ICBAA2017-15

CLIMATE-SMART DECISION SUPPORT SYSTEM FOR CLIMATE-SMART AGRICULTURE

Rowshon M.K and Dlamini N.S.

Department of Biological and Agricultural Engineering, Faculty of Engineering
Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia
rowshon@upm.edu.my and dlaminileko@gmail.com

Abstract: Global water scarcity remains the main growing challenge faced by the agriculture sector. This condition is attributed partly to the tremendous increase in the demand for different water uses and the climate change phenomena. Modeling crop water demands and irrigation water allocation under climate change involves several step-by-step approaches that may be tedious and time-consuming for many water users who may be laymen in this field. Climate-smart Rice Irrigation Management Information System (CSRIMIS) is a user-friendly interactive program consisting of four main modules integrated in MATLAB and its graphical user interface development environment (GUIDE). The program comprises of 4 key modules; stochastic rainfall, reference evapotranspiration, water demand and water allocation and monitoring. MATLAB programming language was used to develop the program and its graphical user interface (GUI). It simulates rainfall, potential evapotranspiration and water allocation deliveries in paddy fields at the Tanjung Karang irrigation scheme while accounting for the impacts of climate change. The model is runs with ten global climate models (GCMs) and three emission scenarios (RCP4.5, 6.0 and 8.5). Several hydro-climatic parameters can be generated from the model based on a daily water balance model with inputs data from GCMs projections, crop, soil and field conditions, and therefore, allows water managers to make a fast decision for rice water management. A stochastic daily rainfall model was developed for forecasting future rainfall. Outputs of a hydrological model were incorporated within the program for assessing flows of the Bernam River, which is a source of irrigation water for the scheme. The program assesses the water requirements by adjusting the reference evapotranspiration (ETo) for projected future emission scenarios based on GCM simulations. The interface is the framework for linking all the modules within the program and provides the user with the ability to access data and output from the system, based on a mouse-driven approach with pop-up windows, pull-down menus and button controls. The multi-model projections show an increase in future temperature (tmax and tmin) in all respective scenarios, up to an average of 2.5 °C for under the worst-case scenario (RC8.5). This paper discusses the CSRIMIS program and presents some of its outputs as relates to the four modules. Generated outputs can be obtained via individual GCMs as well as multi-models (ensemble) projection in the form of graphs and tables that can be converted into excel format for further analysis. The model was applied to evaluate climate change impacts on irrigation water demand and other key hydro-climatic parameters over the time period 2010-2099 with respect to the baseline period (1976-2005) in the Tanjung Karang Rice Irrigation Scheme, in Malaysia. The analyses show that the irrigation water demand will increase in the off-season and, a decrease is expected during the main season due to significant contribution from effective rainfall. The tool can be used as a guideline for managing water resources under climate change, and could therefore be helpful in promoting adoption of appropriate adaptation and mitigation strategies that can lead to more sustainable water use at farm level climate forcing. CSA-DSS gives a faster and reliable projection of the future conditions of global climate systems. It allows improved water management and adaptation of agricultural systems to enhance water use performance and water productivity, particularly, to face water scarcity. This tool provides better understanding of the Government sectors for instituting water policy and implementing allocation measures for irrigation and water resources. It has the capability to support the knowledge-based decision making through intensive climate-related research and development; and capacity building of adaptation and mitigation measures. It helps to develop new strategies to adapt to climate change impacts and new climates. Methodological limitations to the study and suggested future improvements are also discussed.

Key words: climate change, CSDSS-RIMIS, GCMs, water footprint, agriculture

INTRODUCTION

Observing significant changes in patterns of rainfall and temperature that are threatening agricultural production and increasing vulnerability. The spatial and temporal scales of much work addressing climate change impact on agriculture are inadequate for national and local-level planning. Uncertainties associated with the outputs of climate models; and technical issues associated with the downscaling of models to scales that are more appropriate. Since there are limited information on future changes in climate variability and their impacts at local scales, current water management practices may not be robust enough to cope with the rapid impacts of climate change on reliability of water supply for agriculture, energy and ecosystems. Management of water resources clearly impacts on many other policies. Climate-smart DSS needs to develop local scale data sets and simple climate-linked computerized models that will foster to study the Water Footprint for agriculture and other sectors under the climate change conditions in the country.

