ISSN: 0974 - 0376

The Ecoscan : Special issue, Vol. IX: 203-207: 2016
AN INTERNATIONAL QUARTERLY JOURNAL OF ENVIRONMENTAL SCIENCES
www.theecoscan.com

VALIDATION OF THE RAJPUT AND SINGH MODEL UNDER DEFICIT EVAPOTRANSPIRATION AND PERDITION OF WHEAT YIELD IN CHANGING CLIMATE

S. A. Chaware *et al.,*

KEYWORDS

Wheat
Climate change
Generalised Rajput
Singh model

Proceedings of National Conference on
Harmony with Nature in Context of
Resource Conservation and Climate Change
(HARMONY - 2016)
October 22 - 24, 2016, Hazaribag,
organized by
Department of Zoology, Botany, Biotechnology & Geology
Vinoba Bhave University,
Hazaribag (Jharkhand) 825301
in association with
National Environmentalists Association, India
www.neaindia.org

The Ecoscan
AN INTERNATIONAL QUARTERLY JOURNAL OF ENVIRONMENTAL SCIENCES

S. A. CHAWARE[1]*, G. S. RAJPUT[2] AND M. R. MESHRAM[3]
[1]Student of Department of Soil and water Engineering, CAE, JNKVV Jabalpur - 482 004, MP.
[2]Professor (Soil and Water Engineering) and Director of Instruction, JNKVV, Jabalpur - 482 004 MP
[3]Pre student of Department of Agronomy, IGKV, Raipur- 492 012, CG.
e-mail: snehal22chaware@gmail.com

ABSTRACT

Predicting yield is increasingly important to optimize irrigation under limited available water for enhanced sustainability and productivity. Accurate crop development models are important tools in evaluating the effects of water deficits on crop yield and future prediction. Rajput and Singh developed generalised Rajput and Singh model for wheat that model had been found to be statistically acceptable at 1% probability. The objectives of this study to validate the model and future prediction of wheat yield under water deficit level in Powerkheda (MP). The result shows that model simulate the wheat yield at coefficient of determination (R^2) was 0.81 and NRMSE was 13.55%. Prediction of yield evaluated at four different date of sowing as 01 Nov, 15 Nov, 01 Dec and 15 Dec for three future year as 2019-20,2049-50 and 2099-2100. Study analysis shows result that projected potential wheat yield reduced as rate of 13.62%, 15.78%, 12.82% and 19.87% at the reduction rate of evapotranspiration 11.6%, 16.9%, 14.3% and 17.22% with respective date of sowing. Result revealed that, rate of reduction of wheat yield in 01 Dec date of sowing less as compare to other date, so that 01 Dec date will be best for cultivation of wheat crop.

*Corresponding author

INTRODUCTION

Water is diminishing resource in India and around the globe with an increasing competition among agricultural, industrial and domestic sectors (Kaveh, 2008). The production of the crop is totally depends on the soil fertility, climatic condition and management practices (Bauder *et al.*, 1988). Where production are optimal throughout the growing season, yield reaches the maximum value as does evapotranspiration (ET_m), water storage (SWS) has an impact on water availability for a crop and subsequently, on actual yield and actual evapotranspiration (ET_a) (English, 1990). In research work found that relation between seasonal evapotranspiration (ET) and yield of crop can be represented as linear function until maximum yield is obtained under optimal irrigation schedule (Stewart and Hagan, 1973; Doorendos and Kassam, 1979; Wenda and Hanks, 1981; Fapohunda *et al.,* 1984; Vaux and Pruitt, 1983). The relationship between relative yield decrease and relative evapotranspiration deficit relationship method shows in FAO (1979, Drainage and irrigation paper no. 33) and Doorendos and Kassam,(1979).

Yield response factor is sensitive with location specific and their transferability to widely different soils and climatic conditions is still a researchable (Rajput and Singh, 1986). Considering above problem Rajput and Singh developed a generalised Rajput and Singh model which is the more transferable under changing climatic condition and soil. Rajput and Singh model show the linear relationship between wheat yield and evapotranspiration. Evapotranspiration and crop growth is totally depending on the climatic parameters like temperature, relative humidity, wind speed, sunshine hour (Manal and Roy,2012). But in present climate change is one of the major challenges facing humanity in the future and effect of climate change has been detrimental to agricultural industry. The pan evaporation and potential evapotranspiration decreased during recent years with the increasing temperature over the India and will be unequal between regions and seasons, (Bandoyopadhyay *et al.,* 2009; Chattopadhyay *et al.,* 1997). In global study wheat production is estimated to fall by 6% for each °C increase in temperature (Asseng, 2015; Jamwal, 2014). In India, 1°C increase in temperature may reduce yield of wheat, soybean, mustard, groundnut and potato by 3-7% (Jamwal, 2014). Considering above facts the study are carried out to validate the generalised Rajput and Singh model and predict wheat yield under changing climate for future years in Powerkheda area in MP.

