



Soil and weather based yield prediction model for rainfed areas

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ABSTRACT

Yield Predictor for Rainfed Areas (YPRA) is a desktop based software application developed in VB.NET programming language using Microsoft Visual Studio 2008 IDE with user friendly and self defining menus. This YPRA is the positive modification and conversion of 'RPEI (Relative Production Efficiency Index) based yield prediction concept' into a 'user-friendly software application'. The RPEI is governed by various easily determinable physiographic, soil physico-chemical, biological and climatic parameters. The yields predicted through YPRA will help in promoting climate resilient agriculture by scheming proper crop contingency planning to meet abrupt weather conditions. This software application can predict yield of one single location as well as multiple locations. The per cent contribution of each parameter can be depicted graphically also. The YPRA was calibrated and validated for four locations representing four states of north-west India. On comparing the predicted yield and observed yield, a prediction variation of 0.01 to 6.1% for maize and 3.0 to 9.61% for wheat crop was observed which is quite acceptable keeping in view the diverse physiographic, climatic and soil conditions in these locations.

Key words: Maize, Rainfed agriculture, Relative Production Efficiency Index, Wheat, Yield prediction

Low productivity of maize and wheat grown in rainfed areas is a matter of great concern. The productivity of these crops is affected by the distribution of seasonal rainfall and soil fertility, apart from applied fertilizer nutrients. In India, 30 to 50% loss in maize yield during *kharif* 2008 and 70 to 100% loss of wheat yield in *rabi* 2009 owing to reduced rainfall has been observed in rainfed foothills of north-west Himalayas. It is believed that this loss happens more frequently in north-west Himalayas can be abridged with use of prediction models based on electronic and computer interventions in the agriculture sector.

Correct information of crop yield behavior of a region is critical for formulating contingency planning. However, crop yield can be extremely dispersed from year to year and create complex scenario for predictability (Choudhury and Jones 2014). In general, historical yield distributions are used to develop yield prediction models. Crop yield prediction, which provides information to decision makers, is important in many ways to the economy. Because of its importance, researchers have proposed many forecasting methods to

improve accuracy of yield estimates. However, obtaining accuracy is not an easy task, as many factors have impacts on crop production and thus crop yield. Many methods have been used in yield forecasts and different models have generated different results (Choudhury and Jones 2014).

Keeping the above mentioned facts in mind a software application- Yield Predictor for Rainfed Agriculture (YPRA) was developed to predict maize and wheat yields under different climatic (rainfall/temperature) scenarios in rainfed areas of north-west Himalayas. The software application (YPRA) has been validated with results of many of the on-going experiments under different schemes in rainfed areas of the foothills of Shiwaliks in Punjab, Himachal Pradesh, Rajasthan as well as Jammu and Kashmir states of India, where maize-wheat system is prevalent. Using this software application (YPRA), the yield reduction due to variation in rainfall or at different rainfall scenarios can be predicted and further it can be used to plan and implement the crop contingency planning for both maize and wheat crop to meet abnormal and abrupt rainfall situations. These yield predictions will help in promoting climate resilient agriculture. The YPRA is an innovative decision support tool that has great potential to assist in crop and land use planning of rainfed areas. In the present paper our aim is to inform researchers and planners about the features and utilization of this new software application.

MATERIALS AND METHODS

Yield Predictor for Rainfed Areas (YPRA) is a

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desktop based software application developed in VB.NET programming language using Microsoft Visual Studio 2008 IDE with user friendly and self defining menus. This software application is based on concept of Relative Production Efficiency Index (RPEI) (Sharma and Arora 2010, Sharma *et al.* 2012) and is an attempt to make yield predictions for maize and wheat crops in rainfed areas more precisely and easily. This YPRA is the positive modification and conversion of 'RPEI based yield prediction concept' into a 'user-friendly software application'.

For the knowledge base, regression equations developed on the basis of RPEI were taken to predict crop yields (Sharma *et al.* 2009, 2013). This RPEI is governed by various easily determinable physiographic, soil physico-chemical, biological and climatic parameters. Furthermore, the regression equations used in developing this application are derived from maize and wheat yield data of rainfed areas.

The expert system has two drag down options for crop selection and soil texture. It has data entry boxes for other parameters (i.e. for slope, organic carbon, available N, P, K, cation exchange capacity, pH, average seasonal temperature and seasonal cumulative rainfall). YPRA has further command options, viz. Bulk input, View graph, Calculate and Reset. For displaying output, it has two output boxes labeled as Relative Production Efficiency Index (RPEI) and Yield in q/ha. Besides these options the suitability classes for maize as well as wheat are also displayed on the YPRA application. In order to minimize the chances of error for selecting crop, image of the crop selected gets displayed on the Expert System. Any person with basic knowledge of computers can use this software application.

