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AWESOME

WATER-ECOSYSTEM-FOOD

Climate change assessment

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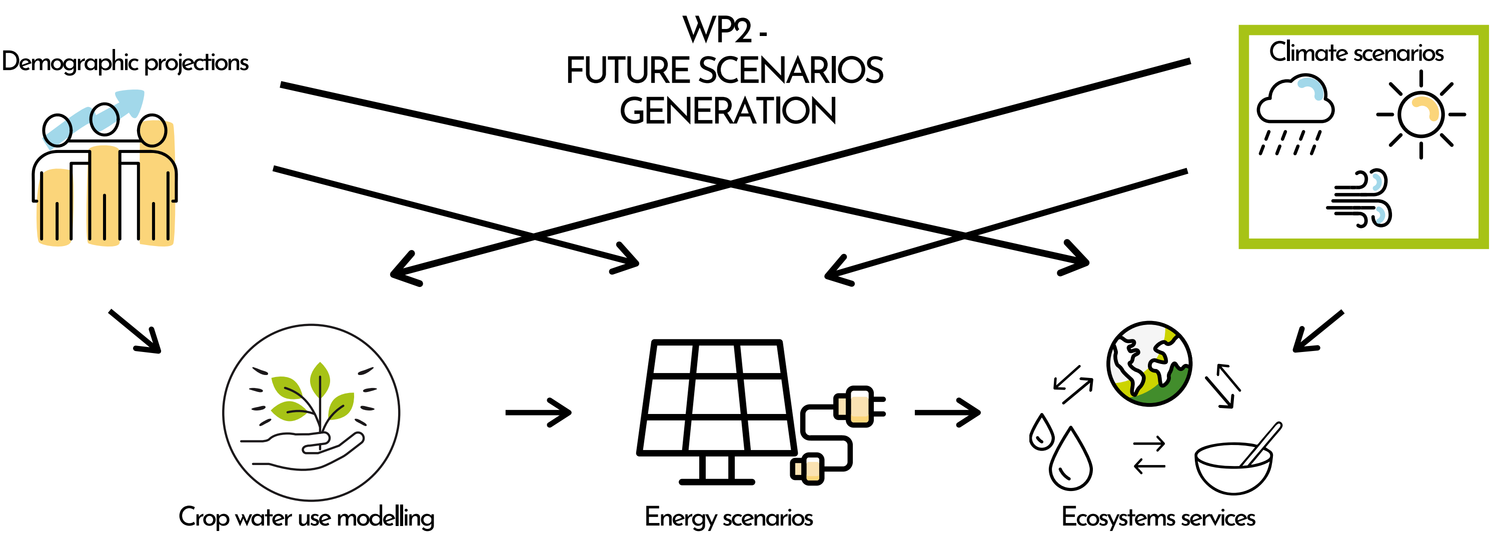
In this factsheet we present the analysis of the **downscaled climate projections** over the **Nile River Basin and Egypt**, which rely on the **IPCC fifth assessment report** exploring different radiative forcings. The climate analysis conducted shows that temperatures will relevantly rise in all scenarios analysed. **Precipitation** reports a more complex behaviour, having a higher spatial and temporal variability, also considering the wide extension of the Nile River Basin and its distinct climatic, topographical, and hydrological characteristics.



Climate change assessment

Countries of **Central and Eastern Africa** are expected to become highly vulnerable to **climate extreme events**, as their frequency and severity is predicted to increase in the future [1]. In **Egypt**, previous studies report that, for high emission scenarios, the air temperature in Cairo is predicted to increase by 4 °C and around 3.1 °C- 4.7 °C in the rest of Egypt by 2050. Consequently, a rise in air temperature could speed up the evapotranspiration process and increase uncertainty in rainfall projections. In this context, the **methodology** applied for the generation of local climate projections involves a global downscaling approach [Figure 1] through different steps: a first set of **General Circulation Models** (GCM) is generated by simulating three different Representative Concentration Pathways (RCP 2.6, RCP 4.5, RCP 8.5), which represent different assumptions of climate-altering gas concentration following various emission policies [Box 1]. Consequently, GCM are dynamically downscaled to **Regional Climate Models** (RCM), which are in turn bias adjusted to obtain **climate projections at the local scale**.

