Optimal Sowing Dates and Cultivars

Crop models as support of decision-making

The AgWise framework contributes to making farming more climate resilient. AgWise determines spatially the optimal planting dates and cultivars for different cropping systems based on soil and climate variability. Therefore, the information provided by AgWise can improve climate risk management and crop productivity in the global South. This is undertaken by coupling diverse crop models with spatial soil data and historical and seasonal forecast weather data.

Determination of the optimal planting dates and cultivars potentially increases the ability of a crop to maximize the available resources for crop growth and development and ultimately increase crop yield. Specifically, an appropriate planting time avoids early, mid, or end-of-season dry spells. The crop, therefore, reduces climate hazards during sensitive phases of growth and development, such as germination, flowering, and yield formation, potentially leading to lower yield. Similarly, different varieties can have contrasting responses to varying seasonal conditions. Under drought, short-season varieties can have more yield stability but relatively lower yield. In contrast, long-seasoned varieties can have high yields under high rainfall conditions but greater yield variability and low yields under low rainfall conditions. AgWise, therefore, defines variety suitability under different season types.

The AgWise framework is utilized to determine the potential areas where the production of certain crops is optimal. In addition, AgWise is a tool that provides agronomic recommendations that contribute to reaching the crop's potential in different environments. Policymakers and researchers can, therefore, make interventions to close the yield gap.

AgWise crop modeling framework

The AgWise crop modeling framework encompasses a range of crop models: APSIM, WOFOST, ORYZA, and DSSAT. APSIM, a process-based model, simulates biophysical processes in agricultural cropping systems. The model is structured around plant, soil, and management modules. The model simulates different cropping systems, such as monocropping, intercropping, and rotations, which are predominant in the global South. The AgWise workflow utilizes the apsimx R package, which enables seamless spatialization of the APSIM model simulations.

WOFOST is a mechanistic and dynamic crop model that determines yield and related components based on the interaction of underlying plant physiological processes with environmental conditions. The major processes driving the WOFOST model are CO_2 assimilation and respiration, phenological development, transpiration, dry matter partitioning, and soil water balance. The model is also available through the R package, *Rwofost*, which was utilized to spatialize WOFOST.

ORYZA is a specialized rice crop model developed by the International Rice Research Institute (IRRI) and Wageningen University and Research Center (WUR). The model simulates growth and development, including water, carbon, and nitrogen balance. The model is mostly applied in designing crop ideotypes that explore the interactions between genotypes, environment, and management. The model also contributes to the yield gap decomposition and adaptation to climate change. The ORYZA, R package, enables the model to be linked to gridded databases and run at scale.

The Decision Support System for Agrotechnology Transfer (DSSAT) comprises a range of dynamic crop simulation models for at least 40 crops. The model integrates the interactive effects of soil, crop phenotype, weather, and management. The management module includes irrigation, fertilizer application, and tillage. The DSSAT R package facilitates the automation of large-scale simulations, especially related to the creation of weather, soil, and experimental files.

Data assimilation

All the models utilized on the AgWise crop modeling framework follow the same generic workflow in terms of 1-Sourcing geospatial data, 2-Processing into model input format, 3-Model calibration and validation, 4-Simulation process, and 5-Post-processing of crop model outputs (Figure 1). This workflow allows adding and inter-comparison of models into the AgWise crop modeling framework.