MATERIALS AND METHODS

The Powerkheda situated at 22° 40'' E longitude and 77° 46'' N latitude, at altitude of 302 m above the mean sea level lies in agro-climatic VI i.e Central Narmada Valley of Madhya Pradesh. The climatic condition of Powerkheda is humid subtropical with vertisol soil order. Major crops cultivated in these areas include rice, maize, pigeonpea and soybean in kharif season and wheat, gram, lentil, linseed, pea and fodder crops during Rabi season.

Data Collection

Model validation data were drawn from Nandeha (1991), the Ph.D thesis. And projected meteorological data collected from the Indian Institute of Tropical Meteorology, Pune. (source: http://cccr.tropmet.res.in/cordex/files/downloads.jsp,IITM).

Generalized Rajput and Singh model

Rajput and Singh (1987) developed generalised Rajput and Singh model based on all India data for wheat, it expresses relative yield decreased in term of relative ET- deficit, at relative period during the maximum temperature below 27°C, relative vapour pressure deficit and finer soil fraction.The generalised model function given as.

$$(1-\frac{Y_a}{Y_m})=13.07\,(1-\frac{ET_a}{ET_m})^{0.89}\times(1-\frac{e_a}{e_s})^{0.84}\times(1-\frac{T_{27}}{T_s})^{0.20}\times(CS)^{-0.41}$$

Where,

Y_a = grain yield of a crop corresponding to any evapotranspiration (ET_a) level, Y_m = maximum crop yield, ET_a = crop evapotranspiration corresponding to Y_a, ET_m = maximum crop evapotranspiration corresponding to Y_m, e_a = mean actual vapour pressure (Mbar), e_s = mean saturation vapour pressure (Mbar), T_{27} = total number of days with maximum temperature below 27°C, T_s = crop period (days), CS = percentage of clay plus silt in the root zone. The generalized function had been found to be statistically acceptable at one percent probability a can be used in predicting wheat yield in India under constrained water supply. The model shows the 93% of variation in reduction yield due to independent variable i.e. temperature factor, soil factor and climate factors and 86% in reduction yield due deficit evapotranspiration.

Model validation

Table 1: Statistical analysis of Generalised Rajput and Singh Model

Statistical tools	Generalised Rajput and Singh Model 1987-88	1988-89	Pooled data
R^2	0.75	0.86	0.81
RMSE (qha^{-1})	2.10	3.11	2.65
CV	0.05	0.07	0.06
d-index	0.88	0.95	0.97
NRMSE (%)	9.50	16.29	13.55

Evaluation is an important step of model verification. It involves a comparison between independent field measurements (data) and output created by the model. The performance of the validated model was evaluated against the independent data sets of experimental data of year 1987-88 and 1988-89. Different statistic indices including Coefficient of determination (R^2), Root mean square error (RMSE), Normalized root mean square error (NRMSE), Willmott's index of agreement (d index), Coefficient of variation (CV). All these statistic indices are calculation methodologies given by (Sharma, 2011; Andarzian *et al.*, 2011; Valizadeh *et al.*, 2014).

Future wheat yield prediction

The validated model is use to prediction of wheat yield under different water deficit condition**.** Prediction were made for different sowing date viz. 01 Nov, 15 Nov, 01 Dec, 15 Dec and that crop season harvesting was decided on the basis of standardize method of growing degree day estimated from the equation (Yousef *et al.,* 2013; Steduto and Raes, 2009; Wilkens 2001; Klepper *et al.*,1998). The potential wheat yield (maximum attainable yield) is the possible production potential for a given climate is calculated for a standard crops by using radiation and evapotranspiration data. The methodology adopted for calculation of potential wheat yield and Maximum Evapotranspiration by De-Wit (1965), FAO (1979, Drainage and irrigation paper no. 33; Khedkar *et al.* 2015; Meena and Rao, 2015). And Actual evapotranspiration are selected on ET levels that is seasonal maximum evapotranspiration on No ET deficit level.

