Production of available water content maps from existing soil properties datasets using pedotransfer models – towards application to spatial crop modeling

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1 - Introduction

Soil water availability is recognized as a vital ecosystem service, playing a key role, notably in provision of food, feed, fiber, and fuel (Adhikari & Hartemink, 2016). In Sub-Saharan Africa, where agriculture predominantly relies on rainfed systems, understanding the availability of water in soil is critical for monitoring crop development, predicting crop yields and hence ensuring food security.

One important factor for estimating the water available to crops is the **available water content (AWC), which refers to the difference between the soil water retention (SWR) at field capacity and the SWR at the permanent wilting point**. This metric represents the total amount of water that can be stored in the soil and made available to plants under normal conditions. AWC is an important parameter in bucket-type models, used in ecological and crop modeling (e.g., DSSAT (Jones et al., 2003), AquaCrop (Salman, M. et al., 2021), SARRA-H/O (Baron et al., 2003; Dingkuhn et al., 2003)) applications.

In particular, **spatial crop simulation models rely on AWC maps** to perform their computations. Despite a growing number of digital soil mapping initiatives and resources for soil properties maps, as well as a number of pedotransfer relationships usable to derive AWC from these resources, only few initiatives focused on the production of such AWC maps.

This poster presents the **first steps in the production of a pilot high-resolution AWC map for Burkina Faso**, derived from the high resolution 30m iSDA Africa soil properties maps and the USDA Rosetta pedotransfer model.

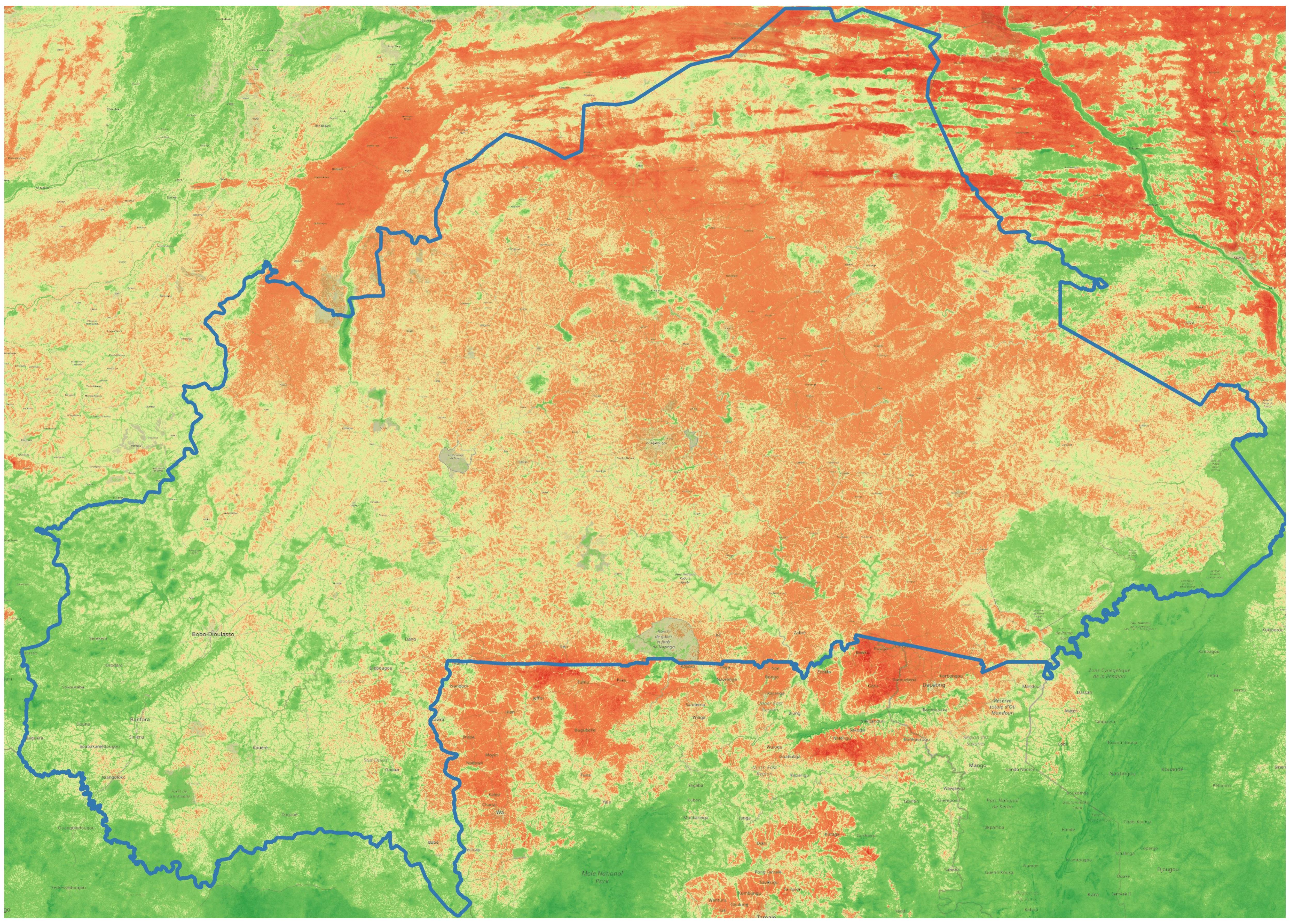
The **research question posed in the student project is how to best develop this new method for determining AWC maps**, through identification of limitations, bottlenecks and challenges towards generalization for other countries, and the use of produced data in crop models.

