Research Journal of Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 2 (4): 275-280, 2008
ISSN 1819-3412

Pre-Harvest Wheat Yield Prediction Using Agrometeorological Indices for Different Regions of Kordestan Province, Iran

[1]S. Bazgeer, [2]Gh.A. Kamali, [3]S.S. Eslamian, [2]A. Sedaghatkerdar and [4]I. Moradi
[1]Agricultural Meteorology Division,
I.R. of Iran Meteorological Organization (IRIMO), Tehran, Iran
[2]Atmospheric Science and Meteorological Research Center (ASMERC), Tehran, Iran
[3]Department of Water Engineering, Isfahan University of Technology, Iran
[4]Department of Physical Geography, Faculty of Geography,
University of Tehran, Tehran, Iran

Abstract: The aim of this study was to establish the relationships between wheat yield and meteorological variables together with agrometeorological indices for prediction of wheat yield for different regions of Kordestan province, Iran. Wheat prediction was carried out using different meteorological variables as well as agrometeorological indices in different regions of Kordestan province, Iran including Sanandaj, Ghorveh and Bijar districts for the years 2004-05 and 2005-06. On the basis of correlation coefficients, standard error of the estimates and relative deviations of the predicted yield from actual yield using different statistical models, the best subset of agrometeorological indices were selected including daily minimum temperature (T_{min}), accumulated difference of maximum and minimum temperatures (TD), accumulated Photothermal Units (PTU) and Sunshine Hours (SH). The results revealed that in Sanandaj district, yield prediction was performed two months in advance before harvesting time which was coincide with end of the second active vegetative stage after dormancy stage of wheat (March 27th to May 31st). For Ghorveh district, yield prediction was done one month before harvesting time which was at the end of reproductive stage of wheat (May 22nd to June 20th). In Bijar district, although there was a significant relationship between yield and agrometeorological variables but a high relative deviation between predicted and actual yields exists. Therefore, none of the suggested models was used for Bijar district. It can be concluded that in the final statistical models, 68% of wheat yield variability was accounted for variation in the above agrometeorological indices for Sanandaj and Ghorveh districts.

Key words: Wheat yield, prediction models, agrometeorological indices, Kordestan

---

INTRODUCTION

Weather is one of the most important factors affecting the crop growth and yield. The important meteorological variables which influence the growth, development and yield of crops are solar radiation, temperature, rainfall (amount and temporal distribution), relative humidity and wind velocity (Abbate *et al*., 2004; Meena and Dahama, 2004; Reddy and Reddi, 2003). Since crop yield is the culmination of many temporal plant processes and is affected by various external factors related to soil, weather and technology, parameterization of these factors and investigation of their relationship with yield are essential for crop yield modeling (Sharma *et al*., 2004; Dadhwal, 2003). Agrometeorological wheat yield forecasting models were developed for the Ludhiana district, Punjab by Bal *et al.*

Corresponding Author: S.S. Eslamian, Department of Water Engineering, Isfahan University of Technology, Iran

(2004). The multiple regression technique has been employed based on both weather parameters and technological trend. The results showed that the regression models based on weather parameters explained 69% of variation in yield whereas inclusion of technological trend in the model improved the prediction considerably ($R^2 = 87\%$). Bazgeer (2005) showed that there was a significant relationship between the wheat yield and minimum and maximum temperatures, cumulative sunshine hours, temperature difference and pan evaporation in Hoshiarpur and Rupnagar districts of Punjab, India.

In this study, an attempt has been carried out to establish the relationships between wheat yield and meteorological variables in addition to agrometeorological indices to predict wheat yield for different regions of Kordestan province, Iran.

MATERIALS AND METHODS

Fourteen years historical yield data (1991-1992 to 2003-2004) were published by Iranian Ministry of Agriculture (IMA) for Sanandaj and Ghorveh districts and also thirteen years data (1992-1993 to 2003-2004) for Bijar district of Kordestan province were used to develop agrometeorological yield models. To integrate various meteorological variables and agrometeorological indices over different growth phases, wheat growing season was divided into six phonological stages, starting from the planting crop on October 7th up to harvesting on July 21st including: (i) early seedling stage (October 7th to November 6th), (ii) the first stage of active vegetative before dormancy phase (November 7th to December 11th), (iii) dormancy stage (December 12th to March 26th), (iv) the second stage of active vegetative after dormancy phase (March 27th to May 21st), (v) reproductive stage (May 22nd to June 20th) and (vi) maturity stage (June 21st to July 21st). In order to select the best yield predicted model, the statistical analysis was done for each phonological stage.