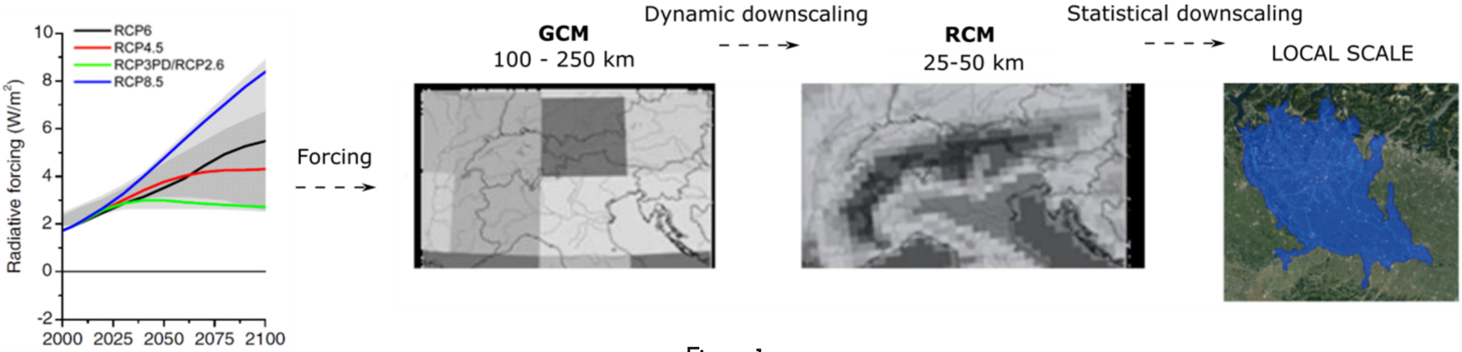


Figure 1

Box 1: Representative Concentration Pathways (RCPs)

RCPs are a set of global datasets produced by the **IPCC** (Intergovernmental Panel on Climate Change, UNEP) representing the trajectories of **radiative forcing** (RF) in the years between 1850 and 2100 following different scenarios of demographic development, greenhouse gas emissions, land and energy use [Table 1]. By definition, the RF (here expressed in W/m^2) is the difference between the amount of solar energy absorbed by the Earth and that radiated into space, which can also be considered as measure of the imbalance in the Earth's energy budget caused by any perturbation of the climate system (e.g. global warming induced by human activites).

RCP name	Radiative forcing	CO2eq concentration [ppm]	Increase in temperature [°C]	Pathway
RCP 2.6	Peak at 3 W/m2 before 2100 and decline	Peak at 490 before 2100 and then decline	1.5	Peak and decline
RCP 4.5	Stabilization around 6 W/m2 after 2100	Stabilization around 650 after 2100	2.4	Stabilization without overshoot
RCP 6.0	Stabilization around 6 W/m2 after 2100	Stabilization around 850 after 2100	3	Stabilization without overshoot
RCP 8.5	> 8,5 W/m2	Stabilization around 1,370 after 2100	4.9	Rising

Table 1

These pathways [Table 1] can also be linked to several social, technological, and economic aspects:

- **RCP 2.6** responds to a situation where the global **ecologic transition** is implemented through the increase of renewable energy and biofuels production coupled with the installation of carbon storage systems as well as the stabilization of population and land overexplotation.
- **RCP 4.5** presents a lower reduction of emissions with respect to the previous case. It corresponds to a **business-as-usual** scenario, where the population peaks in 2050 and declines afterwards.
- **RCP 6** foresees a **population increase** after 2050 and a **slow economic and technological growth**.
- **RCP 8.5** forecasts an important **population and economic growth**, which causes an increase in the demand for energy production from fossil fuels and in land use change

[1] Gebrechorkos, S. H., Hülsmann, S. & Bernhofer, C. Long-term trends in rainfall and temperature using high-resolution climate datasets in East Africa. Sci. Rep. 9, 1-9 (2019).

Climate data

To produce the **downscaled climate projections** on the targeted spatial domain, i.e. the **10 Nile River sub-basins** [Figure 2], global and regional data sources have been considered. In particular, **global** datasets on **precipitation** and **temperature** produced by the Climate Hazard Centre (CHC) of UC Santa Barbara (CHIRPS and CHIRTS) provide daily and monthly information at 0.05° resolution (from 1981 to date for precipitation data, from 1983 to 2016 for temperature data) whereas at **regional** level, the COordinated Regional Downscaling EXpriment (CORDEX) offers **climate projections** under different RCP. Within the AWESOME project, the climate analysis considers the RCA4 Regional Climate Model under three different RCPs, namely RCP 2.6 (low impact), 4.5 (business-as-usual) and 8.5 (high impact) scenarios.

