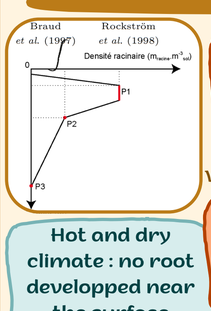
Contribution



Proposed modification of the root density function



Velluet, 2014

New function criterias :

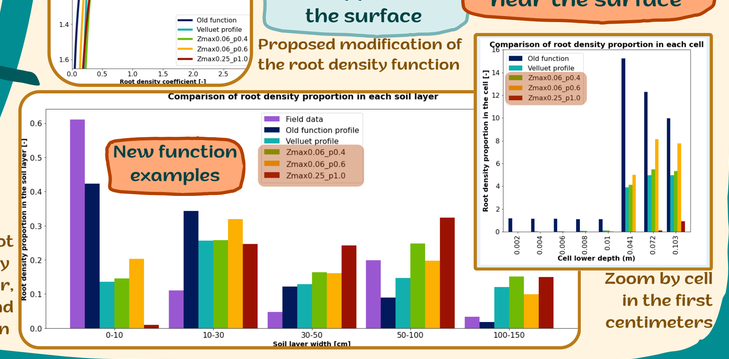
$\lim_{z \to 0} f(z) = 0$

$f_{Rootzone} = 1$

2 parameters 5

Hot and dry climate : no root developped near the surface

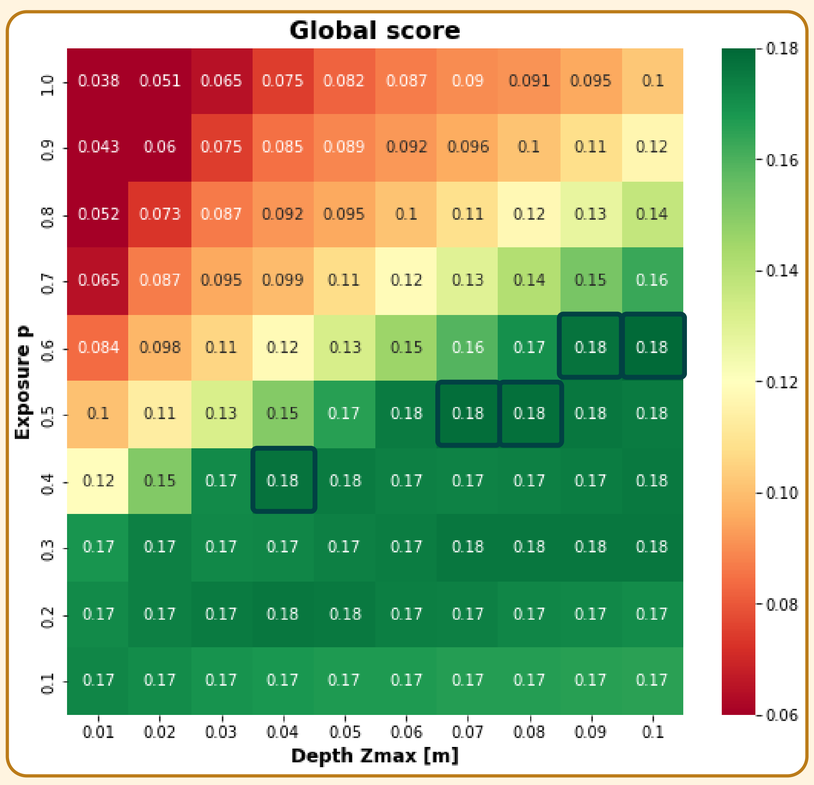
We propose a new parametrized function tending to 0 near the surface



Root fraction by soil layer, for old and new fuction

Zoom by cell in the first centimeters

Sensitivity analysis



Global score for different parametrization of the new root density function.

Comparison observations data vs 1D test case simulations outputs. The global score, is the product of 5 weighted (power coef) quantities :
- KGE^4 score on evapotranspiration
- KGE scores on soil moisture content at different depths : 10, 50, 100 and 150cm from the surface

Simulations with the highest global score (framed in the tab) show similar root density profile and thus, similar hydrological behaviour in the results. The one framed in red is presented beside.

