Water stress changes the relationship between photosynthesis and stomatal conductance in rice

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Introduction

- Understanding the relationship between stomatal conductance and photosynthesis in water stress conditions helps to accurately estimate gas exchange by land surface models.

Objectives

- To investigate changes in the linear relationship between stomatal conductance and photosynthesis due to water stress in rice.

Materials and Methods

- A glasshouse experiment was conducted at National Institute for Environmental Studies, Japan.
- Severe (no watering) and mild stresses (watering once in three days), and a control, no water stress, were applied from flowering onwards.

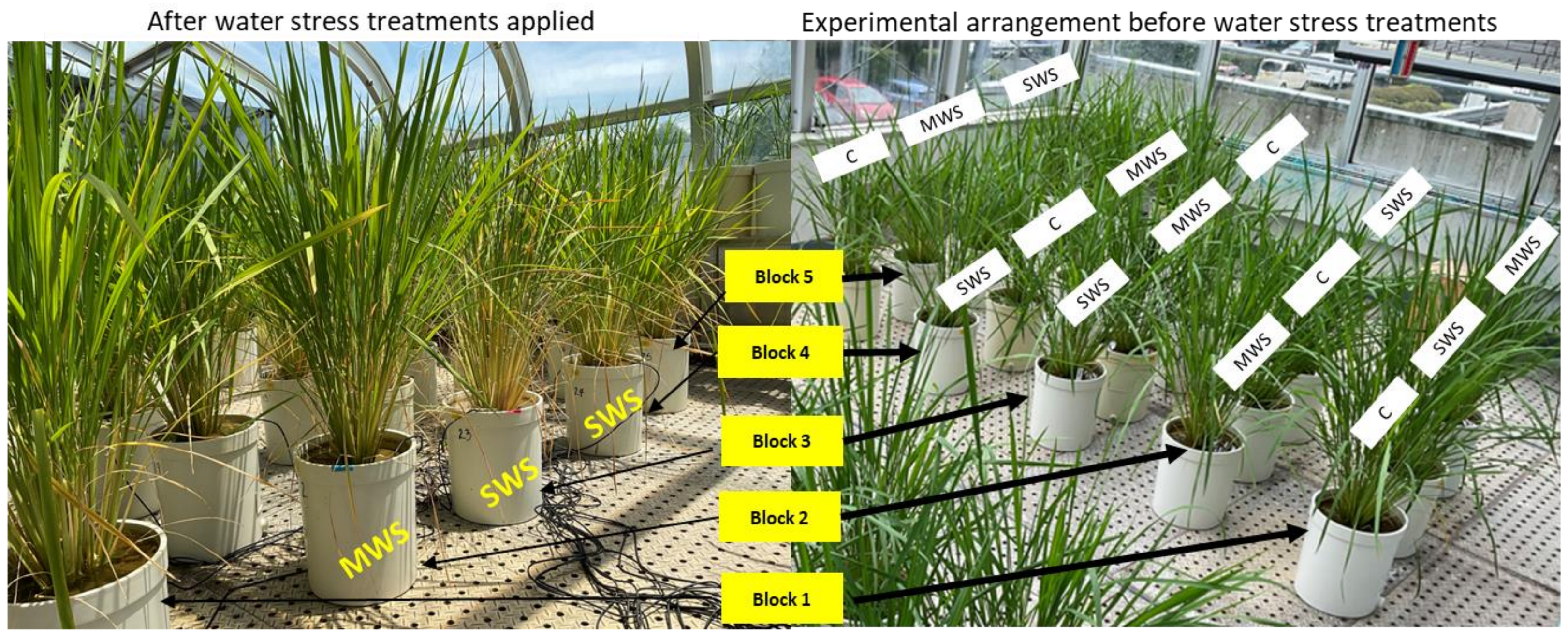

Fig1: Treatment before the start of the water stress (left) and after the water stress after flowering stage of rice (right).

- Portable LICOR 6800 photosynthesis system was used to measure gas exchange .

- Ball-Woodrow-Berry (BWB) model was used to assess relationship between stomatal conductance and photosynthesis.

$$g_s = a \times A_n \frac{RH}{Cs} + b$$

Slope; Photosynthesis; Relative humidity; Stomatal conductance; Intercept; CO_2 concentration; **Ball index (BI)**