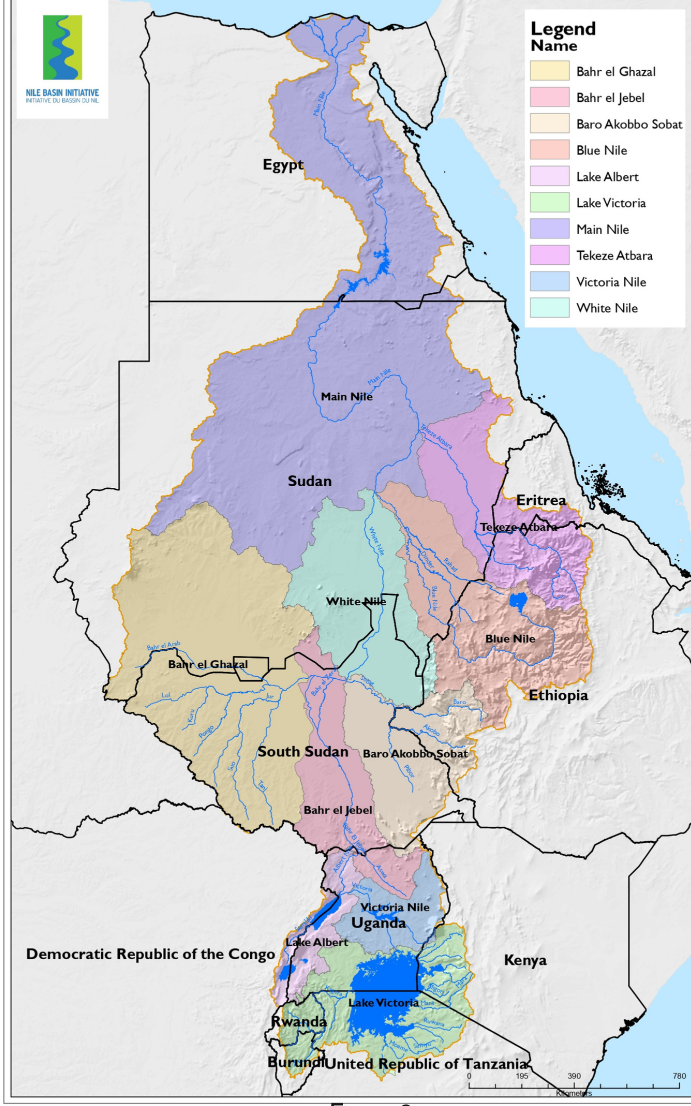


Figure 2

Map provided by the Nile Basin Intitative (NBI). https://nilebasin.org/media-center/maps.

Climate Analysis - Methodology

To investigate how precipitations and temperatures can evolve under the effects of climate change, the **MASH** method is applied [2], considering all of the different 10 sub-basins. This tool allows to simultaneously investigate the seasonality in the data and filter out the effects of interannual variability. Another fundamental tool to assess climate impacts and to analyse extreme events at the local level is the calculation of **Climate Change Indicators (CCI)**, which consist in (usually linear) transformations of the historical daily precipitation and temperature series at the annual scale, considering the extremes of the probability distribution of these variables (e.g. annual cumulative intense rainfall or the maximum annual drought duration). To create a common framework for the CCI, the Expert Team on Climate Change Detection and Indices (ETCCDI) has drawn up a list of 27 indicators [3], from which we select 6 indexes:

1. PRCPTOT, i.e. the annual total precipitation in wet days with RR (Rainfall) >= 1 mm
2. R95P, i.e. the annual total precipitation when RR > 95th percentile
3. CDD, i.e. the maximum number of consecutive dry days with RR < 1 mm
4. TX90, i.e. the percentage of days when TX (Maximum Temperature) > 90th percentile within a year
5. TR, i.e. the annual count of days when TN (Minimum Temperature) > 20 °C
6. WSDI, i.e. the annual number of days with at least 6 consecutive days when TX > 90th percentile

[2] Anghileri, D., Pianosi, F. & Soncini-Sessa, R. Trend detection in seasonal data: From hydrology to water resources. J. Hydrol. 511, 171–179 (2014).
[3] Zhang, X. et al. Indices for monitoring changes in extremes based on daily temperature and precipitation data. Wiley Interdisciplinary Reviews: Climate Change vol. 2 851–870 (2011)

Climate Analysis - Results

The temporal period considered for the climate analysis includes a **control period** (CP) from 1981 to 2005 and a **projection period** from 2006 to 2100 for all of the 10 Nile River sub-basins and Egypt .

Trend analysis (MASH)

In this analysis, the MASH plots are obtained by collecting the trajectories of the moving average over 10 consecutive dayscomputed on a shifting horizon of 10 consecutive years. The outcoming figures are generated following the RCA4 model under three different RCPs: 2.6, 4.5 and 8.5 emission scenarios. An example on the Main Nile sub-basin - RCP 4.5 is given by Figure 3, where observations on temperature (black line) are compared to temperature projections (blue to green to yellow color scale). As shown in the graph, temperature is expected to increase progressively in the future (with the exception for RCP 2.6, which shows an increase until the mid of the century and a decrease afterwards).