Meteorological Parameters

Daily meteorological data from meteorological stations including Sanandaj with 35°20' N latitude, 47° 00' E longitude, 1373.4 m above mean sea level (msl) elevation and Ghorveh with 35°10' N latitude, 47 °48' E longitude, 1906.0 m (msl) elevation and Bijar with 35°53' N latitude, 47° 37' E longitude, 1883. Four meter (msl) elevation were used from 1991-1992 to 2005-2006 for this study. Daily maximum and minimum temperatures (respectively T_{max} and T_{min}), Accumulated Rainfall Depth (ARF) and Sunshine Hours (SH) were used as meteorological parameters.

Agrometeorological Indices

Growing Degree-Days (GDD)

The heat unit or growing degree-days concept was proposed to explain the relationship between the growth duration and temperature. The method described by Nuttonson (1955) was selected to compute GDD using a base temperature of 5°C.

Temperature Difference (TD)

Temperature difference was computed using the following expression:

$$TD = \sum_{a}^{b} (T_{max} - T_{min})$$

Where:

TD = Temperature difference
a = Starting date of phenophase
b = Ending date of phenophase

Photothermal Units (PTU) and Heliothermal Units (HTU)

Because of the phasic changes taking place due to the influence of both temperature and photoperiod, it is better to calculate Photothermal Units (PTU) instead of the heat units for accurate prediction of flowering and maturity. Therefore, photothermal units are proposed, where in, the degree days are multiplied by length of the night in case of short-day plants and length of the day for long-day plants (Reddy and Reddi, 2003).

In general, PTU is the product of GDD and day length (maximum possible sunshine hours, N) and HTU is the product of GDD and bright sunshine hours (actual sunshine hours, n). Therefore, they can be computed using the following expressions:

$$PTU = \sum_{a}^{b} (GDD \,.\, N)$$

$$HTU = \sum_{a}^{b} (GDD \times n)$$

Where:

PTU = Photothermal units (°C day hours)
HTU = Heliothermal units (°C day hours)
GDD = Growing degree-days (°C day)
N = Maximum possible sunshine hours (Doorenbos and Pruitt, 1975)
n = Actual sunshine hours

Relative Deviation

In order to evaluate the performance of different yield models for prediction of yields, predicted yields for the years 2004-05 and 2005-06 were compared with corresponding IMA estimates using Relative Deviation (RD) as a measure of prediction accuracy.

$$RD\,(\%) = 100\,[(\text{Model Predicted Yield-IMA Estimate})/(\text{IMA Estimate})]$$

RESULTS AND DISCUSSION

The simple, multiple linear and stepwise regression analysis have been developed (no data due to brevity). On the basis of examination of determination coefficients (R^2), Standard Error of estimates (SE) as well as Relative Deviation (RD) values resulted from different agrometeorological models, the best agrometeorological subset was selected to develop agrometeorological yield models for all of the districts. Accordingly, the appropriate time of prediction for Sanandaj district was found to be at the beginning of reproductive stage i.e., May 22nd (2 months before harvesting) using meteorological data of the second stage of active vegetative after dormancy stage (March 27th to May 21st). The best agrometeorological subset to incorporate in the agrometeorological yield models was selected as T_{min}, TD and PTU.

The final regression equation to predict the wheat yield (Y) for Sanandaj is given below:

$$Y = 34286.01\text{-}6485.27\,T_{min}\text{-}59.19\,TD+8.62\,PTU \qquad (R^2 = 0.684,\ SE = 161.3\ kg\ ha^{-1},\ n = 14)$$

For Ghorveh district, the suitable time of prediction was found to be at the end of reproductive stage i.e., June 20th (1 month before harvesting) using meteorological data of reproductive stage (May 22nd to June 20th). The best agrometeorological subset to incorporate in agrometeorological yield models were selected as minimum temperature (T_{min}), accumulated Temperature Differences (TD), accumulated Photothermal Units (PTU) and Sunshine Hours (SH).

The final regression equation to predict the wheat yield (Y) for Ghorveh is given below:

$$Y = 15550.23-2786.01T_{min}-47.79TD+6.59PTU-79.82SH \qquad (R^2 = 0.683, SE = 152.5 \text{ kg ha}^{-1}, n = 14)$$

In both districts the variation explained by models was 68% and standard error ranged from 152.5 to 161.3 kg ha^{-1}. The results showed that for both of the districts, the agrometeorological yield models explained about 68% of the yield variability that is due to variations in minimum temperatures (T_{min}), accumulated Temperature Differences (TD), accumulated Photothermal Units (PTU) and Sunshine Hours (SH) during the second stage of active vegetative after dormancy stage (March 27th to May 21st) for Sanandaj district and reproductive stage (May 22nd to June 20th) in case of Ghorveh district. In both districts maximum temperature (T_{max}), Accumulated Rainfall (ARF) and Growing Degree-Days (GDD) had no significant correlations with wheat yield.