Preliminary results

Effect on Root punction, hence on transpiration

- Zmax → **Deep** layer root punction
- p → **Specific** layer root punction

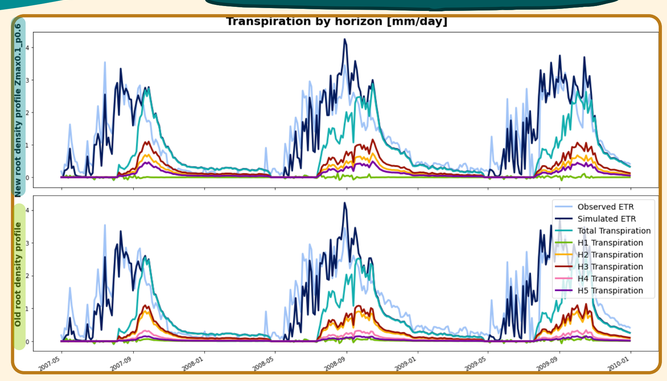
Effect on Evapotranspiration

- Zmax → Global evapotranspiration
- p → Global evapotranspiration

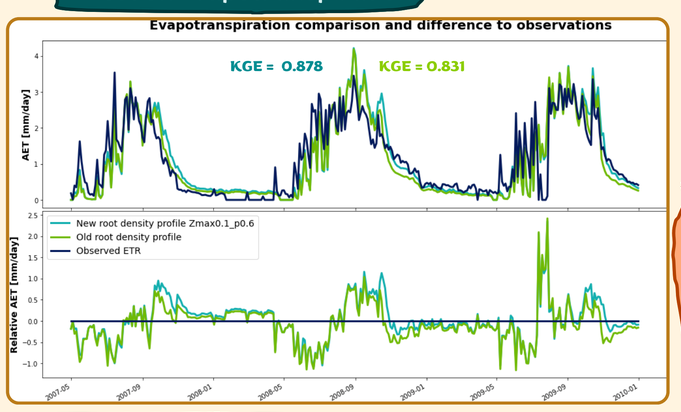
Effect on Soil Moisture

- Zmax → Soil moisture until 10cm / Soil moisture below 10cm
- p → Soil moisture until 10cm / Soil moisture below 10cm

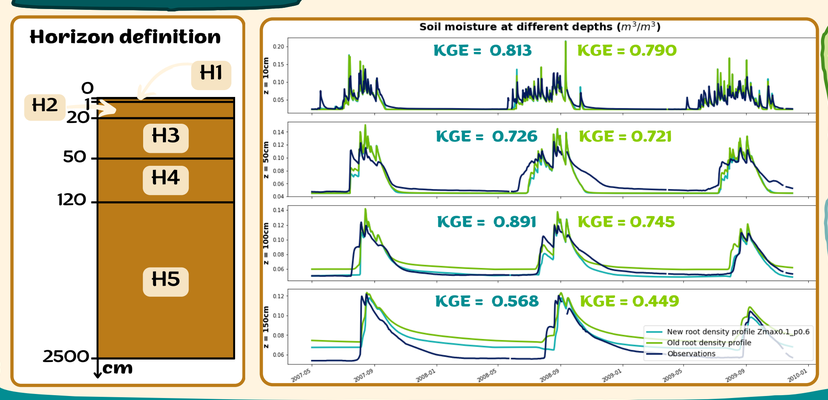
Effect on Root punction, hence on transpiration



Effect on Evapotranspiration



Effect on Soil Moisture



Results comparison

Comparison between the original exp. function with the proposed function (Zmax=10cm and p=0.6, red frame on Fig. to the left).

The new root density profile :
- uptake more water from the deepest horizons (looking at the red (H3) and purple (H5),
- allow more global transpiration especially at the end of the rainy season.
- better scores for AET and Soil moisture dynamics in all horizons.

Conclusions on the new root density profile

- better fit the data with no roots at z=0
- easy to implement in CLM
- physical interpretation of parameters
- can be adapted according to water punction
- show better results in terms of AET and soil moisture content.

Perspectives

Parameters have to be adjusted together with soil parameters to be included in CLM5.0 with the vegetation model.

References

1 Panthou et al, 2014
2 Massaza et al, 2017
3 Galle et al., 2018
4 Maxwell et al., 2005
5 Velluet et al., 2014

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