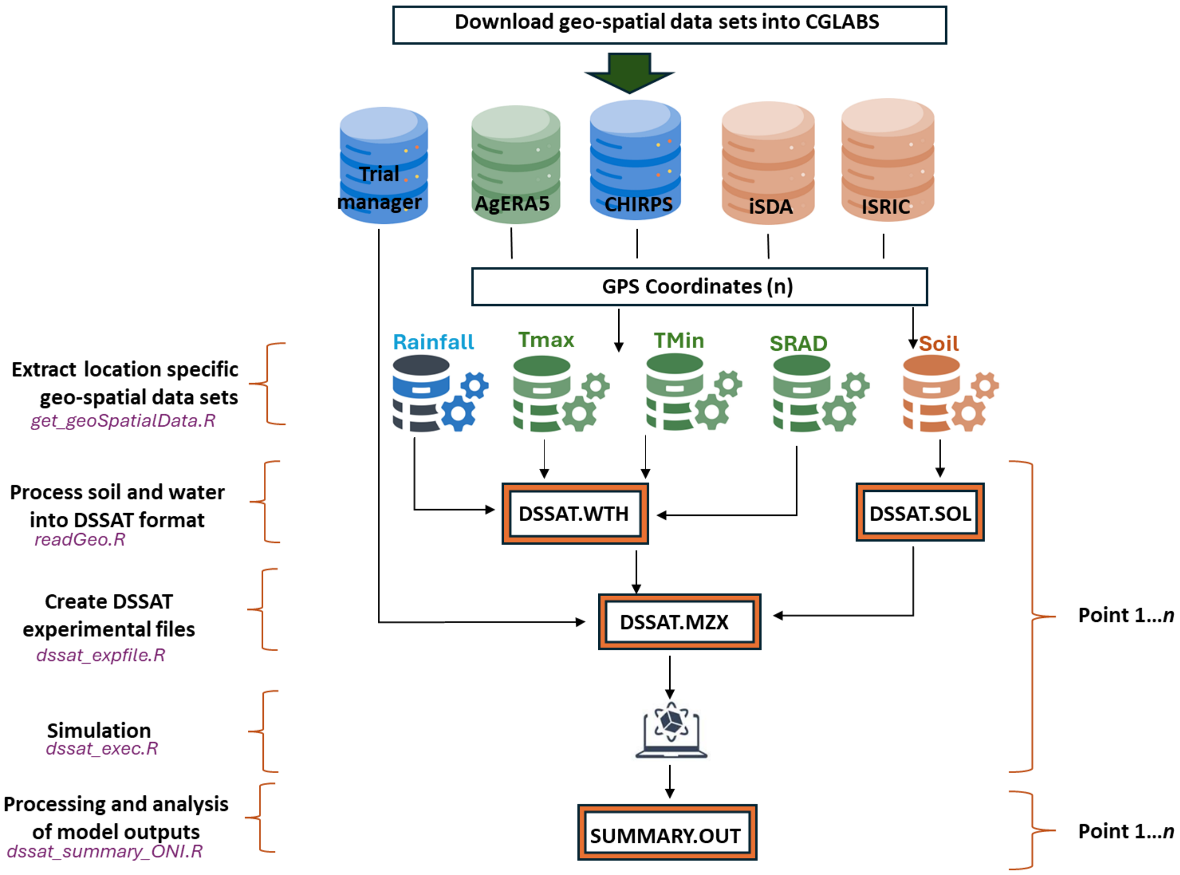

Figure 1. AgWise spatial crop modelling generic workflow applied to the DSSAT model.

The minimum weather data required to run all the crop models in the AgWise framework is similar: daily rainfall, solar radiation, minimum and maximum temperatures. Geospatial datasets of the weather data are downloaded from the various sources through APIs, into CGLABS, the server where all the data are stored, and the simulations are run. Rainfall is sourced from CHIRPS while the solar radiation and minimum and maximum temperature, are sourced from AgERA5. Soil is obtained from ISRIC. Using translators, spatial coordinates, and other guiding input parameter information, data for specific area of interest is extracted and formatted into crop model input format.

Prior to the use of crop models, there is need for robust calibration and validation. As a result, some countries have either adequate, average or no data required for model calibration and validation. The AgWise crop modelling team has therefore devised approaches for reliable model calibration and validation across different data availability conditions.

Output aggregation and processing

The simulation outputs are processed to determine the optimum sowing date and variety across dry, wet, and average rainfall seasons. A farmer can, therefore, decide when and what variety to plant, given a forecast of whether the season will be dry, normal, or wet. To define the different seasons (dry, normal, or wet), the weather of historical seasons is classified based on the El Niño-Southern Oscillation (*ENSO)*. With the Oceanic Niño Index (ONI), we classify the ENSO phases as El Niño, La Niña, or *Neutral*. The phases are determined based on a threshold of +/- 0.5°C of the Sea Surface Temperatures (SSTs), where ONI above 0.5 ℃, is characteristic of *El Niño*. ONI less than -0.5 ℃ is characteristic of *La Niña*. Finally, ONI between 0.5 and -0.5 ℃ is characteristic of the Neutral phase of *ENSO*. El Niño usually leads to high rainfalls in the tropics, while La Niña tends to be correlated to a reduction of rainfalls. However, the pattern is the opposite in the Southern hemisphere, e.g., Malawi. Therefore, optimal sowing dates and varieties are estimated across the 3 ENSO phases (Figure 2). The sowing date and variety with the highest yield for each location are defined as the optimum (Figure 2). As part of the outputs of AgWise, we evaluate the yield stability of the different varieties and environments (Figures 3 & 4).