Major findings

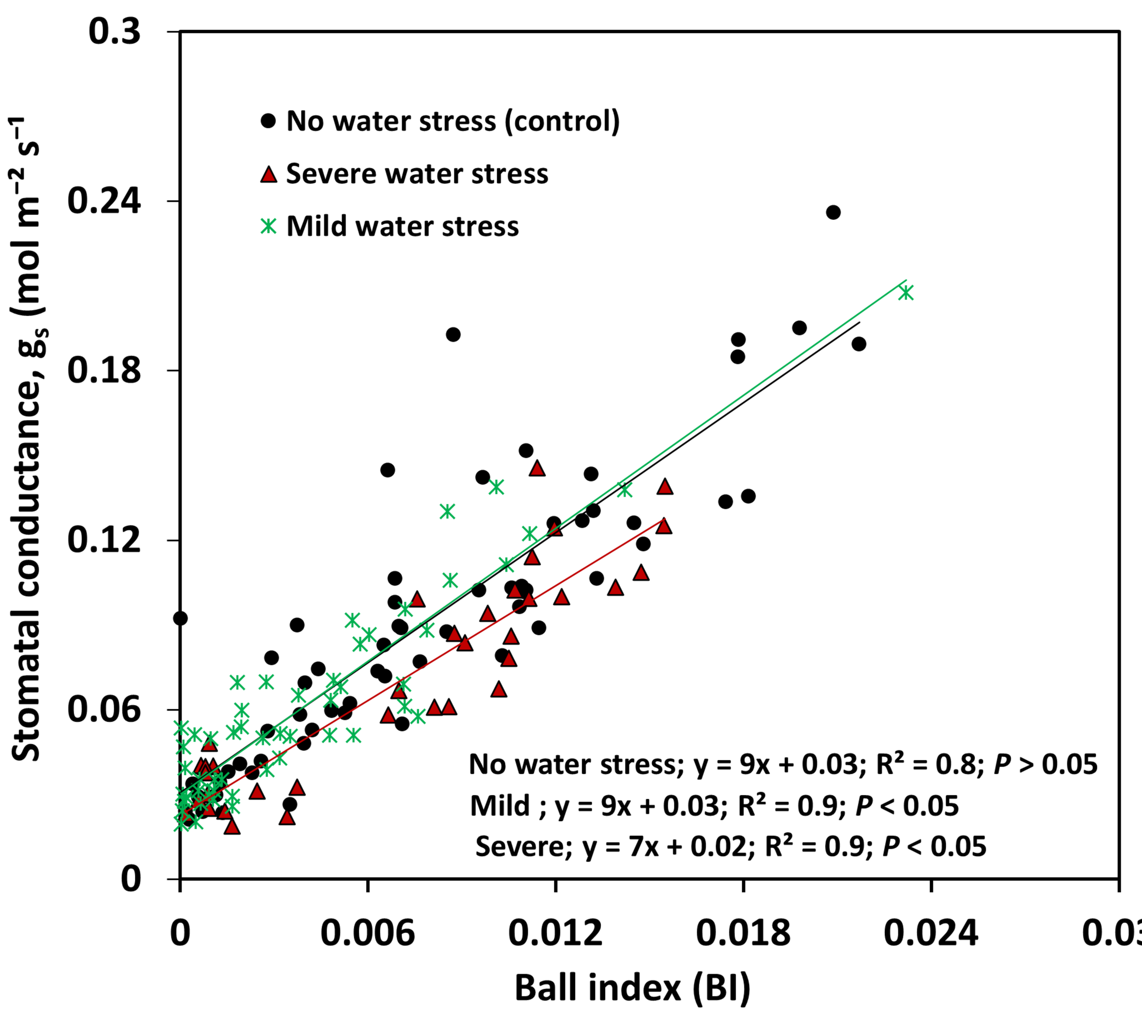

Fig 2. Effect of water stress on the linear (BWB) relationship of stomatal conductance and photosynthesis.

- Slope of the relationship between stomatal conductance and photosynthesis reduced by 30% due to severe water stress.

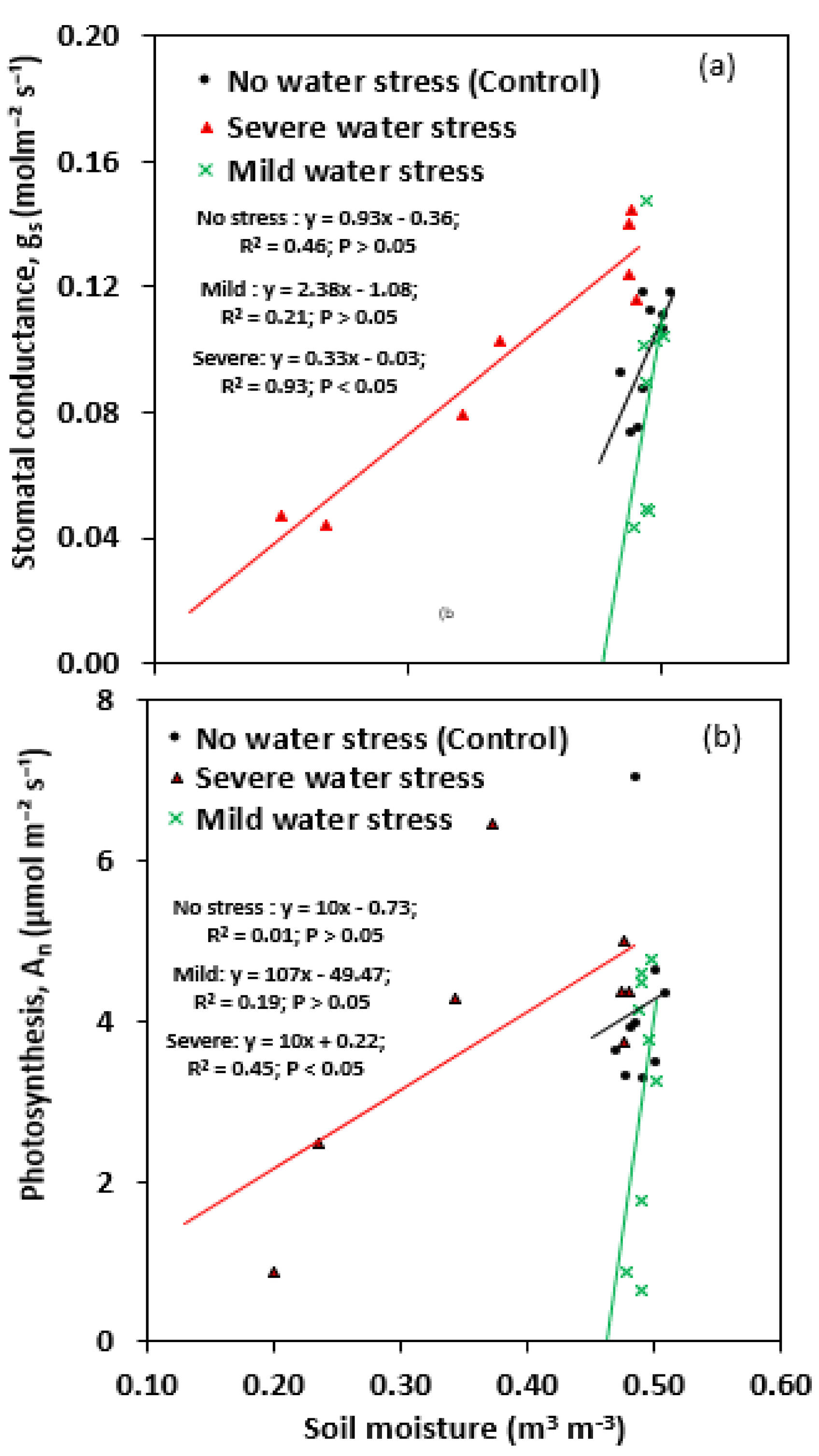

Fig 3. The relationship of stomatal conductance (a) and photosynthesis (b) with soil moisture.

Table 1. Effect of water stress on the linear relationship (BWB) between stomatal conductance and photosynthesis.

Water stress	Slope, *a* (n=17)		Intercept, *b* (n=17)
	Mean	% Reduction	
No stress	9.2±2.2b	-	0.03±0.01
Severe	6.5±2.3a	33	0.02±0.02
Mild	9.0±1.6b	-	0.03±0.01
P (0.05 & 0.01)	*		ns

Conclusion

Shifts in the linear relationship of stomatal Conductance and photosynthesis through reduction in slope implies a conservative water use strategy of rice under intense water stress.

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This study was supported by JPMEERF20202005, JPNP18016 and the Climate Change Adaptation Research Program at National Institute for Environmental Studies.

DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

Seasonal Cover Mapping in Oueme-Beterou Catchment Using Machine Learning Algorithm on Google Earth Engine Cloud-Based Platform

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Introduction

- Land plays an important role in agricultural production and also provides environmental goods and services for human sustainability (Showqi *et al.*, 2014)
- Research indicated that the Sub-Saharan Africa is expected to account for 20% of the world population, by 2050 (Alexandratos, Nikos & Bruinsma, 2012)
- Benin is no exception to this reality. Beterou catchment(northern part of Benin) is subject to strong immigration that causes huge land use changes (Orekan, 2007).
- The expansion of agricultural land combined with the rapid growth of population cause the destruction of vegetation in this region (Judex & Menz, 2006) .
- As a result the resources of land become limited and land right conflicts arrived. Therefore, essential to assess its spatial pattern dynamics to provide information that is needed as planning tools for decision maker.

Objective

Evaluate the capabilities of the GEE cloud computing platform in producing accurate seasonal cover maps.

Study area

Mean annual rainfall is around 1160 mm (Biao & Alamou, 2018), while the average annual temperature ranged between 25°C to 30°C. It belongs to the Soudanese savanna zone. Main crops grow are yams, manioc, maize, millet, and peanuts (Judex & Menz, 2006).

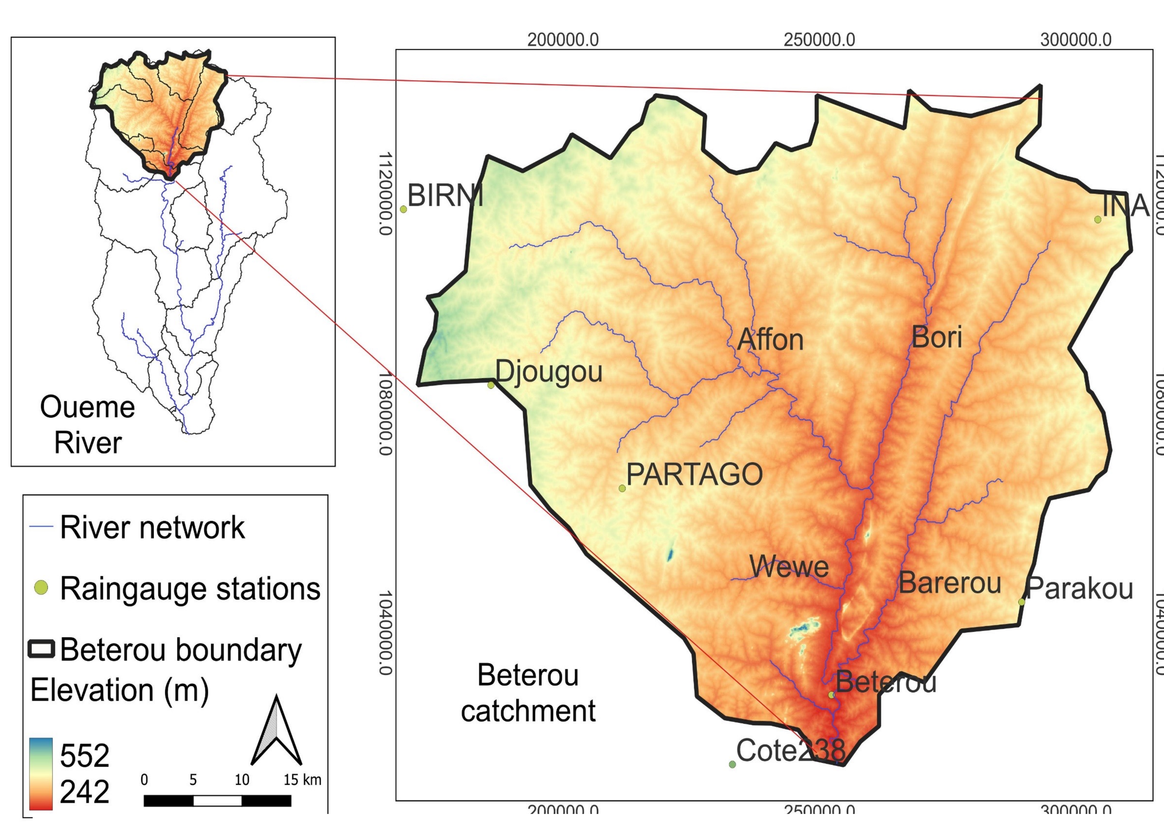