The results revealed that minimum temperature showed a negative relationship with grain yield. It might be due to the fact that the high night temperatures associated with accelerated respiration, which decreases translocation of photosynthesis from the leaf to grain and hence reduced the yield (Marcellos and Single, 1972). Peters *et al*. (1972) found that a rise in night temperature from 9 to 26°C, reduced grain yield of wheat almost by half by reducing the period of grain filling at maturity phase. TD showed a significantly negative relationship with the yield. It could be due to the higher daily temperatures and lower nightly temperature (high ranges of temperature) resulting in heat and cold stresses at reproductive stage and hence yield adversely affected. Similar result reported by Sharma *et al.* (2004) which indicated that negative correlation between TD and wheat yield during reproductive phase result in frequent termination of grain filling or reduction in grain size. A significantly positive relation between wheat yield and photothermal units might be due to the fact that as wheat is a long-day crop the more day length, the faster flowering stage will be(the shorter floral initiation phase). Therefore, crop could not be faced with the higher day time temperature which caused sterility and hence yield reduction. In fact flowering is hastened as the length of the day increases in long day plants (Reddy and Reddi, 2003).

For Ghorveh district, a significantly negative relation was also found between the wheat yield and sunshine hours. It could be due to the fact that the longer sunshine hours resulting in higher evapotranspiration and water stress and hence the progressive loss of dry weight and overall growth rates become negative (Musick *et al*., 1994; Slatyer, 1967).

In Bijar district, although a significant relationship was found in different models but due to the higher relative deviations between the predicted yields by models and actual ones (63 and 36% deviations for the years 2004-05 and 2005-06, respectively) none of the models was used.

Model Validation

In order to evaluate model validity, the model predicted yields were compared with the corresponding IMA estimates (actual yields) using the Relative Deviation (RD) values for the years 2004-05 and 2005-06 (Table 1), for both Sanandaj and Ghorveh districts.

The predicted wheat yield obtained from these models ranged from -28.5 to 6.5% deviation from actual yield in different years. In Sanandaj district for the year 2004-05, the predicted yield by the model was less than the actual yield (-1.8%) and for the year 2005-06, it was more than the actual one (5.4%). On the other hand, in Ghorveh district, the model predicted yield was higher than the actual yield for the year 2004-05 (6.5%) but for the year 2005-06, it was lower than the actual wheat yield (-28.5%). Comparing performance between the wheat yield predictions and its corresponding IMA estimates (Table 1), it revealed that in both of the districts, the estimated yield using agrometeorological

Table 1: Performance evaluation of agrometeorological yield models for the years 2004-05 and 2005-06

	Sanandaj		Ghorveh	
Variables	2004-05	2005-06	2004-05	2005-06
Actual yield (kg ha^{-1})	1105	1282	879	1284
Model predicted yield (kg ha^{-1})	1085	1351	936	918
RD (%)	-1.8	5.4	6.5	-28.5