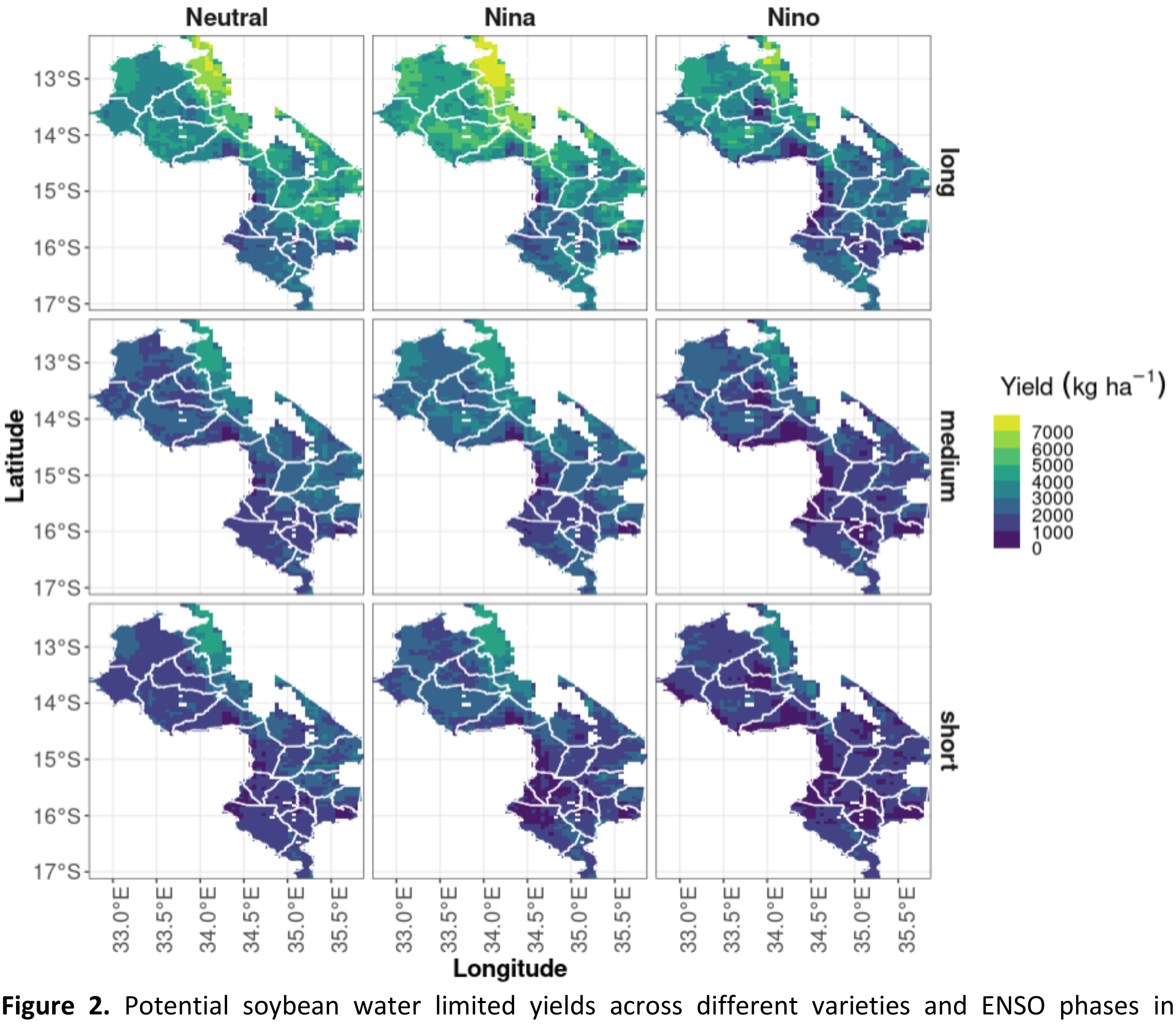

Figure 2. Potential soybean water limited yields across different varieties and ENSO phases in Malawi.