RESULTS AND DISCUSSION

In extreme north-west India, maize-wheat cropping system is prominent especially in rainfed areas. If we see last 17 years (200-207) land use data, (Digest of Statistics 2017) (Table 1), we can conclude that 90.31 to 93.31% and 61.37 to 73.66% of area under maize and wheat, respectively, is rainfed. Poor socio-economic condition of the farmers and small land holdings is another curse which prevent farmers to adopt modern expensive technologies. About 81.42% of the farmers have land holdings less than 1 ha and around 12.39% farmers have land holdings between 1 to 2 ha (Digest of Statistics 2017) (Fig 1). Hence both these marginal (having land holdings <1 ha) and small farmers (having land holdings 1–2 ha) constitute 93.81% of the farmers of the region. Besides small land holdings, climate change is another curse which farmers of the region are facing. Last 15 years trend revealed that with every one degree rise in cropping season temperature maize and wheat yield reduces by -1.76 and -2.39 q/ha (maize, $y = .76 \times + 65.27^\circ$; Wheat, $y = 2.39 \times + 57.68$). Projected air temperature increases throughout the remainder of the 21st century suggests that grain yields will continue to decrease for the major crops because of the increased temperature on all major grain crops (Hatfield *et al.* 2011). Beyond a certain point, higher air temperatures adversely affect plant

Table 1 Year-wise status of maize and wheat crop in rainfed foothills of north-west India

Year	Area under crops (000 ha)		% area under rainfed		Average grain yield (q/ha)	
	Maize	Wheat	Maize	Wheat	Maize	Wheat
2000-01	330.21	280.96	90.31	73.66	15.92	05.29
2001-02	326.48	259.60	91.12	73.42	16.48	13.21
2002-03	329.46	248.30	91.80	73.02	14.11	16.33
2003-04	321.19	254.66	92.84	72.91	16.59	18.04
2004-05	322.70	252.78	91.94	71.91	15.25	18.92
2005-06	320.92	252.83	91.59	71.13	14.13	18.10
2006-07	323.60	266.11	93.20	72.19	15.05	18.72
2007-08	302.44	278.30	92.73	72.33	15.69	17.82
2008-09	315.81	278.72	92.72	70.94	20.05	17.35
2009-10	311.02	288.94	92.60	69.89	15.66	10.03
2010-11	308.22	290.72	91.89	71.45	17.12	15.35
2011-12	314.03	296.17	93.31	71.64	15.11	16.89
2012-13	310.91	292.38	90.67	71.61	16.48	15.89
2013-14	298.68	292.07	91.96	71.24	17.76	20.60
2014-15	298.87	320.97	93.64	61.37	12.05	09.79
2015-16	293.86	281.87	91.49	70.20	17.82	19.33
2016-17	295.17	290.30	90.51	70.38	18.33	18.89

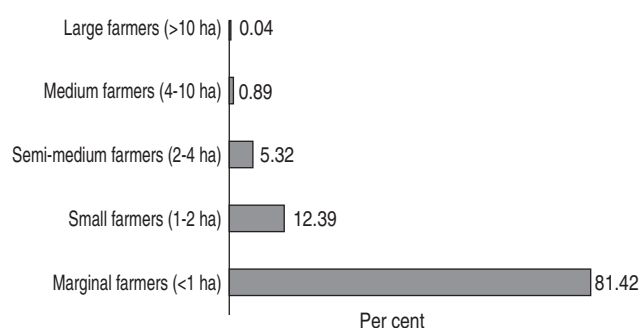


Fig 1 Land holdings of the farmers of rainfed foothill region of north-west India.

growth, pollination, and reproductive processes (Sacks and Kucharik 2011). However, as air temperatures rise beyond the optimum, instead of falling at a rate corresponding with the temperature increase, crop yield losses accelerate. Keeping these constraints in mind, this user friendly software application (YPRA) was developed, which can predict the maize and wheat yields under different rainfall scenarios and can further help in land use planning.

In order to simplify and understand the working of YPRA, an operational diagram was prepared for the user (Fig 2). YPRA has two operational arms— first one shows the path key to predict yield for single location and the second one is the path key for multiple locations.

For single location: The first step to operate YPRA

includes the selection of crop followed by the selection of soil textural class. Next option will work only if the previous option is selected or entered successfully. After selecting the crop and textural class data entry begins. Data is entered in the data entry boxes given in front of each labeled parameters. After entering the data, click on the calculate button, the outputs i.e. RPEI and Yield predicted will display. The value of RPEI can be compared with the suitability classes given below in this software application. If the RPEI value will be extremely low and the area or soil is not suitable for the crop, a message will display as “RPEI very low, not suitable for maize/wheat crop”. The yield predicted in YPRA is on the basis of RPEI. After getting the RPEI value and predicted yield, we can also get a graph (click View graph) reflecting percent contribution of each of these entered/selected parameters towards RPEI.

