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Calibration & validation of Aquacrop model for wheat crop in *Tarai* region of Uttarakhand

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Abstract
The research was carried out in order to calibrate & validate FAO developed AquaCrop model for *Tarai* region of Uttarakhand. The calibration was performed against grain and biomass yield of wheat crop for the three treatments of sowing dates *viz.*, 3rd December, 18th December and 3rd January. A set of conservative parameters were obtained after calibrating the Aquacrop model. The calibrated Aquacrop model was then applied to validate wheat yield and biomass for three consecutive years viz., 2010-11, 2011-12, and 2012-13. Results showed that winter wheat yield & biomass can be simulated with relative accuracy using Aquacrop model. Overall, the agreement between simulated and observed wheat grain yield was satisfactory with correlation coefficient =0.94, RMSE =0.27,. On the basis of statistical indicators it can be concluded that the model mode fitted the observed data set very well. The simplicity of AquaCrop in its required minimum input data, which are readily available or can easily be collected, makes it user-friendly.

Keywords: Aquacrop, Calibration, Validation, Wheat, Sowing date, Simulation & *Tarai* region

1. Introduction
A model is a schematic representation of the conception of a system or an act of mimicry or a set of equations, which represents the behaviour of a system (Murthy *et al*). Crop growth models have been developing along with the progress of computer technology since the 1960s, which can provide the simulation of plant physiological processes and crop growth and development (Boote *et al.*, 2003). It has been used for decades to analyze crop responses to environmental stresses, and to test alternate management practices (Boote *et al.*, 1996; Sinclair and Seligman, 1996) [5, 10]. Aqua Crop is a new decision support tool useful in modelling and devising strategies for efficient management of crop-water productivity at farm level. To make Aqua Crop globally applicable, it must be tested in different locations with different soil conditions, crops, agronomic practices and climatic conditions. Calibration and performance evaluation has been done for maize by Abedin pour *et al.* (2011) and for wheat by Singh *et al.* (2012) [6] in west Bengal. Wheat (*Triticum aestivum* L.) is one of the most important crop plants in world. It grows under a broad range of latitudes and altitudes. It is not only the most widely cultivated crop but also the most consumed food crop all over the world. Wheat is grown in India in an area of about 30 million hectares with a production of 93 million tonnes. The normal National productivity is about 2.98 tonnes/ha & production in 2015-16 is 93.82 million tonnes. The major wheat producing states are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, Karnataka, West Bengal, Uttarakhand, Himachal Pradesh and Jammu & Kashmir. These States contribute about 99.5% of total wheat production in the country. Remaining States, namely, Jharkhand, Assam, Chhattisgarh, Delhi and other North Eastern States contribute only about 0.5 % of the total wheat production in the country. The primary objective of this work was to calibrate and test Aqua Crop model for wheat crop in *Tarai* region of Uttarakhand, a prime area under wheat production.

2. Materials and Methods
The field experiment was conducted in C_6 block of the N.E. Borlaug Crop Research Centre of the G. B. Pant University of Agriculture and Technology, (29°N latitude and 79.3°E longitude) Pantnagar during rabi season of 2013-14 on wheat crop with treatments comprising 3 dates of sowing (3 December, 18 December and 2 January 2014). The daily meteorological data used for the study (i.e. minimum and maximum temperature, bright sunshine hours, relative humidity, rainfall and pan evaporation) were taken from agro meteorological observatory at Norman E. Borlaug Crop Research Centre. Aqua Crop requires identifying generic growth stages of time to emergence, maximum canopy cover, start of senescence, and maturity. For the purpose of Aqua Crop simulate on, time to emergence, maximum canopy cover, and start

of senescence were based on field observations. During the 2013- 2014 season, canopy development was monitored in terms of growth stages and aboveground biomass. Before cutting the plants at the ground level, growth stage was recorded. Based on visual plant observations at two to three days interval the occurrence of various phenological events of wheat, nine important phenological events viz, emergence, maximum canopy cover, senescence and maturity stage were demarcated as per the input requirement for model. The required input soil parameters for AquaCrop are the saturated hydraulic conductivity (Ksat), volumetric water content at saturation (θsat), field capacity (θFC), and permanent wilting point (θ PWP). These parameters were derived from field measurements.