Figure 1. Location of Bétérou within the Ouémé Basin in Benin

Methods

1-Sentinel-2 images collection and filtering

2-Execution of median composite, vegetation and water index computations

3- Image classification using random forest and accuracy assessment

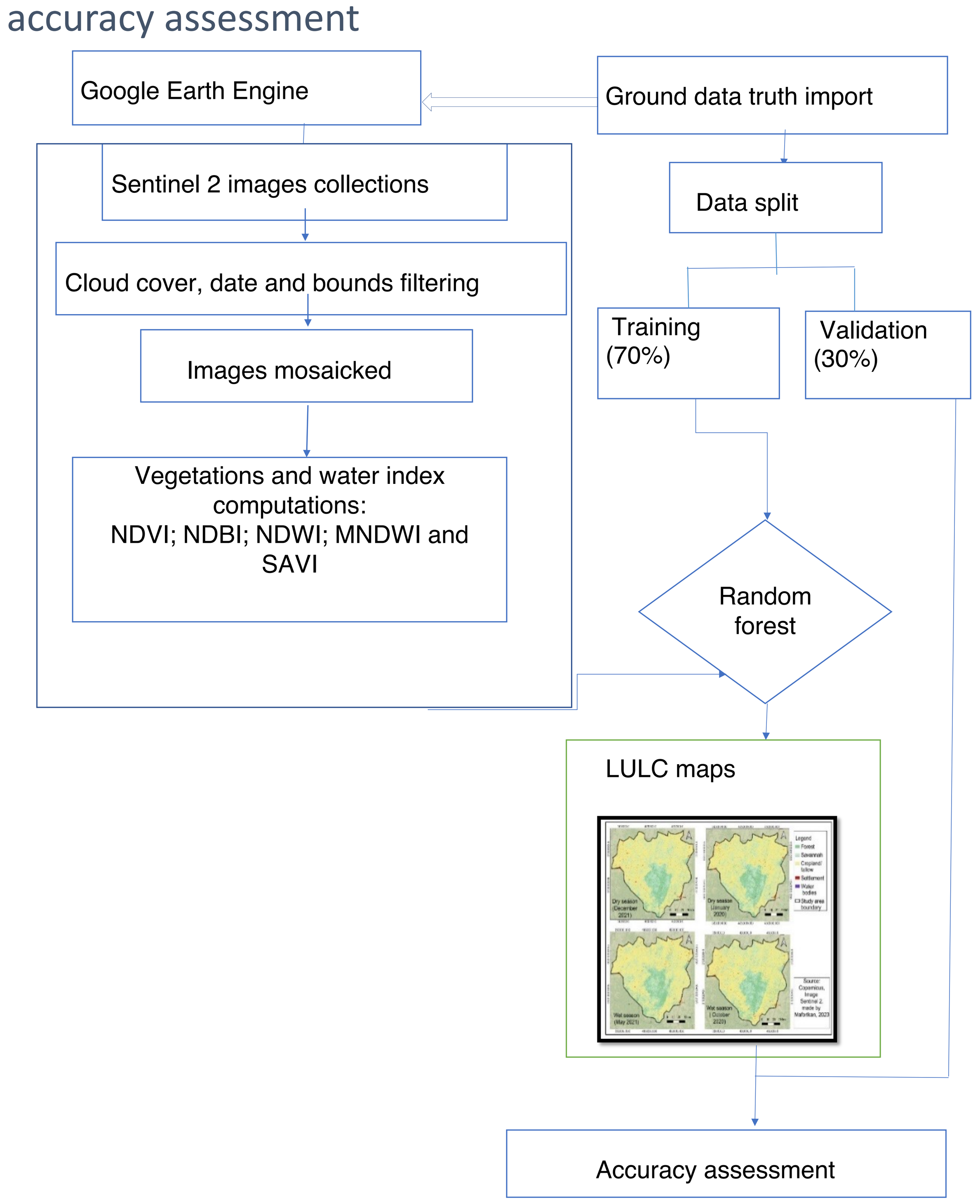

Figure 2. General methodology flowchart used in the study.

Results

Table 1. L U classes (area% for year 2020)

	Rainy season		Dry Season	
LULC/ types	Area (Km^2)	Percent (%)	Area (Km^2)	Percent (%)
Forest	1588.1	15.2	1488.9	14.3
Savannah	2731.8	26.2	2840.6	27.1
cropland/fallow	6020.1	57.7	6022.8	57.7
Settlement	87.5	0.8	79.2	0.8
water bodies	15.5	0.1	11.5	0.1
Total	10443	100	10443	100

Results (continuation)

Table 2. L U classes (area % for year 2021)

	Rainy season		Dry Season	
LULC/ types	Area (Km^2)	Percent (%)	Area (Km^2)	Percent (%)
Forest	1545.6	14.8	1408.7	13.5
Savannah	2711.6	26	2845.5	27.2
cropland/fallow	6102.2	58.4	6091.9	58.4
Settlement	86	0.8	88.1	0.8
water bodies	15.6	0.1	8.8	0.1
Total	10442.97	100		100

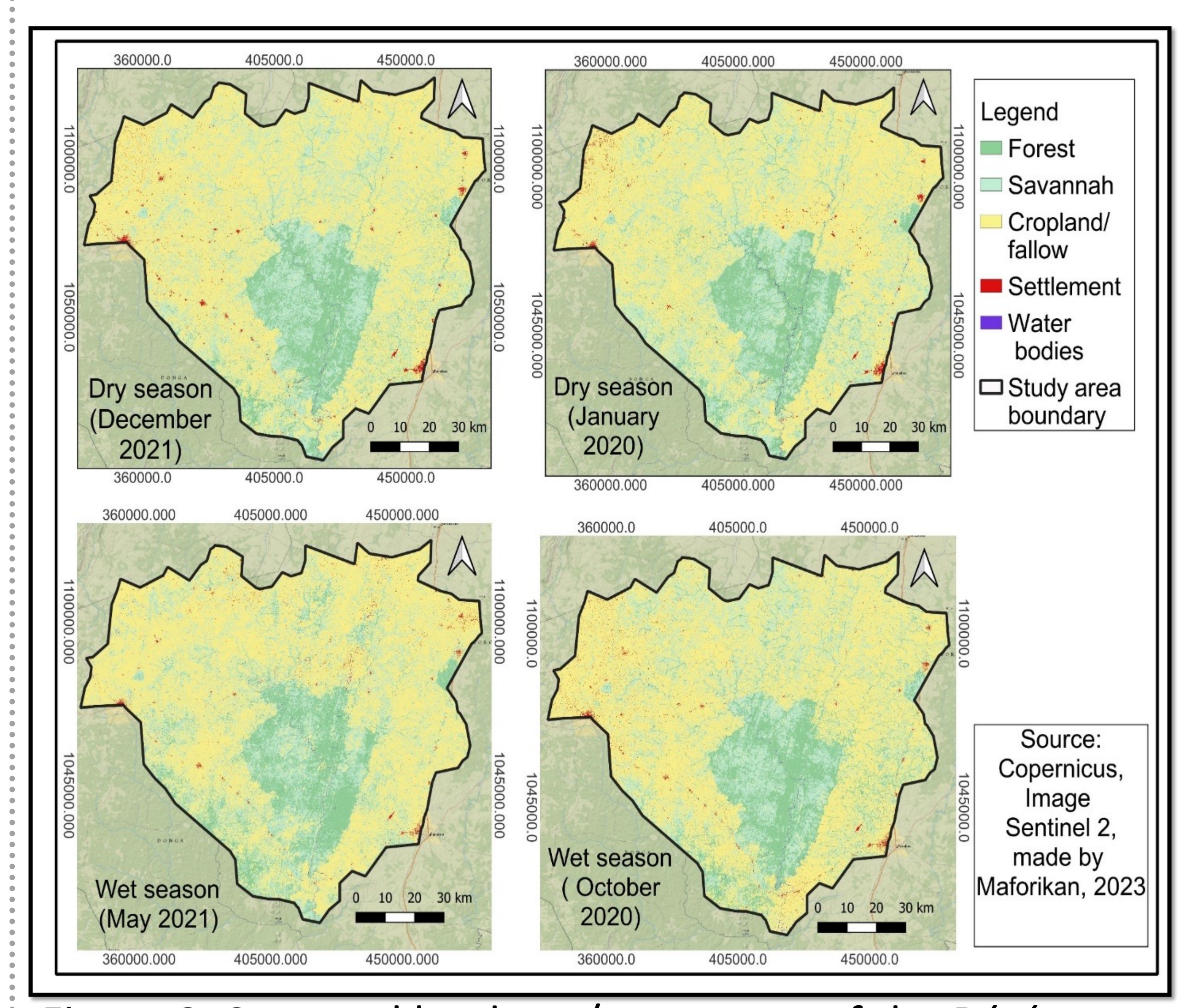

Figure 3. Seasonal land use/cover map of the Bétérou catchment

Table 3. Overall Accuracy and kappa coefficient

	Rainy season		Dry season	
Year	Overall accuracy (%)	Kappa coefficient	Overall accuracy (%)	Kappa coefficient
2020	93.58	0.91	92.63	0.90
2021	89.72	0.86	92.80	0.90

Conclusion

The cloud computing platforms such as GEE was successful produces good results in supervised image classification with higher overall accuracies ranging from 89.7 % to 93.5 %.