2 - Material and methods

- Gathering of iSDA Africa 30m soil property maps (silt, clay, sand content, bulk density, depth to bedrock) (Hengl et al., 2021),
- Application of the USDA Rosetta3 pedotransfer model (Zhang & Schaap, 2017) to estimate the Van Genuchten soil water retention curve parameters
- Calculation of volumetric water content at field capacity (FC), permanent wilting point (PWP) and calculation of AWC
- Spatial interpolation of filtered data and missing values
- Integration of AWC over the soil depth to produce a total soil water storage estimation map

Data handling from steps 1 to 4 was performed with Python 3.9.6 using pandas, numpy and xarray. The openly available jupyter notebook used in the software pipeline for this computation is available on our GitHub repository : https://github.com/SARRA-cropmodels/iSDA-calcs. Step 5 was performed using the Raster calculator function of QGIS v3.26.2-BuenosAires.

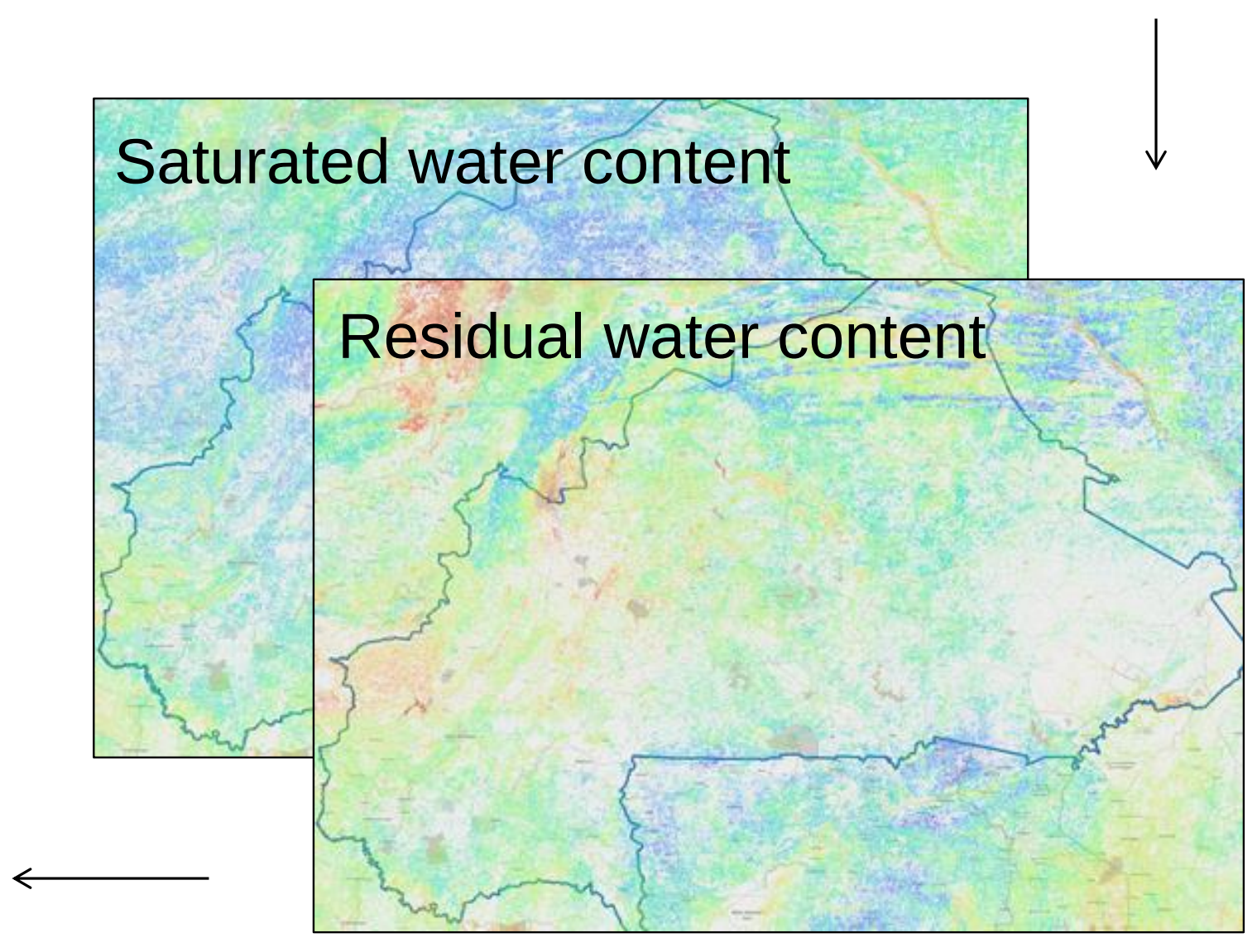
3 - Results



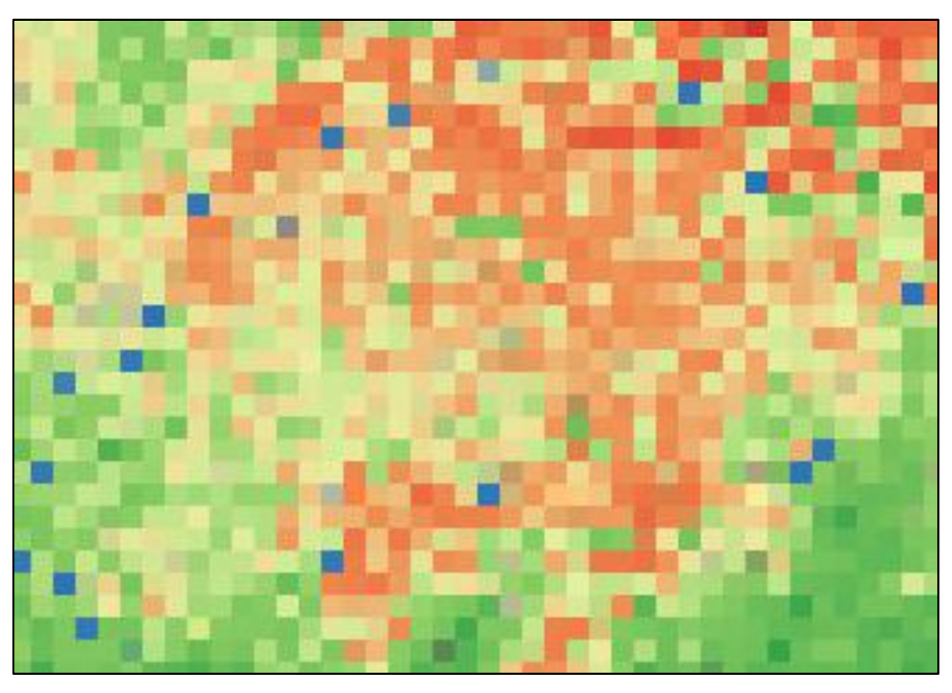
AWC
(mm/cm)
🟥 0,06
🟧 1,10
🟨 1,16
🟩 1,22
🟩 1,31
🟩 1,79

Available water content, expressed as height of water (mm) per depth unit of soil (cm), and interpolated via nearest neighbor method in the 0-20cm horizon, as calculated from iSDA soil properties map. Color scheme scattered over six groups of centiles (balanced classes/weighted color map). Background map provided by OpenStreetMap.