Climate change impact is one of the major environmental challenges that make future rice production vulnerable. The Inter-Governmental Panel on Climate Change (IPCC), (2007) reports have highlighted three main signals of climate change, including; (1) gradual increase in global average temperatures, (2) rise in sea levels, and (3) changes in rainfall patterns across the globe. It is expected that climate change will take the world into a new phase of water stress and uncertainty in future. Many studies reveal that climate change will alter the hydrological and affects agricultural water supplies leading to a sharp increase in water demand (Wang et al., 2014). Increases in temperature and changes in rainfall patterns could lead to higher crop evapotranspiration (water demand) and at the same time water shortage in stream flows (water availability). Previous studies have shown that even small changes in the rainfall intensity can results in significant impacts on streamflow (Risbey and Entekhabi 1996). On the other hand, rice is the most common staple food for the majority of the world's population, with more than 142 million hectares under cultivation, 90% of which is cultivated in the monsoon regions of Asia (De Wrachien, 2003; FAO 2013), and of this, 75% is produced from irrigated lands. By 2020, global rice consumption is projected to increase by 35% relative to the 1995 baseline (Lee et al., 2005). With this projected increase, it is a given that climate change will put a severe strain on future water resources for food production under irrigation, especially rice. Therefore, these contradictory occurrences warrant development of water management tools that would be consistent future water resources planning and management under climate forcing.

Climate Smart Agriculture (CSA) is an integrated approach for transforming and reorienting agricultural systems to support food security under the new realities of climate change. CSA is composed of three main pillars: (i) Increasing agricultural productivity; (ii) Adaptation and building resilience to climate change and (iii) Reducing GHG emissions, where possible. CSA promotes coordinated actions by farmers, researchers, private sector, civil society and policymakers towards climate-resilient pathways. One of the challenges affecting the development of water management related mitigation plans is lack of climate projections at the local scale. Moreover, climate models do not simulate directly some of the hydro-parameters (effective rainfall, reference evapotranspiration, irrigation requirements, etc.) that are of interest in the agriculture sector. This paper describes the development of a water management tool known as CSDSS-RIMIS for modeling water demand for the rice irrigation scheme under climate change impacts and for climate-smart Agriculture practices at the IADA Selangor Rice irrigation scheme.

METHODS

Climate-smart Decision Support System (CSDSS) was developed to give a faster and reliable projection of the future conditions of global climate systems. The main window of CSDSS and its flowchart methodology adopted in this study is shown in Figures 1 and 2.

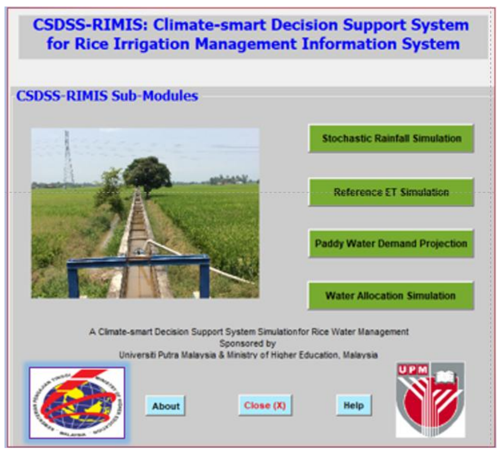

Figure 1: Main window of Climate-smart DSS Graphical-user Interface (GUI).