This research reveals that the most dominant vegetation cover across the study area was the cropland/fallow, savannahs, and forest.

The patterns of seasonal land cover change from 2020 to 2021 show a slight decrease in the areas of the forest by 0.9% in 2020 and 1.3 % in 2021.

By contrast to the forest, the savannah land increased by 1 % in 2020 and 1.3 % in 2021 from wet months to drier months.

References

Alexandratos, Nikos & Bruinsma, J. (2012). WORLD AGRICULTURE TOWARDS 2030 / 2050 The 2012 Revision PROOF COPY. ESA Working Paper, 12 (12), 146.https://ageconsearch.umn.edu

Biao, E., & Alamou, E. (2018). Stochastic Modelling of Daily Rainfall for Decision Making in Water Management in Benin (West Africa). Research and Advances: Environmental Sciences, 1(1), 12–21. https://doi.org/10.33513/raes/1801-03

Judex, M., & Menz, G. (2006). Modeling of land-use changes in a West African catchment. ISPR Archives, 36(7), 18.

Orekan, V. (2007). Implementation of the local land-use and land-cover change model CLUE-s for Central Benin by using socioeconomic and remote sensing data.D.Ph.D. Thesis, The University of Bonn.

Showqi, I., Rashid, I. and Romshoo, S. A. (2014). Land use land cover dynamics as a function of changing demography and hydrology. *GeoJournal*, 79(3): 297-307.

Acknowledgement

This work was funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). I am also most indebted to the local community of the districts for supporting the field study and responding to questions.

Modelling long-term effect of combined hill-placed manure and chemical fertilizer on maize yield, water- and N- use efficiencies in Sudan Savanna of West Africa

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Introduction and objectives

- Maize yields in SSA is expected to decrease by 5-20% due to climate variations (Reas et al., 2020).
- Reduction in production risk of smallholder farmers can be achieved through water and nutrient maximization.
- There is a need for site-specific recommendation of Integrated nutrient management based on long-term investigation to improve maize production in SSA.
- We sought to formulate an optimal combination rate of hill-placed farmyard manure and chemical fertilizer for maintaining the best, achievable and sustainable maize productivity.

Methodology

Model calibration:

- **Crop simulation model:** DSSAT CERES-Maize
- **Soil organic dynamics:** CENTURY
- **Cultivar coefficient:** GLUE
- **Crop management data:** Retrieved from Tovihoudji et al (2018)

Model validation:

- Model accuracy was tested by calculating the RMSE, nRMSE and the index of agreement (d)

Model simulation:

- DSSAT sequential tool: 32-year continuous trial
- Drought index: DI $= \frac{P-M}{\sigma}$ [dry (DI< -0.35), normal ($-0.35 \leq$DI≤ 0.35) and wet (DI > 0.35) years]

Simulation treatment:

- **Manure:** NM, 3M and 6M representing manure at 0, 3 and 6 t/ha
- **Fertilizer:** NF, 25F, 50F, 75F and 100F representing fertilizer at 0, 25, 50, 75 and 100% of recommended rate 0.2 t/ha NPK + 0.1 t/ha urea

Results

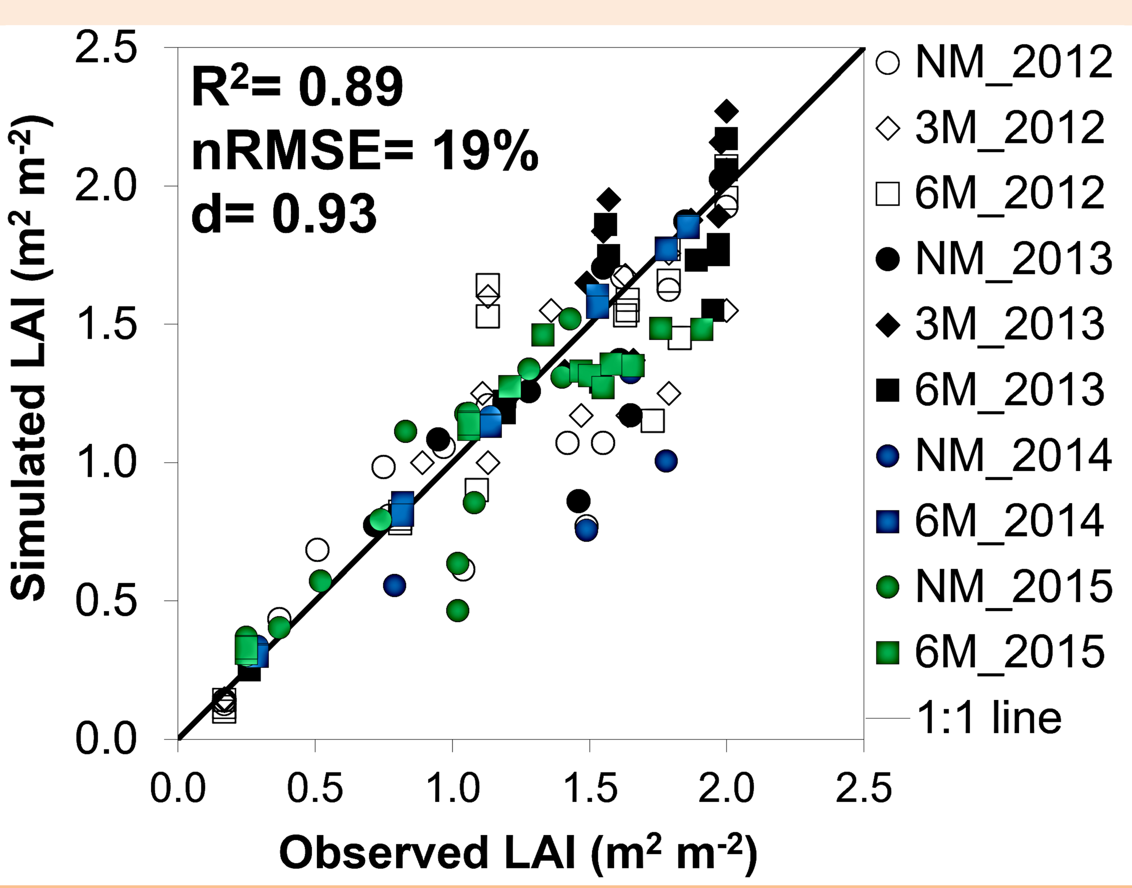

Fig. 1. Comparison between simulated and observed leaf area index

- There was a good model accuracy for LAI (Fig. 1).
- Similar good model performance was observed for soil properties, growth and yield simulation.

