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Shedding light on complexity using sensitivity analysis

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Abstract: Simulation modelling is used to increase our understanding of real or model systems. In this paper we use sensitivity analysis to help us to understand an African maize-soybean intercropping system. The Morris method is used within the APSIM modelling framework to not only corroborate the parameterisation decisions made during model configuration but also to provide information on the likely cause of yield responses observed within the field data. Such tools can add great value to researchers seeking understanding of complex systems.

Keywords: *APSIM, Sensitivity Analysis, Intercropping*

1. INTRODUCTION

Simulation modelling is used extensively because it can help us to understand complex systems where it is difficult to understand responses or to determine factors driving system behaviour. Similarly, model representations of these systems are inherently difficult to configure with confidence because choices made by modellers to reproduce system behaviour are not always easy to substantiate. In this paper we explore the use of sensitivity analysis within the APSIM modelling framework to tackle the issues described above to increase our understanding of a real agricultural system and our model representation of it.

2. INTERCROPPING: AN EXAMPLE OF A COMPLEX PROBLEM

The Chinyanja Triangle includes parts of Malawi, Mozambique and Zambia sharing the Chinyanja language and culture. Current research is exploring opportunities for smallholder farmers in this area to use soybean as an entry point for agricultural intensification (Sheila et al, 2024). APSIM has previously been used to explore agronomic interventions, such as choice of crop maturity class and planting date, to increase soybean production (Omondi et al, 2023). Current modelling efforts are now investigating use of non-traditional planting geometries, such as intercropping and strip cropping (Wu et al, 2021), to incorporate soybean into existing maize production systems.

Data was obtained for the area of interest for intercropping trials (maize-soybean) studying the interactions between planting date and planting geometry (sole crops, intercrops and strip crops) at Chitedze, Malawi (13.9815° S, 33.6372° E). Initial simulation of the dataset indicated several problems facing the modelling team:

- Modelled yield responses to planting geometry were subtle compared to measured treatment variation and even ranking of treatment response did not agree with observation. Investigation suggested that treatment effects within and between years seemed more driven by plot variation in plant population.
- Difference in yield between seasons seemed to not be strongly driven by weather but year-to-year variation in site preparation (e.g. tillage vs no tillage).
- Productivity was low in good seasons suggesting a resource limitation even though soil fertility was high raising questions about fertiliser response.
- Imposed treatment effects seemed difficult to extract amidst the impacts of other factors.

We determined to undertake a sensitivity analysis to better understand our data and our modelling approach.

3. METHODOLOGY AND RESULTS

The sensitivity analysis was configured using the Morris method as described in Compolongo et al (2007). Eight factors were included to cover the main treatments (Planting Date, number of rows in each crop strip) and the issues of concern, such as plant population (Maize and Soybean), soil organic matter (soil fertility), N management (Maize fertiliser amount), and possible effects of tillage (runoff response, soil compaction impacts on rooting). The strip crop system was simulated using the approach in Wu et al (2021) and the Morris capability provided within the APSIM user interface. Parameter ranges were chosen to represent the ranges within the dataset (e.g. treatment variations of measured plant populations) or those required within the model to capture measured yield variation. Initial observations suggested that sensitivity metrics stabilised after approximately 100 iterations and so this were doubled to ensure confidence in the results. In all, this required just 1800 simulations (ie 200*(8+1)) of 20 growing season (2005-2024) to capture seasonal variability. Results are shown in Figure 1. Note that Mu* represents the overall sensitivity as the average absolute elementary effect of changing a parameter across the entire 8-dimensional space. The standard deviation of these elementary effects (Sigma) indicates either nonlinearity in parameter response or interactions between parameters.