Calibration or fine tuning of the AquaCrop model was accomplished by using the observed values from the field experiment during 2013-14 as model input and then simulating the model to predict the output viz. the biomass and yield. Subsequently, the predicted output values were compared with the observed yield and biomass of the experimental plot.

Model Validations in its simplest form is a comparison between simulated and observed values. In particular, the following crop growth parameters were analyzed: (i) final biomass and harvestable yield, and (ii) water use efficiency (WUE) representing the ratio between the dry grain yield at harvest and the cumulative crop evapotranspiration.).

3. Results and discussion

3.1 Calibration of Aquacrop model: Aquacrop model was calibrated using experimental data set of the year 2013-14.The calibration was performed against grain and biomass yield for the three treatments of sowing dates *viz.*, 3rd December, 18th December and 3rdJanuary.

Model was run keeping the measured or observed data constant. Model parameters such as the reference harvest index (HI_o), the canopy growth coefficient (CGC), early canopy decline, normalized biomass water productivity (WP_b) etc. adjusted during model calibration. The parameters values were changed systematically realizing their practical range, literature value, suggested conservative parameters, and local conditions (crop characteristics, crop duration, soil and climatic conditions) for the crop cultivar and/or local condition (soil/climatic).Special care was taken to the sensitive and moderately sensitive parameters of.

Table 1: Calibrated parameters of crop growth, morphology, and other soil and management aspects.

Parameters	Value	Way of Determination*
Initial canopy cover,%	8.10	E
Maximum canopy cover,%	95	E
Canopy expansion,%/GDD	3.695	E
Canopy decline coefficient, %/GDD	1.202	E
Shape factor for stress coefficient for canopy expansion	3	E
P_upper threshold for canopy/leaf expansion	0.25	E
P_upper threshold for canopy/leaf expansion	0.55	E
P_upper threshold for stomatal closer	0.50	E
Shape factor for stomatal closure	3	E
P_upper for pollination	0.90	E
P_upper threshold for canopy senescence	8.5	E
Shape factor for stress coefficient for canopy senescence	3	E
Maximum effective rooting depth	0.90	F
Shape factor for root expansion	1.5	E
Maximum evapotranspiration crop coefficient (Kc)	1.1	F
Time to reach full canopy (d)	59	F
Time to reach maximum root depth (d)	70	F
Time to reach senescence (d)	91	F
Base temperature (0C)	4	L
Harvest index (%)	34	E
Soil water content at saturation (% vol)	50	F
Field capacity(FC) (% vol)	45	L
Permanent wilting point (PWP) (% vol)	19	L

* F= Field observed/measured data; E= calibrated; L= comparing with the literature, adapted

3.2 Comparison between simulated and observed parameters: Aquacrop model was run to simulate the yield and biomass of wheat crop during the year 2013-14 for three treatments of sowing dates. The observed yields for the treatments T_1, T_2 and T_3 were 5.67, 4.15 and 2.50 ton/ha, respectively while the simulated yields were 5.72, 4.23 and 2.4 ton/ha, respectively which is quite close to the simulated yield.