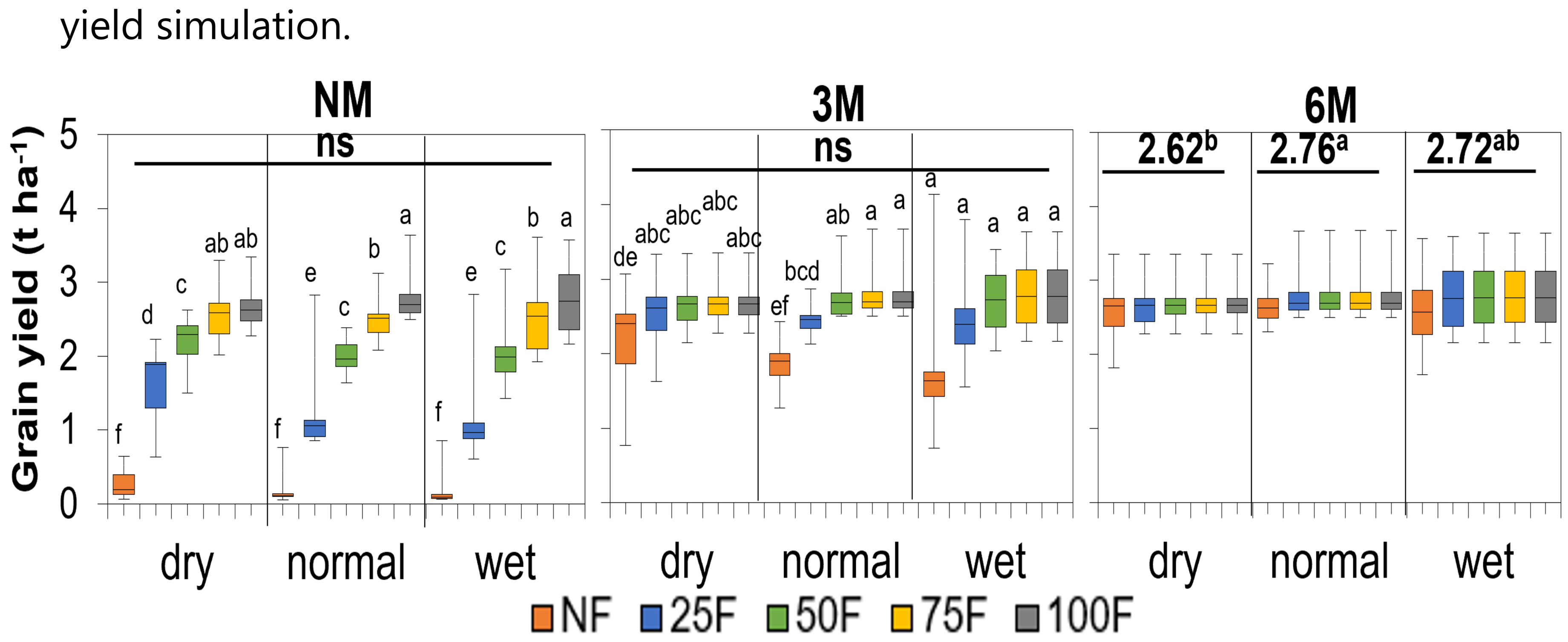

Fig. 2. Simulated grain yield at different rainfall type following manure and fertilizer application

- Grain yield was sensitive to manure and fertilizer.
- Yield did not vary with fertilizer in 6M but varied with rainfall type (Fig. 2).

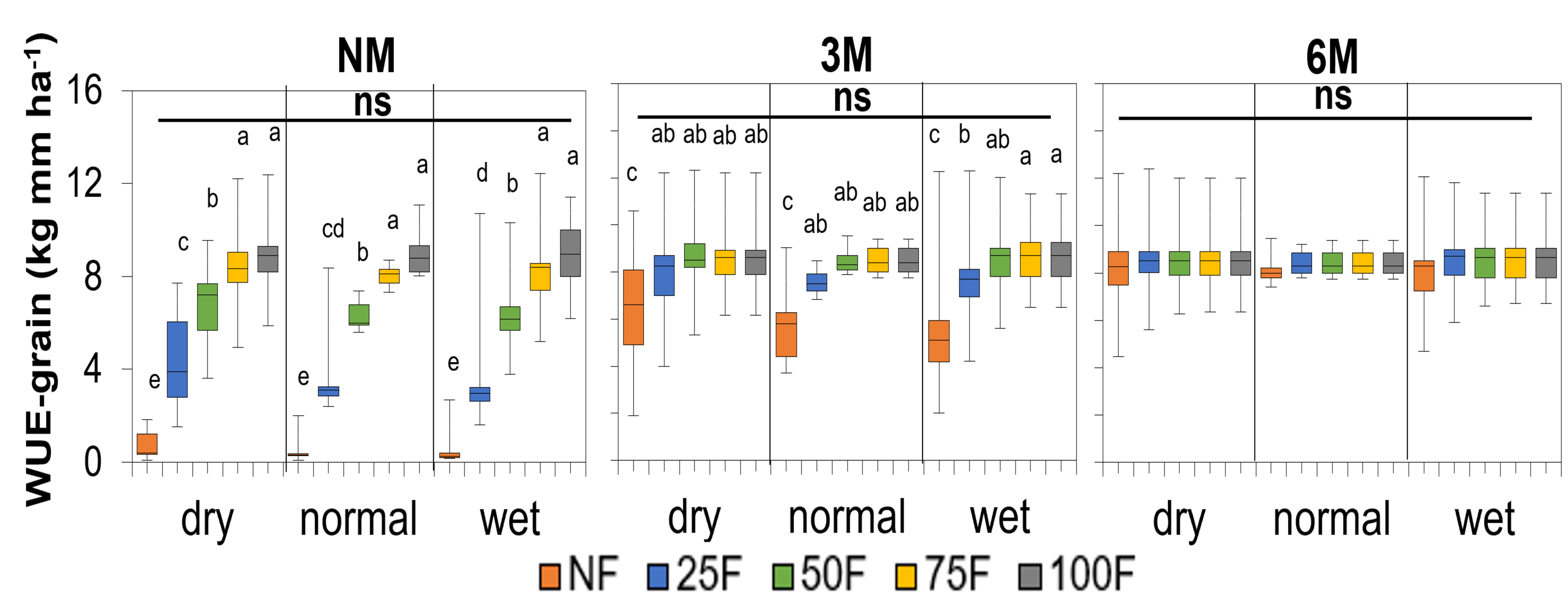

Fig. 3. Simulated water use efficiency at different rainfall type following manure and fertilizer application

- Water use efficiency was sensitive to manure and fertilizer, but not to rainfall types.
- WUE did not vary with fertilizer in 6M (Fig. 3).