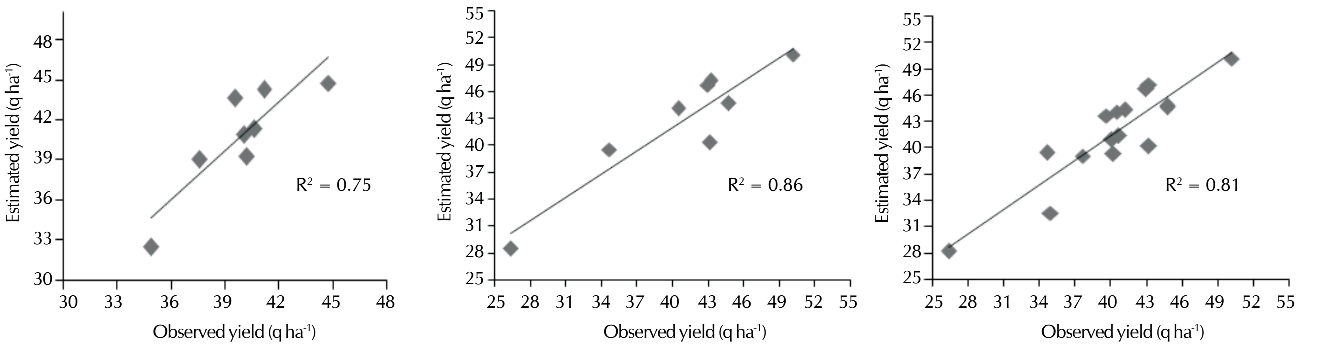
RESULTS AND DISCUSSION

Validation of model

The two years data was used to validate the generalized Rajput and Singh model. The total crop period was 115 days and 118 days during 1987-88 and 1988-89, respectively. The day below 27° C was 55 days and 60 days with respective years. The clay plus silt percentage (CS) of experimental field was 89%. The mean temperature of crop period was 20.00°C and 21.52°C and the relative humidity (RH) was 69% and 66% in 1987-88 and 1988-89 respectively. During the field experiment data obtain as, Y_m (Maximum yield) and ET_m (Maximum

Table 2: Predicted crop Season of wheat, wheat yield under non constraint ET- deficit for different date of sowing at Powerkheda in future years

Future prediction Year	Date of sowing	Crop Season (days)	Evapotranspiration (cm)	Wheat yield(qha^{-1})
2019-20	01 Nov	131	38.31	49.16
	15 Nov	128	43.42	48.50
	01 Dec	122	45.14	50.30
	15 Dec	117	52.65	44.76
2049-50	01 Nov	120	32.08	46.47
	15 Nov	119	33.83	43.32
	01 Dec	116	39.02	47.52
	15 Dec	113	42.19	42.56
2099-2100	01 Nov	107	34.37	32.77
	15 Nov	107	40.16	33.56
	01 Dec	105	38.40	36.54
	15 Dec	103	41.16	31.50



(a) Year 1987-88 **(b) Year 1988-89** **(c) Pooled data**

Figure 1: Relationship between observed yield and estimated yield by using generalised Rajput and Singh model in year 1987-88, 1988-89 and pooled data at Jabalpur

evapotranspiration) is the 44.76 qha^{-1} and 44.49 cm and 50.14 qha^{-1} and 45.41 cm in year 1987-88 and 1988-89, respectively. The model performed very well for simulating the wheat yield under different evapotranspiration levels. Figure 2 shows the Relationship between observed yield and estimated yield calculated by model.

Statistic indices are evaluated under the observed wheat yield and estimated yield for the both years. Table 1 shows the statistical analysis of model. The calculated R^2 for the both year's pooled data shows as 0.81 that is closer to the 1. Also other parameter like RMSE, CV, d-index, NRMSE shows best result. It concluded that generalized Rajput and Singh model found to be statistically acceptable at one percent probability and can be used in predicting wheat yield under constrained water supply.

Wheat crop season

Wheat crop season was evaluated on the base of growing degree days (GDD). The simulated amounts of the number of days from planting to harvesting of wheat in all years are shown in the Table 2. In future climatic condition observed that numbers of days required to complete maturity of crop are gradually decreased 15-20 day in Year 2020, 2050, and 2100. The maximum crop season was observed is 131 days at 01 Nov date of sowing. And minimum duration was 103 in 15 Dec date of sowing. Also it observed that when the date of sowing are shifted 01 Nov to onwards the growing days was decreased with 5-10 days. This is agreement with Valizadeh et al. (2014), Jalota *et al.* (2013), Lawlor and Mitchell, (2000) with the reason that the increases in temperature rate accelerate growth stages of wheat. Lal *et al.,*(1998) reported that 1°C rise in temperature leads to a reduction of about 5 days in the flowering time of the wheat, also reduces the crop growing season as a result reduces the wheat yield in India.