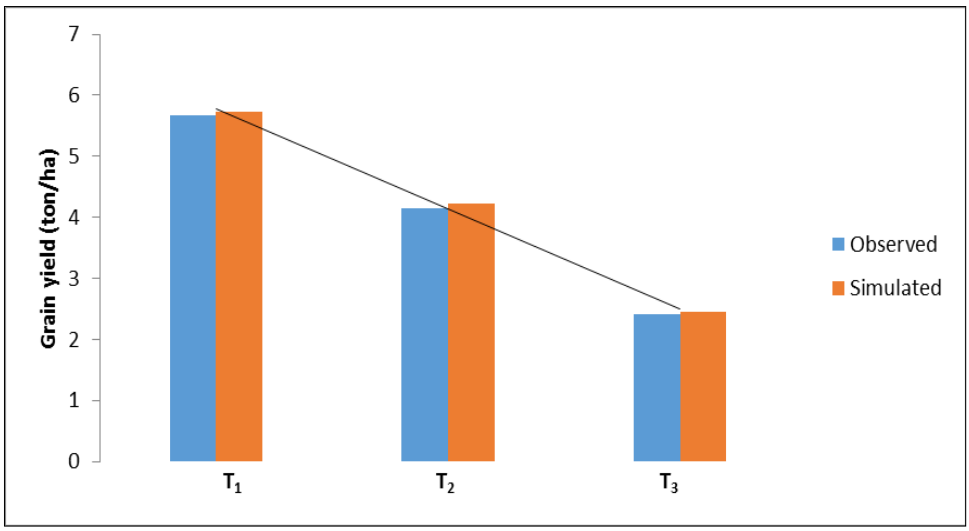

Fig 1: Observed and simulated grain yield in the year 2013-14 for treatments T1, T2, T3 respectively.

A close scrutiny of values e.g. coefficient of determination (0.89), correlation coefficient (0.97), RMSE (0.23), MBSE (0.41) indicates that simulated values by Aquacrop model are in good agreement with observed values.

Similarly observed biomass for the three treatments of sowing date was 14, 9.80 and 6.60 ton/ha, while simulated biomass was 14.79, and 10.50 and 7.50 ton/ha which is also close to the observed biomass.

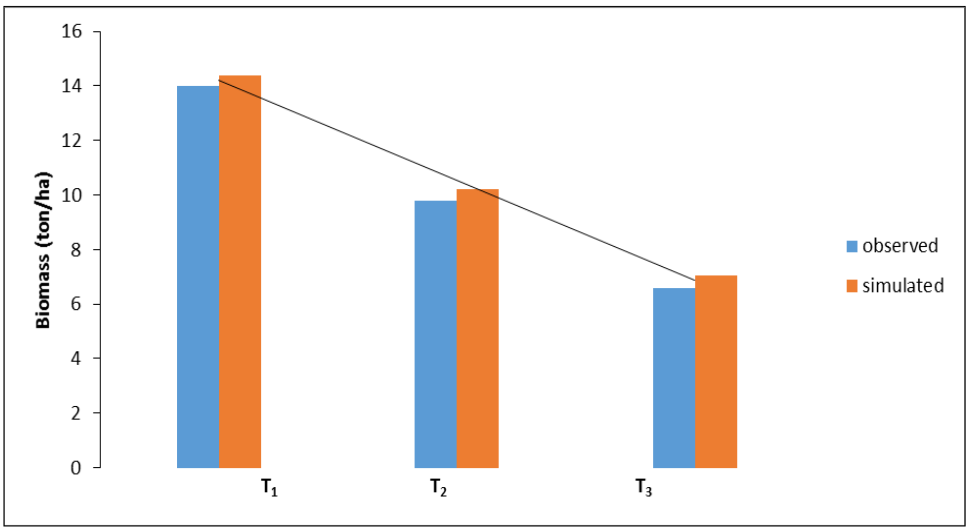

Fig 2: Observed and simulated biomass in the year 2013-14 for treatments T1, T2, T3 respectively.

On the basis of statistical indicators it can be concluded that the model mode fitted the observed data set very well.

3.3 Validation of Aquacrop model: Validation of Aquacrop was done by using the data set of grain yield and biomass of wheat crop for the year 2010, 2011-12 and 2012-13.