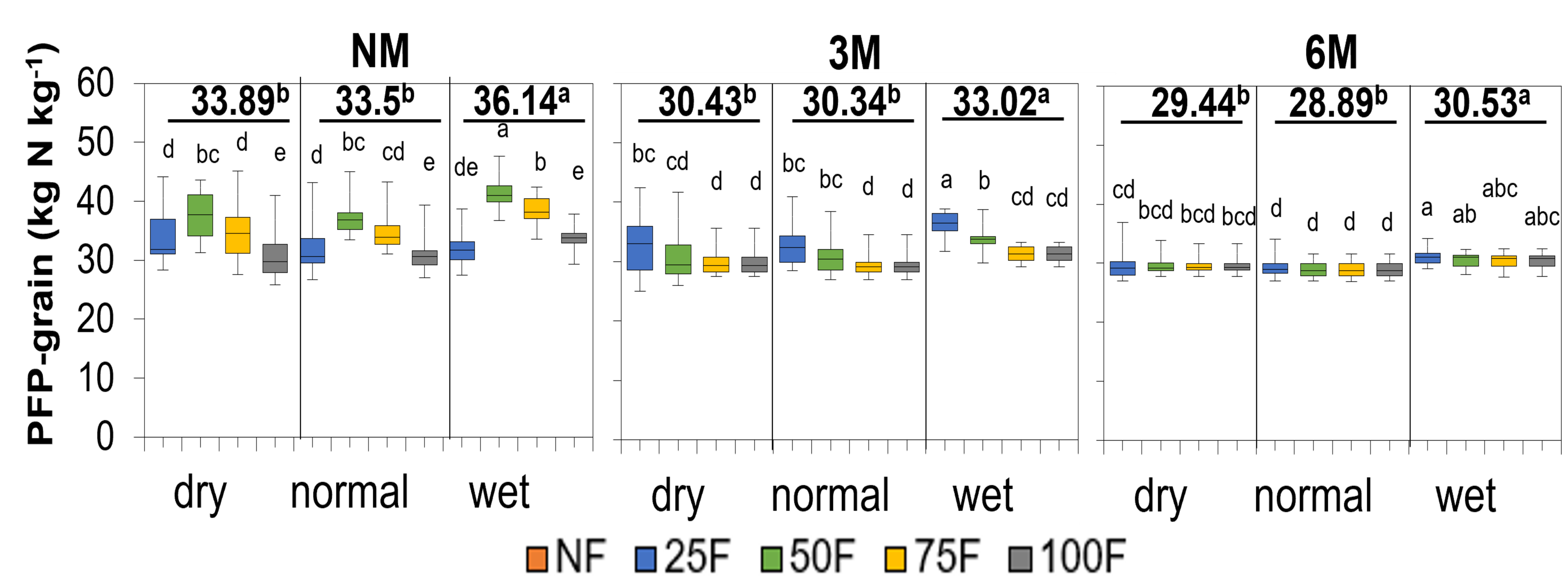

Fig. 4. Simulated partial factor productivity at different rainfall type following manure and fertilizer application

- Partial factor productivity was sensitive to manure, fertilizer and rainfall type (Fig. 4)

Conclusions

- Smallholder farmers can apply a combination of 3 t/ha farmyard manure with 100 kg/ha NPK under rainfed maize production systems
- Regarding agroecology options, areas with available farmyard manure are advised to apply 6 t/ha of farmyard manure without additional NPK fertilizer to maintain best and achievable maize grain yield

References

- Raes, D., Waongo, M., Vanuytrecht, E., & Moreno, P. M. (2021). Improved management may alleviate some but not all of the adverse effects of climate change on crop yields in smallholder farms in West Africa. Agricultural and Forest Meteorology, 308, 108563.
- Tovihoudji, P.G., Akponikpè, P.B.I., Adjogboto, A., Djenontin, J.A., Agbossou, E.K., Bielders, C.L., 2018. Combining hill-placed manure and mineral fertilizer enhances maize productivity and profitability in northern Benin. Nutrient cycling in agroecosystems 110, 375–393

AgMIP9 Modeling the Future of Food

26-29 June 2023

Parameterization of APSIM mungbean model for different water-management options in semi-arid conditions

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Abstract

Mungbean (*Vigna radiata* L.) is a warm season pulse legume. This crop fixes most of its own nitrogen requirement and contributes significantly to improving the sustainability of farming systems. The objective of this study was to evaluate the APSIM mungbean model under two cultivars and water-management conditions in northwestern Iran. A 2-year field experiment was conducted at Agricultural Research Station of Ferdowsi University of Mashhad, Iran, from 2019 to 2020. The experiment was split plot based on a randomized complete block design with four replications. The main irrigation factor was three levels of 80, 60, and 40% of crop capacity and subfactors including Indian and Uzbek cultivar as early- and late-maturity, respectively. The evaluation simulated and measured grain yield, total dry matter, leaf area index (LAI), and soil water content by adjusted coefficient of correlation and by normalized root mean square errors (nRMSE) plus EF (model efficiency). Results showed that predicted grain yield agreed well with observed yield (nRMSE =12% and EF =0.92). The simulated and observed total dry matter were also in reasonable agreement (nRMSE = 13% and EF = 0.83). The observed and predicted soil water content revealed good agreement. The APSIM mungbean model can be applied for research purposes (irrigation and cultivar).
Keywords: Grain yield, irrigation, LAI, soil water content.

Intoduction

Mungbean is one of the most important pulse crops in Iran which grows in many places under clear sunshine and low humidity conditions. It is currently cultivated on about six million hectares worldwide, most of which are located in Asia. As a legume, the crop fixes most of its own nitrogen requirement and contributes significantly to improving the sustainability of farming systems (Chauhan and Williams, 2018). Mungbean also provides an important source of dietary protein for millions of people living in Southern and Southeastern Asia, many of whom are also vegetarians. Mungbean seeds contain about ~24% easily digestible protein, are rich in fiber, antioxidants, and phytonutrients, and are consumed as whole or split, ground into flour, or used as sprouts.
The APSIM cropping system framework is such a model, with a proven track record in modelling the performance of diverse cropping systems, rotations, fallowing, crop, and environmental dynamics. A distinctive feature of this model compared to most other‘ crop models’ is APSIM’s primary focus on simulating crop resource supply (rather than a primary focus on resource demand), with the soil forming the central simulation component. Crops, with their own resource demands impacted by weather and management, find the soil in one condition, and leave it in another condition for the next crop.
The objective of the present study was to calibrate and evaluate APSIM-legume, for a warm-season grain legume mungbean (*Vigna radiata* (L.) Wilczek) for simulation of growth and development of two cultivars of mungbean.