Wheat yield predication at different ET deficits

The prediction results of wheat yield on the no deficit evapotranspiration level showed that this trait will decrease under the influence of future climate change in all date of sowing with an years of 2020, 2050 and 2100 (Table 2). It means that the predicted climate change in Powerkheda region will have a negative impact on the wheat yield. The evapotranspiration rate will be increase as the date of sowing are shifted in 15 days intervals. As the temperature increase day by day the evapotranspiration rate also increase, it directly related to the changing temperature. In future predication years highest evapotranspiration rate will be recorded as 52.65 cm on 15 Dec date of sowing with a year of 2020, further the rate will be lower down as 42.19cm and 41.6 in future years 2050, and 2100 at same date of sowing. The potential evapotranspiration decreased during future years with the increasing temperature over the India, (Bandoyopadhyay *et al.,* 2009; Chattopadhyay *et al.,* 1997). When model run wheat yield is directly influences by the evapotranspiration, number of growing day when temperature below 27°C, vapour pressure ratio, and soil fraction. Table 2 shows the no deficit level of evapotranspiration affect to the wheat yield.

In prediction year 2019-20, highest wheat yield will be 50.30 qha^{-1} at ET will be 45.14 cm in 01 Dec date of sowing as compare to the other date of sowing. Similarly in year 2049-50 and 2099-2100 highest wheat yield will be 47.52 and 36.54 qha^{-1} at ET will be 39.02 and 38.40 cm in 01 Dec date of sowing. From the projections it is observed that under non constraint water supply ET will be decrease at magnitude of 11.6%, 16.9%, 14.3% and 17.22, on that reduction rate wheat yield will be reduced at magnitude of 13.62%, 15.78%, 12.82% and 19.87% for respective dates of sowing at Powerkheda region. And Wheat yield showed reduction rate between 10% - 20% under the impact of temperature rise within the future years. In many tropical and subtropical region, potential wheat yield are projected to decrease for most projected increases in temperature (Mitchell *et al.,* 1995, Lat *et al.,* 1998, Houghton *et al.,* 2001).From result observed that the predicted climate change in Powerkheda region will have a negative impact on the wheat yield. Wheat yield reduction rate will be lower for date of sowing on 01 Dec as compared to other dates of sowing for the Powerkheda region. This study revealed that 01 Dec date of sowing most suitable for wheat productivity for future years.

ACKNOWLEDGEMENT

The Authors express their gratitude to the Indian Institute of Tropical Meteorology, Pune for providing meteorological data, and to the editors and reviewers whose comments and suggestion were extremely valuable and helped improve this paper.

REFERENCES

Andarzian, B., Bannayan, M. , Steduto, P., Mazraeh, H., Barati, M. E., Barati, M. A. and Rahnama. 2011. Validation and testing of the AquaCrop model under full and deficit irrigated wheat production in Iran. *Agricultural Water Management*. **100:** 1-8.

Asseng, S., Ewert, F., Martre, P., Rotter, P., Lobell, D.B., Cammarano, D., Kimball, B. A., Ottman, M. J. and Wall, G. W. 2015. Rising temperature reduce global wheat production. *Nature Climate Change*. **5:**143-147.

Bandyopadhyay, A., Bhadra, A., Raghuwanshi, N. S. and Singh, R. 2009. Temporal trend in estimates of evapotranspiration over India. *J. Hydrologic Engineering*. **14:** 508-515.

Bauder, J. W., Bauder, T., Cardon, S. and Schneekloth, J. 1988. Guide to choosing crop well-suited to limited irrigation. Montano State university, *Colorado State University and Utah State University*.

CCCR. 2015. India Institute of Tropical Meteorology data server, http://cccr.tropmet. res.in/cordex/files/downloads.jsp, IITM Pune.

Chattopadhyay, N. and Hulme, M.1997. Evaporation and potential evapotranspiration in India under conditions of recent and future climate change. *Agricultural and Forest Meteorology*. **87(1):** 55-73.

De Wit, C. T. 1965. Photosynthesis of leaf canopies. *Agricultural Research Report, 663, Wageningen.*

Doorenbos, J. and Kassam, A. H. 1979. Yield Response to Water Irrigation and Drainage paper 33, Food Agric. *Organ, Rome*. p. 193

English, M. 1990. Deficit irrigation I: Analytical framework. *J. Irrigation Drainage Eng*. **116(3):** 399-411.

FAO. 1979. Yield Response to Water Irrigation and Drainage Paper number 33. *FAO, Rome, Italy*. p. 193.