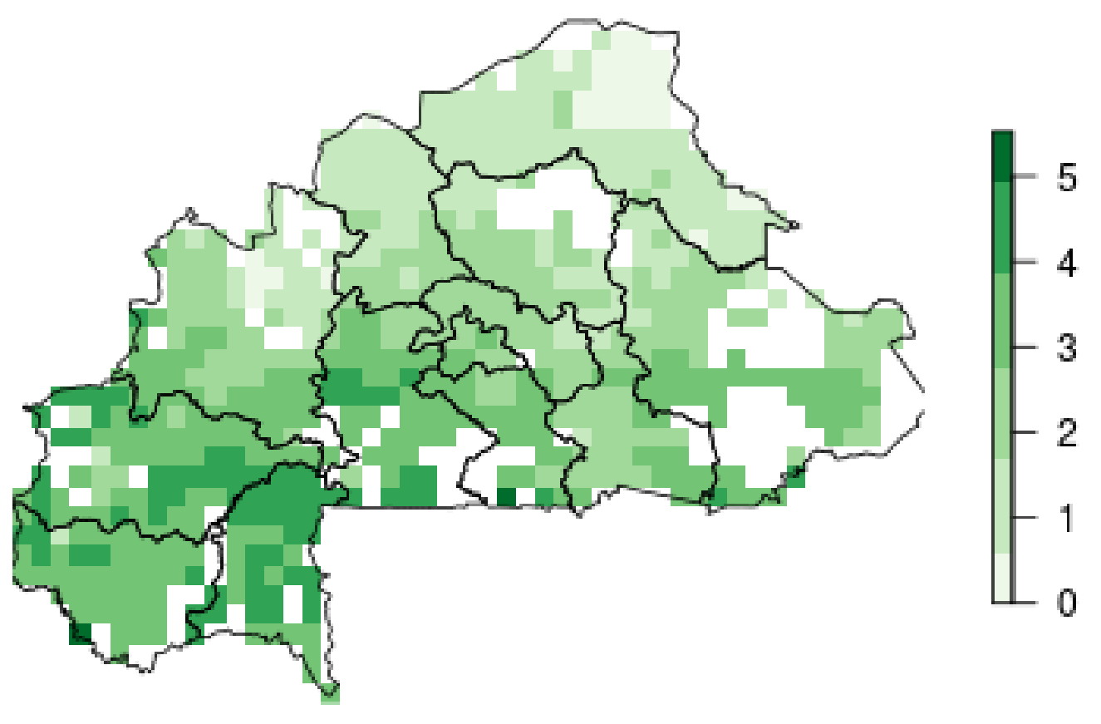
iSDA → Rosetta



We produced high-resolution maps for Burkina Faso of available water content (AWC) and intermediate calculation variables, covering 0-20 cm and 20-50 cm depth intervals. The AWC map exhibits spatial variability, with the lowest AWC values in the north and the highest in the southwest, providing valuable information for crop simulation models and water management. The dataset, including intermediate variables, is publicly available in digital form with a DOI (10.18167/DVN1/QNX5HU) for accessibility and reproducibility.



Upscaling for use in spatial crop models ?



Evaluation of agreement of newly ran crop simulations with reported yields ?

3- Discussion and perspectives for student projects

As tracks for expected outcomes of students' work: 1) a global critical overlook of the methodology can be performed ; 2) further investigations are necessary to compare the AWC mapping results obtained for the Burkina Faso pilot study with other existing similar products, evaluating consistency and variability ; 3) Additionally, the potential of upscaling this high-resolution product to the resolution used in bucket-type crop simulation models should be explored to verify if this approach can help enhance the accuracy of crop simulations.

As for the generalization of this methodology to other contexts or countries, it is first important to acknowledge that challenges exist in terms of the quantity of data at stake, and the computation power needed to perform these high-resolution calculations. Overall, overcoming these challenges will provide valuable experience for students, and insights into regional variations in AWC, facilitating targeted soil and water management strategies. This pilot study in Burkina Faso sets the stage for expanding the methodology to other countries within the iSDA Africa dataset or similar soil properties mapping initiatives, thereby advancing our understanding of soil-water dynamics on a broader scale.

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