Climate Indicators (CCI)

With respect to the analysis on climate change indicators (CCI), Figure 4 displays the projected frequency of extreme rainfall events (i.e. the RC95P index) in the White Nile sub-basin - RCP 4.5. As shown in the graph, total precipitation is expected to change significantly from one year to another (e.g., from 0 in 2084 to 300 mm/d in 2085).

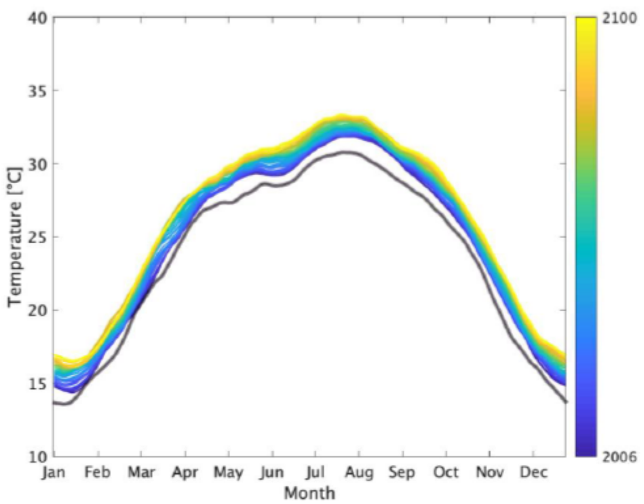


Figure 3

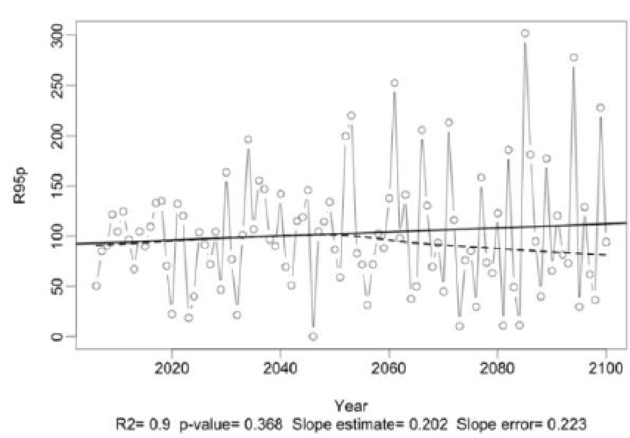


Figure 4

Box 2: A Closer Look at Egypt

An additional analysis based on high-resolution data is provided for **Egypt**, as shown in Figures 5 and 6 below, with some snapshots on the spatial distribution for selected climate projections under the **three RCPs** (i.e. RCP 2.6- left hand side, RCP 4.5 -middle, and RCP 8.5 - right hand side).

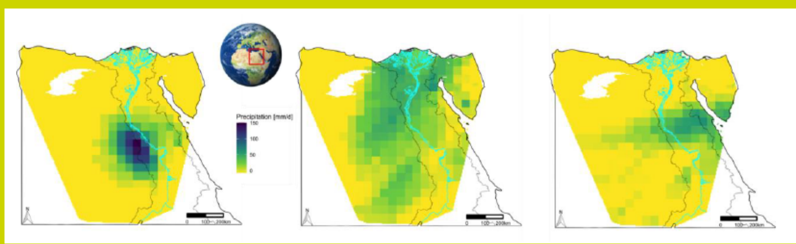


Figure 5

In particular, Figure 5 presents values on the mean precipitation occurring on the three wettest days by 2100, where values shade from yellow (low) to dark blue (high). Similarly, Figure 6 shows values on the maximum temperature reached in the three hottest days by 2100, with values ranging from dark blue (cold) to yellow (hot). In both cases, white colors corresponds to the Qattara depression area.

Looking at the two maps, precipitation shows a significantly higher spatial variability in comparison to temperature, presenting a hard-to-predict behaviour. In general, the amount of rainfall is predicted to be lower and occasional with respect to historical data.

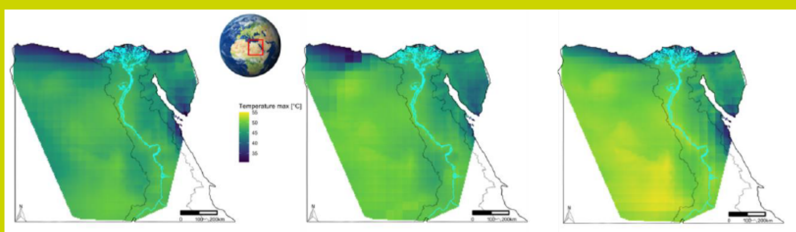


Figure 6