Fapohunda, H. O., Aina, P. O. and Hussain, M. M. 1984. Water use-yield relations for cowpea and maize. *Agricultural Water Management*. **9:** 219-224.

Houghton, J. T., Filho, M., Callander, B. A., Harris, N., Kattenberg, A. and Maskell, K. 2001. Climate change 2001: The scientific Basis. Contribution of working group I to TAR of the Intergovernmental Panel on climate change. *Cambridge University press: Cambridge,UK.*

Jamwal, N. 2014. How climate change is going to affect India specifically. https://in.news.how climate change is going to affect India specifically.

Jolota, S. K., Kaur, H., Kaur, S. and Vashisht, B. B. 2013. Impact of climate change scenarios on yield, water and nitrogen balance and use efficiency of rice- wheat cropping system. *Agricultural Water Management*. **116:** 29-38.

Kaveh, F. 2008. Handbook of water management in the farm. *Islamic Azad University Science and Research. Tehran, Iran*

Khedkar, D. D., Singh, P. K., Bhakar, S. R., Kothari, M., Jain, H. K. and Mudgal, V. D. 2015. Performance evaluation of different reference evapotranspiration models. *The Ecoscan, International Quarterly J. Environmental Sciences*. **8:** 193-201.

Klepper, B., Rickman, R. W., Waldman, S. and Chevalier, P. 1998. The physiological life cycle of wheat: Its use in breeding and crop management. *Euphytica*. **100:** 341-347.

Lal, M., Singh, K. K., Rathore, L. S., Srinivasan, G. and Saseendran, S. A.1998. Vulnerability of rice and wheat yield in NW India to future changes in climate. *Agricultural and Forest Meteorology*. **89:** 1-13

Lawlor, D. W. and Mitchell, R. A. C. 2000. Crop ecosystem response to climate change: wheat in, Reddy, KR Hodges, Climate change and Global crop productivity. *CAB International Canbridge*. pp. 57-80.

Mandal, S. K. and Roy, S. P. 2012. Impact of enviromental factor on certain pulse crops of north-eastern bihar (india) with reference to resource management. *The Ecoscan*. **1:** 35-40.

Meena, H. M. and Rao, A. S. 2015. Determination of actual evapotranspiration and crop coefficient of sesame (sesamum indicum l. cv. RT-127) from lysimetric studies. *The Ecoscan*. **9(3&4):** 765-769.

Mitchell, R. A. C., Lawlor, D. W., Mitchell, V. J., Gibbard, C. L., White, E. M. and Porter, J. R. 1995. Effect of elevated CO_2 concentration and increased temperature on winter wheat: test of ARCWHEAT1 Simulation model. *Plant cell Environment*. **18:** 739-748.

Nandeha, K. 1991. Effect of various irrigation schedules and fertility level on the growth characters and yield of wheat. *Ph.D. Thesis, JNKVV, Jabalpur*. p. 15-99.

Rajput, G. S. and Singh, J. 1987. A generalized water Production function for Wheat. *Agric. Engg. ISAE*. **24:** 335-342.

Sharma, H. L. 2011. Experimental Designs and survey sampling: method and application. *Publ. Agrotech Publishing Academy*, pp. 517-525.

Steduto, P., Hsiao, T.C., and Raes, D. 2009. AquaCrop - the FAO crop model to simulate yield response to water, Concepts and underlying principles. *Agronomy J*. **101:** 426-437.

Stewart, J. I. and Hagan, R. M. 1973. Function to predict effect of crop water deficit. *Journal of Irrigation and Drainage,* Div ASCE. **99(4)**: 421-439.

Valizadeh, J., Ziaei, S. M. and Mazloumzadeh, S. M. 2014. Assessing climate change impacts on wheat Production. *J. the Saudi Society of Agricultural Sciences*. **13**:107-115.

Vaux, H. J. and Pruitt, W. O. 1983. Crop water production function. *Advance Irrigation*. **2:** 61-99.

Wenda, W. I. and Hanks, R. J. 1981. Corn yield and evapotranspiration under simulated drought condition. *Irrigation Science*. **2(4):** 193-204.

Wilkens, P. and Singh, U. 2001. A Code-Level Analysis for Temperature Effects in the CERES Models. *Resource Development Division, International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama, USA.*

Yousef, K. H., Salama, M. A. and Mostafa, A. Z. 2013. Estimation of growing degree days and actual evapotranspiration for squash crop using heat units and neutron scattering method. *J. American Science*. **9(10):** 302-307.