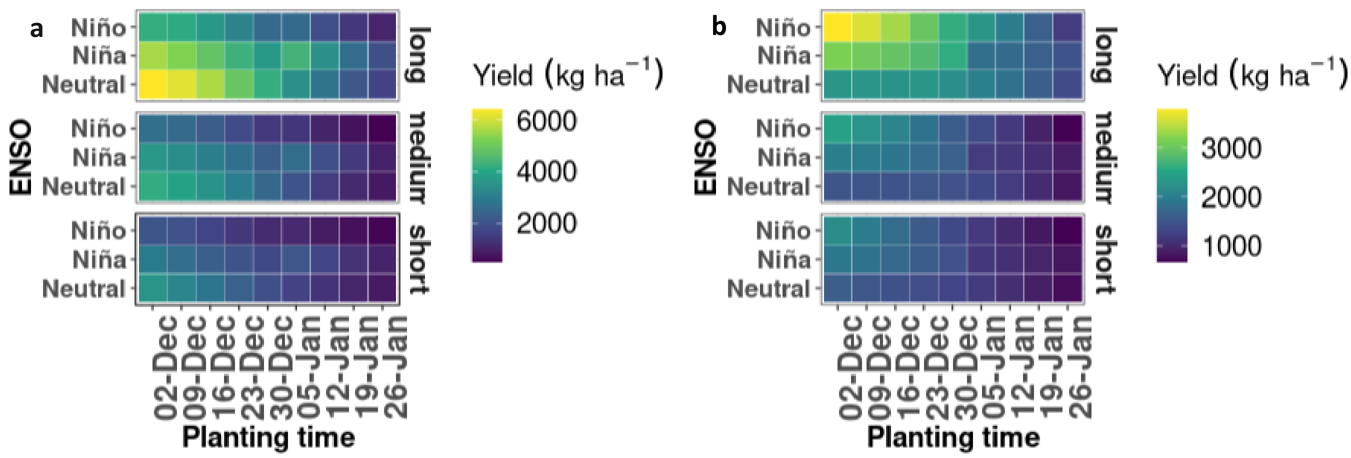

Figure 3. Soybean (a) yield and (b) stability (standard deviation) across different varieties, planting dates, and ENSO phases in Malawi.

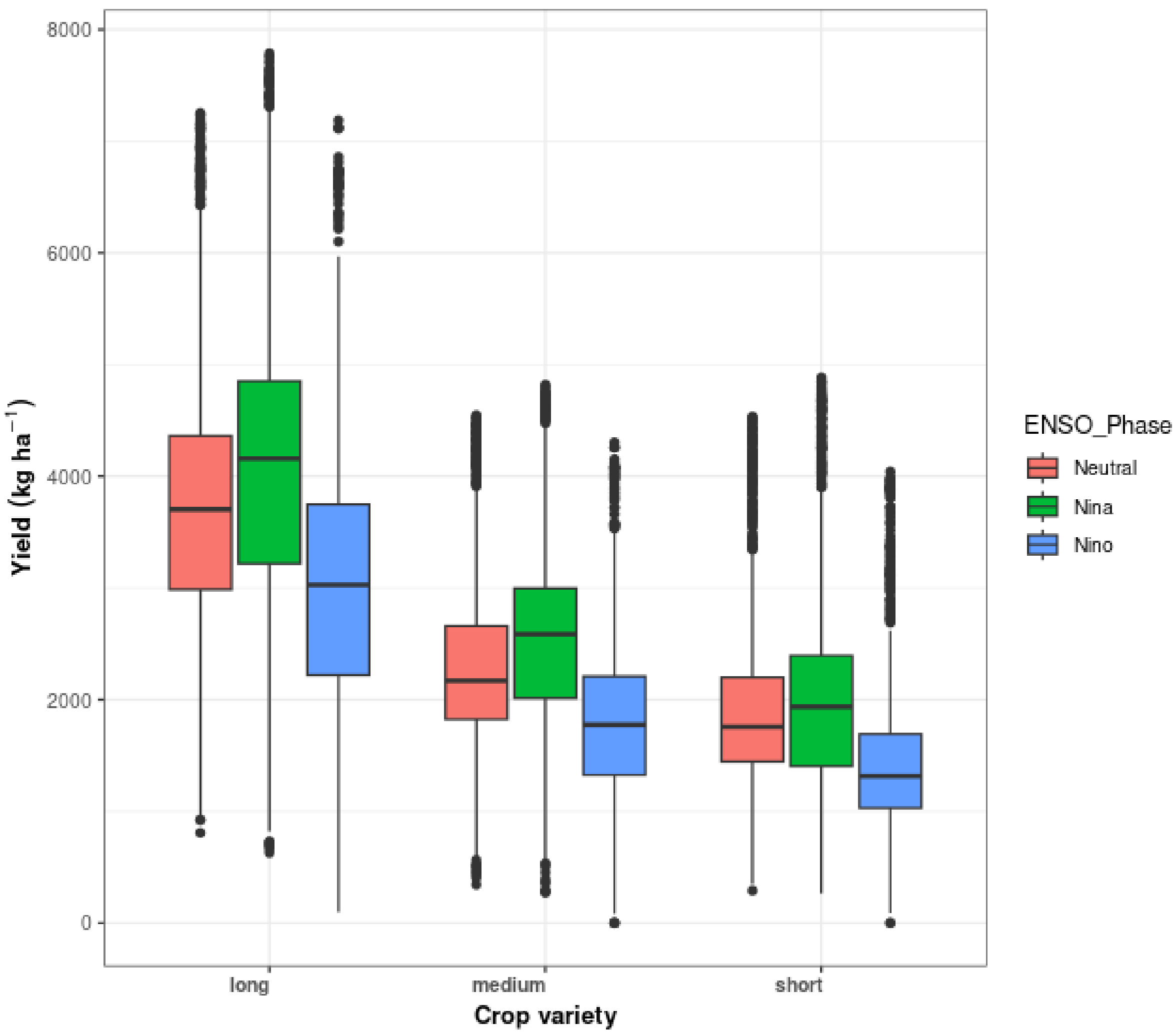

Figure 4. Soybean yield variation across different varieties and ENSO phases for Malawi.