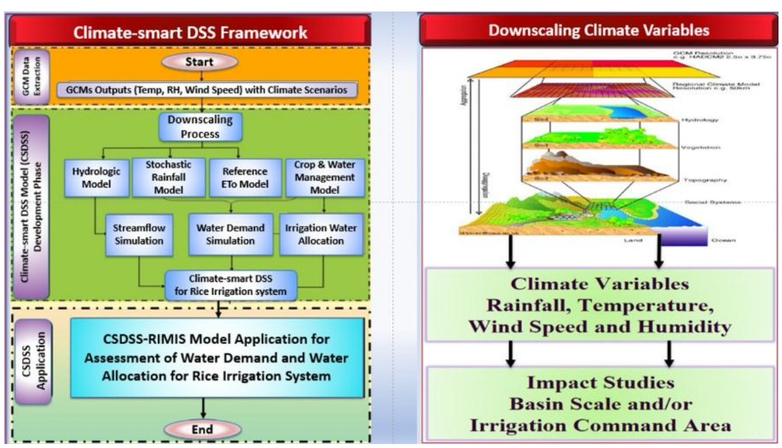

Figure 2: Flowchart illustrating the step-by-step development of CSDSS.

RESULTS AND DISCUSSION

Simulation of Hydro-meteorological variables

The rainfall simulation window shown in Figure 3 is activated instantly by clicking on “Stochastic Rainfall Simulation” command button in Figure 1. To run a simulation, user selects the station, variable of interest, GCM-RCP scenario combination and simulation period using the drop-down buttons. The “Simulation of Future Time Series” button will then appear green denoting that simulation has been completed, and a confirmation window will appear. Future hydro-climatic parameters are produced by perturbing the station observed Future hydro-climatic parameters using change factors derived from mean projected changes simulated from GCMs for the same variables. Simulation outputs can be obtained from each of the ten GCMs or through multi-models projections based on selected RCP emission scenario. Outputs can be generated as daily time series and long-term monthly time scale, and can be viewed from the “Analysis and Statistics” button as tables and graphs. Outputs can be imported to water demand module for simulation of irrigation water demands.

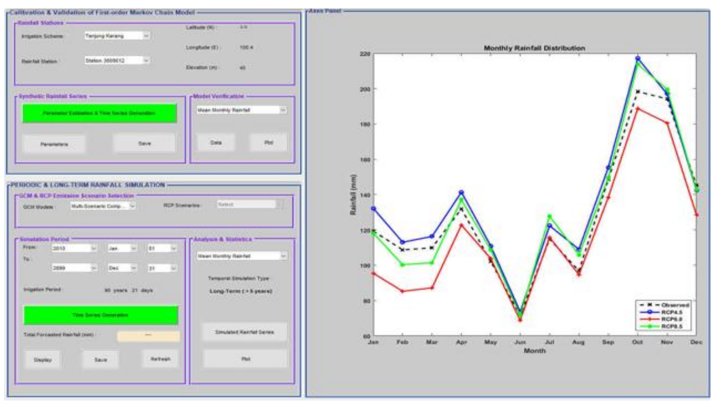

Figure 3: Multi-models changes in future rainfall under RCP scenarios.

Simulation of Daily Reference Evapotranspiration (ETo)

To run ETo simulation, a dialog window shown in Figure 4 will pop up by clicking on the command button “*Reference ET Simulation*” in the main dialog window of CSDSS-RIMIS model (Figure 1). The procedure for simulating ETo is in a sequential mode similar to the previous module (that is, hydro-meteorological Module). Basic information such as station, GCM-Scenario selection, and irrigation date are selected by user using drop down buttons. The hydro-meteorological variables generated from the GCMs outputs are the main inputs in computing reference evapotranspiration (ETo). Future ETo series is produced based on perturbed station observed hydro-meteorological variables using change factors derived from mean projected changes simulated from GCMs for the same variables. Once the “*Simulation of ETo Time Series”* button is pressed, the time series is generated for the selected irrigation period and the button will appear green confirming that simulation has been achieved. Simulated ETo outputs include, daily ETo series, mean monthly ETo, multi-scenario comparisons and multi-future comparisons. Outputs can be located in the “*Analysis and Statistics”* ControlBox and is presented in the form of tables and graphs and can saved in excel format for further analyses, and/or can be used as inputs to other models. The ETo outputs can also be imported to the *Water demand module* for computing recommended irrigation water demands for the target irrigation areas.