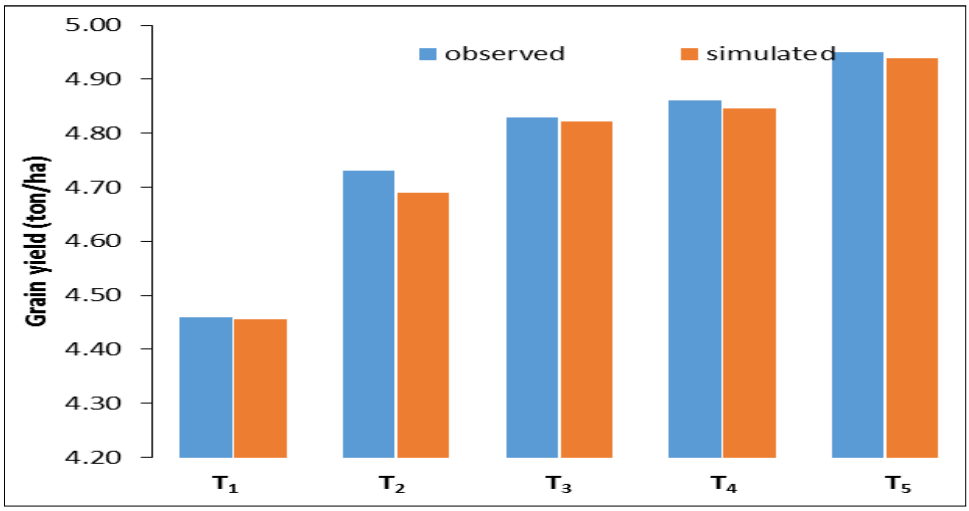

Fig 3: Observed and simulated grain yield in the year 2010-11

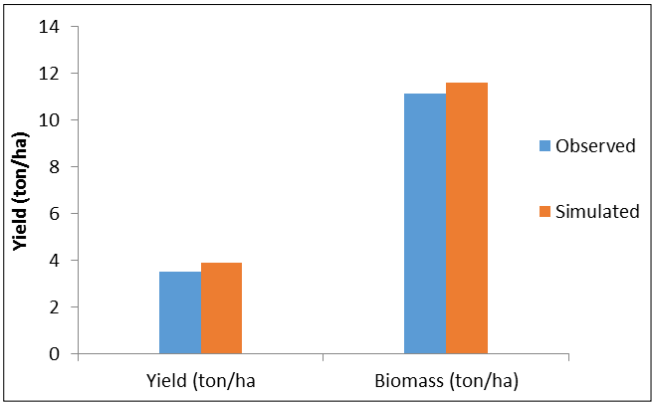

Fig 4: Observed and simulated grain and biomass the year 2011-12.

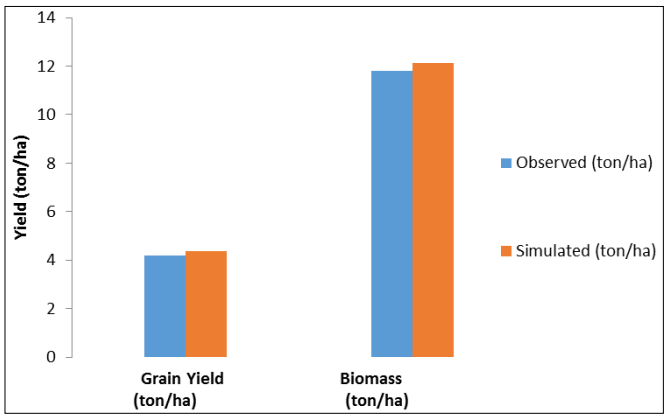

Fig 5: Observed and simulated grain and biomass the year 2011-12.

The calibrated AquaCrop model was applied for validation for the wheat growing period, viz: 2010-11, 2011-12, and 2012-13, in all the cases, observed values of yield and biomass of wheat crop are quite close to the simulated values. Statistical indicators like coefficient of determination, correlation coefficient, RMSE and MBSE also indicates that the model fitted to the observed data set very well and the model was found to be valid in simulating wheat biomass and grain yield in *Tarai* region of Uttarakhand for wheat crop.

4. Conclusion

On the basis of these experiments and simulation outcomes Aquacrop model can be considered as useful tool for wheat crop simulation in *Tarai* region of Uttarakhand. For all the experiments conducted in different years model validation results were satisfactory and it can be concluded that Aquacrop could simulate wheat production with reasonable accuracy in *Tarai* region of Uttarakhand.

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