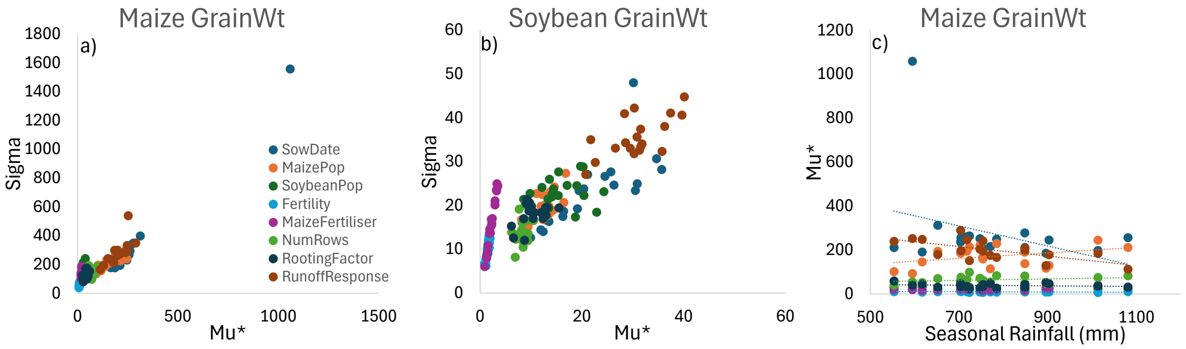

Figure 1: Morris sensitivity results for a) Maize and b) Soybean yield for 2005 to 2024. Changes in sensitivity of c) Maize yield to seasonal rainfall are also shown for all chosen parameters.

Results in Figure 1 supported the approaches employed by the modellers. Site fertility and fertiliser management were unlikely to be factors in the low observed yields as these factors interacted strongly (sigma) resulting in low effect (Mu*) (note impact of maize fertiliser on soybean yield will be via its effect on maize competitiveness). Sowing date, a main treatment within the experiment, showed high effect moderated by season and interactions with other factors suggesting the model may be able to explain these effects within the data. The effect of strip crop configuration (number of rows) was small compared to the effect of variation in population observed in the field for both crops and in all seasons. Runoff response was identified as more important than compaction impacts on root growth under these conditions. The last two points uphold the decision of the modelling team to simulate these experiments using measured populations for each treatment and soil properties tailored to capture tillage differences in each site-year. Parameter ranking (Figure 1c) did not show seasonal differences or trends with rainfall suggesting that some consistent approaches could be used across treatment years. Note though that results did highlight higher sensitivity of sowing date in the 2021 season (outside of experimental period) for sowing date as a result of crop failures during an extended dry period within the sowing window. This suggests further consideration prior to any larger scenario analysis using the parameterisation derived from this dataset.

4. CONCLUSIONS

Not only did our sensitivity analysis give us greater confidence in our choice of parameters to describe the data, but it will also allow us to evaluate reduction in the number of parameters used across the dataset (application of Occam's razor). With this greater insight into key drivers within the experimental responses, we can now consider how best to approach statistical evaluation of the field data itself with our eyes now opened.

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REFERENCES

Campolongo F, Cariboni J,and Saltelli A, (2007) An effective screening design for sensitivity analysis of large models. Environmental modelling & software 22, 1509-1518.

Holzworth D, Huth NI, et al. (2018) APSIM Next Generation: Overcoming challenges in modernising a farming systems model. Environmental Modelling & Software 103, 43–51. https://doi.org/10.016/j.envsoft.2018.02.002

Omondi JO, Mkuhlani S, et al. (2023) Closing the yield gap of soybean (Glycine max (L.) Merril) in Southern Africa: a case of Malawi, Zambia, and Mozambique. Frontiers in Agronomy, 5:1219490. https://doi: 10.3389/fagro.2023.1219490

Sheila CM, Silva J, et al. (2024) Soybean Intensification-based Farm Typology for the Chinyanja Triangle, Initiative on Excellence in Agronomy, CGIAR, 2024.

Wu Y, He D et al. (2021) Modelling soybean and maize growth and grain yield in strip intercropping systems with different row configurations. Field Crops Research, 265: 108122. https://doi.org/10.1016/j.fcr.2021.108122.