MATERIALS AND METHODS

The model was calibrated using data measured from a two-year field experiment conducted in growing seasons of 2019 to 2020. The experiment was split plot based on a randomized complete block design with four replications conducted in Agricultural Research Station of Ferdowsi University of Mashhad (36.16N, 59.38E), Iran. The main irrigation factor was three levels of 80, 60, and 40% of crop capacity and subfactors including Indian and Uzbek cultivar as early- and late-maturity, respectively.

For water content calibration and validation, the data observed from two field experiments in 2019 and 2020 were also used. Meanwhile, dry matter, LAI, and grain yield traits obtained from the field experiments were considered to validate the crop model.

RESULTS AND DISCUSSION

Fig. 1 indicates the model validation results for two cultivars of Indian and Uzbek using experimental data collected in 2019. The validation results revealed that the model predicted leaf area index reasonably well (Fig. 1). For instance, the nRMSE and EF for LAI were 20% and 0.62, respectively. Further, the coefficient of determination (R2) value for the regression between the observed and simulated LAI was 0.83 for the two cultivars.
Model validation results indicated that the model could also predict mungbean dry matter and grain yield in 2019 to 2020 reasonably well. Based on Fig. 3, the values of nRMSE, EF, and R2 for the grain yield were 12%, 0.92, and 0.97, respectively, while these values for dry matter were 13%, 0.83, and 0.91, respectively. All these suggest that APSIM-legume model could simulate the growth and grain yield of mungbean reasonably well for two years and cultivars.
The nRMSE values for soil water content ranged from 14% (2019) to 12% (2020) (Fig. 2). The EF varied from 0.94 (2019) to 0. 80 (2020) (Fig. 2). This suggests that the APSM-Legume model captured the soil water balance with high accuracy during the growing period of mungbean under different years. APSIM-Legume model was tested on an independent set of experiments, predominantly from the tropics and subtropics of Australia, varying in cultivar, sowing date, water regime (irrigated or dryland), row spacing, and plant population. The model is an attempt to simulate crop growth and development with satisfactory comprehensiveness, without the necessity of defining a large number of parameters. A generic approach was adopted in recognition of the common underlying physiology and simulation approaches for many legume species. The simulation of grain yield explained 77, 81, and 70% of the variance (RMSE = 31, 98, and 46 g m2) for mungbean (n = 40, observed mean = 123 g/m2). Biomass at maturity was simulated less accurately, explaining 64, 76, and 71% of the variance (RMSE = 134, 236, and 125 g m2) for mungbean, peanut, and chickpea, respectively.
However, it has been stated that the 10–20% nRMSE level for the average model error is very common (Hammer et al., 2010). Indeed, model errors lower than these levels are very difficult to achieve since models are compared with experimental work and a level of error is expected as an inherent feature of any experimental results. In addition, parameters and variables inputted to the model include errors of observation.

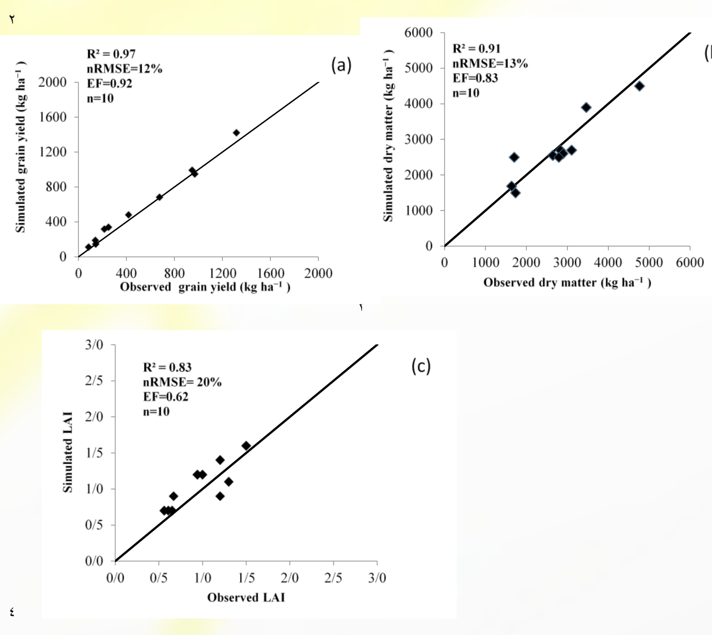

Fig. 1. Simulated versus measured grain yield (A), dry matter (B) and maximum LAI (C) of mungbean in different treatments (2019 and 2020 field experiments). Continuous line: 1 to1 line.

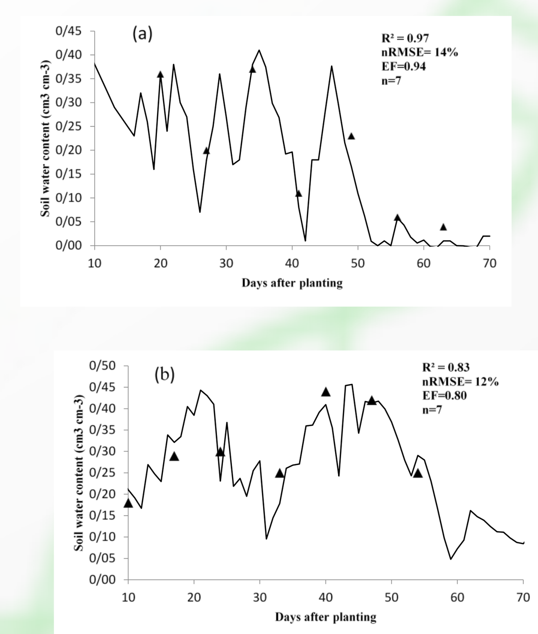

Fig. 2. Comparison of simulated (lines) and observed (data points) soil moisture content at the top soil layer (0–20 cm) in two growing seasons: (A) 2019 and (B) 2020.

References

Chauhan, Y.S. and R. Williams. 2018. Physiological and agronomic strategies to increase mungbean yield in climatically variable environments of Northern Australia. Agron. J. 8(6), p.83.
Hammer, G.L., van Oosterom, E., McLean, G., Chapman, S. C., Broad, I., Harland and R.C. Muchow. 2010. Adapting APSIM to model the physiology and genetics of complex adaptive traits in field crops. J. Exp. Bot. 61 (8): 2185–2202.