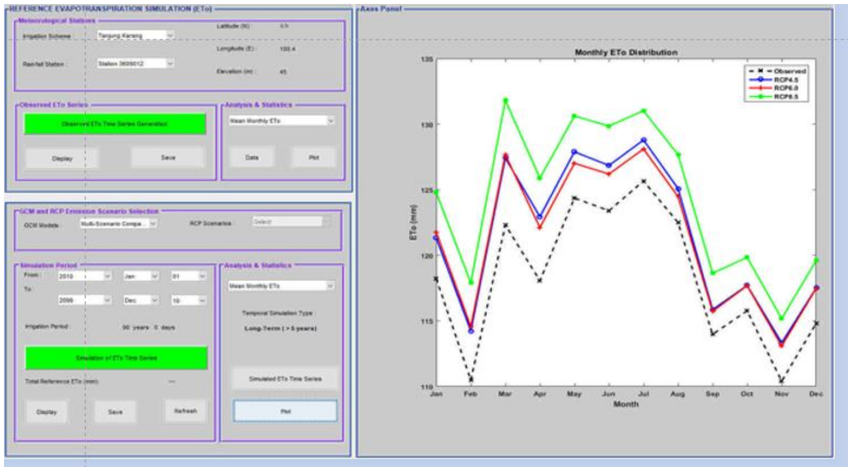

Figure 4: Multi-models changes in future potential reference evapotranspiration under RCP scenarios.

CONCLUSIONS

A user-friendly climate-smart rice irrigation management system known as CSDSS-RIMIS model was developed for simulation of climate scenarios to enhance planning and management of irrigation water under future climate forcing for a large-scale irrigation scheme in Malaysia. The model consists of four main modules integrated in MATLAB and its graphical user interface development environment (GUIDE). The model simulation is based on a daily water balance model with inputs data from climate projections, crop, soil and field conditions. The system reduces the task of downscaling and simply allows water managers to select climate models (GCMs), emission scenarios and simulation period using control buttons and pop-up windows to generate station-site series of hydro-climatic parameters such as effective rainfall ($Peff$), reference evapotranspiration (ETo), crop evapotranspiration (ET), present standing water depth (SW), crop factors (Kc), seepage-percolation (SP) and irrigation requirements (IR_{req}). Generated outputs can be obtained via individual GCMs as well as multi-models (ensemble) projection in the form of graphs and tables that can be converted into excel format for further analysis. The advantage of this model is quick simulation of such comprehensive information, and therefore allows water managers to make fast decision for rice water management.

Therefore, future challenge in managing the water resources will be the monthly variability of water demand of the scheme which could lead to uncertainty in water supply, since this is a run-of-the-river irrigation scheme with no storage reservoir. The tool can be used as a guideline for managing water resources under climate change, and could thus be helpful in promoting adoption of appropriate adaptation and mitigation strategies that can lead to more sustainable water use at farm level climate forcing. Possible adaptation strategies could include construction of storage reservoir for the conservation of rainwater for subsequent use during those months where rainfall will not be sufficient to fulfill crop water demand.

REFERENCES

De Wrachien, D. (2003). Paddy and Water Environment: Facilitation information exchange and identifying future R & D needs. *Paddy and Water Environment, 1*(1), 3-5.

IPCC. (2007). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D.

Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge and New York, 996 p. Available at http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

Lee, T. S., Haque, M. A., & Najim, M. (2005). Scheduling the cropping calendar in wet-seeded rice schemes in Malaysia. *Agricultural Water Management, 71*(1), 71-84. http://dx.doi.org/10.1016/j.agwat.2004.06.007.

Wong, C.; Venneker, R.; Jamil, A.; Uhlenbrook, S. Development of a gridded daily hydrometeorological data set for Peninsular Malaysia. *Hydrol. Process*. **2011**, *25*, 1009–1020.

Risbey JS, Entekhabi D (1996) Observed Sacramento Basin streamflow response to precipitation and temperature changes and its relevance to climate impact studies. J Hydrol 184(3–4):209–223.