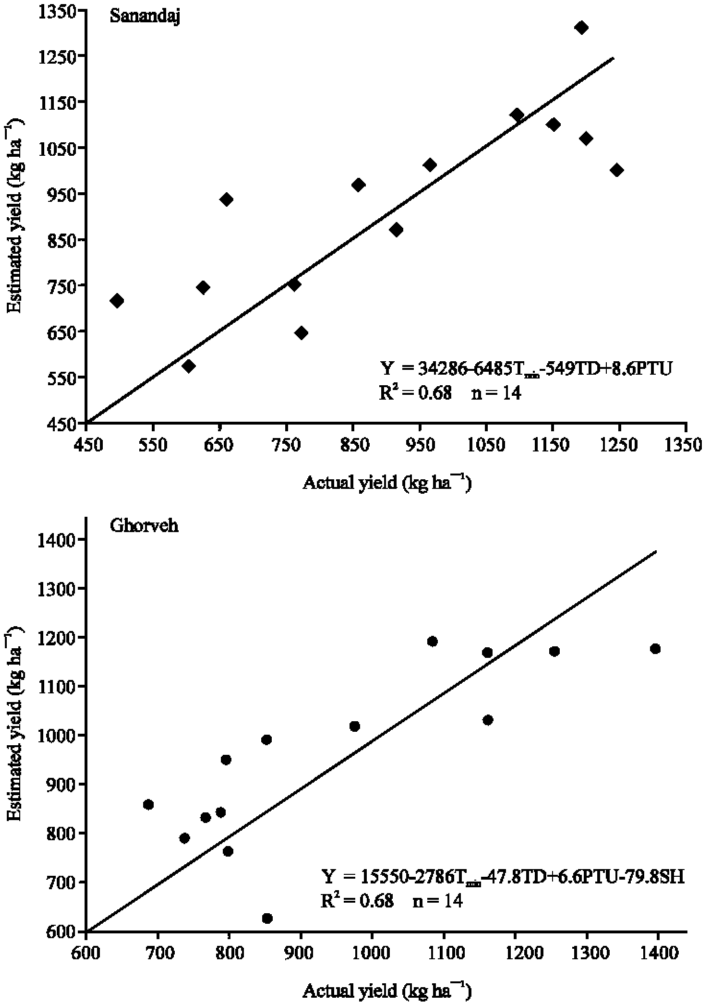

Fig. 1: Relationship between the observed and estimated wheat yields for Sanandaj and Ghorveh districts

models was closer to the actual yield for the year 2004-05 in comparison with the year 2005-06. The response of crop meteorological conditions is not always the same during the entire life cycle of the crop and also with different ranges of the parameters (Mahey, 1999). Figure 1 shows that the estimated wheat yield of different years for both Sanandaj and Ghorveh districts using the agrometeorological models is generally in good agreement with the observed yield from IMA.

CONCLUSION

The wheat yield prediction is better performed when both meteorological parameters and agrometeorological indices are used in combination rather than when they used individually in the model. However, it might be possible to improve the accuracy of yield prediction when agrometeorological indices integrate with remotely-sensed based indices due to the high spatial resolution of satellite data.

REFERENCES

Abbate, P.E., J.L. Dardanelli, M.G. Cantarero, M. Maturano, R.J.M. Mechiori and E.E. Suero, 2004. Climatic and water availability effects on water use efficiency in wheat. Crop Sci., 44 (2): 474-483.

Bal, S.K., J. Mukherjee, K. Mallick and S.S. Hundal, 2004. Wheat yield forecasting models for Ludhiana district of Punjab state. J. Agromet., 6: 161-165.

Bazgeer, S., 2005. Land use change analysis in the submountainous region of Punjab using remote sensing, GIS and agrometeorological parameters. Ph.D Thesis, Punjab Agricultural University (PAU), Ludhiana, India.

Dadhwal, V.K., 2003. Crop Growth and Productivity Monitoring and Simulation using Remote Sensing and GIS. In: Satellite Remote Sensing and GIS Application in Agricultural Meteorology, Sivakumar, M.V.K., P.S. Roy, K. Harmsen and S.K. Saha (Eds.). Proceedings of a Training Workshop in Dehra Dun, India, pp: 263-289.

Doorenbos, J. and W.O. Pruitt, 1975. Guidelines for Predicting Crop Water Requirements. Tech. Note 24, Food and Agriculture Organization of United Nations, Rome.

Mahey, R.K., 1999. Acreage estimation and technique development for yield prediction through remote sensing. Final Technical Report: 8-10/95-AFC dt. 5.1.995/ICAR Adhoc Scheme, Department of Agronomy, Punjab Agricultural University, Ludhiana, India.

Marcellos, H. and W.V. Single, 1972. The influence of cultivar, temperature and photoperiod on post-flowering development of wheat. Aust. J. Agric. Res., 23 (4): 533-540.

Meena, R.P. and A.K. Dahama, 2004. Crop weather relationship of groundnut (*Arachis hypogaea* L.) during different phenophases under irrigated condition of Western Rajasthan. J. Agromet., 6: 25-32.

Musick, J.T., O.R. Jones, B. Stewart and D.A. Dusek, 1994. Water-yield relations for irrigated and dryland wheat in the US Southern plains. Agron. J., 86 (5): 980-986.

Nuttonson, M.Y., 1955. Wheat climate relationships and use of phenology in ascertaining the thermal and photo-thermal requirements of wheat. American Institute of Crop Ecology, Washington DC., pp: 54-55.

Peters, D.B., J.W. Pendelton, R.H. Hageman and C.M. Brown, 1972. Effect of night air temperature on grain yield of corn, wheat and soybeans. Agron. J., 63 (5): 809.

Reddy, T.Y. and G.H.S. Reddi, 2003. Principles of Agronomy. Kalyani Publishers, Ludhiana, India, pp: 48-77.

Sharma, A., R.K. Sood and M.H. Kalubarme, 2004. Agrometeorological wheat yield forecast in Himachal Pradesh. J. Agromet., 6: 153-160.

Slatyer, R.O., 1967. Plant-Water Relationships. Academic Press, London, pp: 287-296.