For multiple locations: We can also go for yield prediction and RPEI evaluation of more than one/multiple locations, having textural similarity, collectively. Here in this case required data is entered and saved in a comma separated file. Bulk input button is clicked, a bulk input window will display. The crop and soil textural class is selected. The comma separated file (prepared earlier) having all the data required is imported by clicking on the import command button. The outputs i.e. RPEI and Yield predicted will display. These results can be exported and can be saved for further utilization.

Validation of YPRA: Initially the YPRA was developed for extreme north-west situations, but later, when tested for some other states it gave very acceptable results. YPRA has been tested/calibrated and validated for representative locations of Punjab (Hadda *et al.* 2004), Himachal Pradesh (Yadav *et al.* 2005), Rajasthan (ORP Annual Report 2010) and Jammu and Kashmir (AICRPDA Annual Report 2008-09) states of north-west India. The observed yield of maize and wheat in Rakh Dhiansar (Jammu and Kashmir) was 19.09 and 20.21 q/ha, where as the yield predicted by using

YPRA was 19.07 and 19.59 q/ha for former and later crop respectively (Table 2). A prediction variation of merely 0.02 (0.1%) and 0.62 (3.0%) q/ha was noticed for maize and wheat crop, respectively. In Johanpur region of Himachal Pradesh the observed yield of maize and wheat was 20.01 and 19.49 q/ha, respectively, where as the simulated yield (using YPRA) was 19.44 (maize) and 20.24 (wheat) q/ha. A prediction variation of 0.57(2.9%) and -0.75(-3.9%) q/ha for maize and wheat was observed in this region of north-west India. The grain yield of 22.7 and 12.7 q/ha for maize and wheat crop was recorded in Hoshiarpur region of Punjab. Here the predicted yield for maize and wheat crops was 21.32 and 13.85 q/ha, respectively. A prediction variation of 1.38 and 1.15 q/ha for maize and wheat crop was observed. In Arjia region of Rajasthan a prediction variation of 5.99 and -9.61% was observed for maize and wheat crops, respectively. The observed and predicted yield for maize in this region was 26.70 and 28.30 q/ha, respectively where as in wheat the observed and predicted yield was 28.40 and 25.67 q/ha, respectively. The prediction variation ranged from 0.01 to 6.1% for maize and 3.0 to 9.61% for wheat crop, which is quite acceptable seeing the diversity in physiographic, climatic and soil conditions within these locations. On seeing the suitability class, for maize crop, based on RPEI values evaluated through YPRA, it was observed that Arjia region of Rajasthan was in suitability class I (i.e. most suitable) where as all the other locations (Rakh Dhiansar, Hoshiarpur and Johanpur) were in class III which means ‘average suitable’. In case of wheat growing areas Rakh Dhiansar and Hoshiarpur were in suitability class III (average suitability) where as Johanpur and Arjia were in suitability class II (fairly suitable for crop production).

The YPRA is an expert-based decision making powerful tool that allows user to predict crop yields in rainfed regions and also guides for soil management to optimize yields. The yield predictions will further help in designing the land

Table 2 Observed and predicted value of grain yield of maize and wheat in four location representing rainfed area

Crop	Actual yield observed (q/ha)	Yield predicted through YPRA (q/ha)	RPEI evaluated through YPRA	Suitability class (as per YPRA)	Prediction variation (q/ha) (%)
<i>Rakh Dhiansar (Jammu and Kashmir) (Year 2008-09)</i>					
Maize	19.09	19.07	73.08	III (average)	0.02 (0.1)
Wheat	20.21	19.59	75.96	III (average)	0.62 (3.0)
<i>Johanpur (Himachal Pradesh) (2002-03)</i>					
Maize	20.01	19.44	73.46	III (average)	0.57 (2.9)
Wheat	19.49	20.24	76.35	II (fairly suitable)	-0.75 (-3.9)
<i>Hoshiarpur (Punjab) (2002-03)</i>					
Maize	22.7	21.32	75.38	III (average)	1.38 (6.1)
Wheat	12.7	13.85	72.50	III (average)	1.15 (9.1)
<i>Arjia (Rajasthan) (2009-10)</i>					
Maize	26.70	28.30	82.50	I (Most suitable)	1.60 (5.99)
Wheat	28.40	25.67	79.62	II (fairly suitable)	-2.73 (-9.61)

Values predicted using Yield Predictor for Rainfed Agriculture ‘YPRA’.

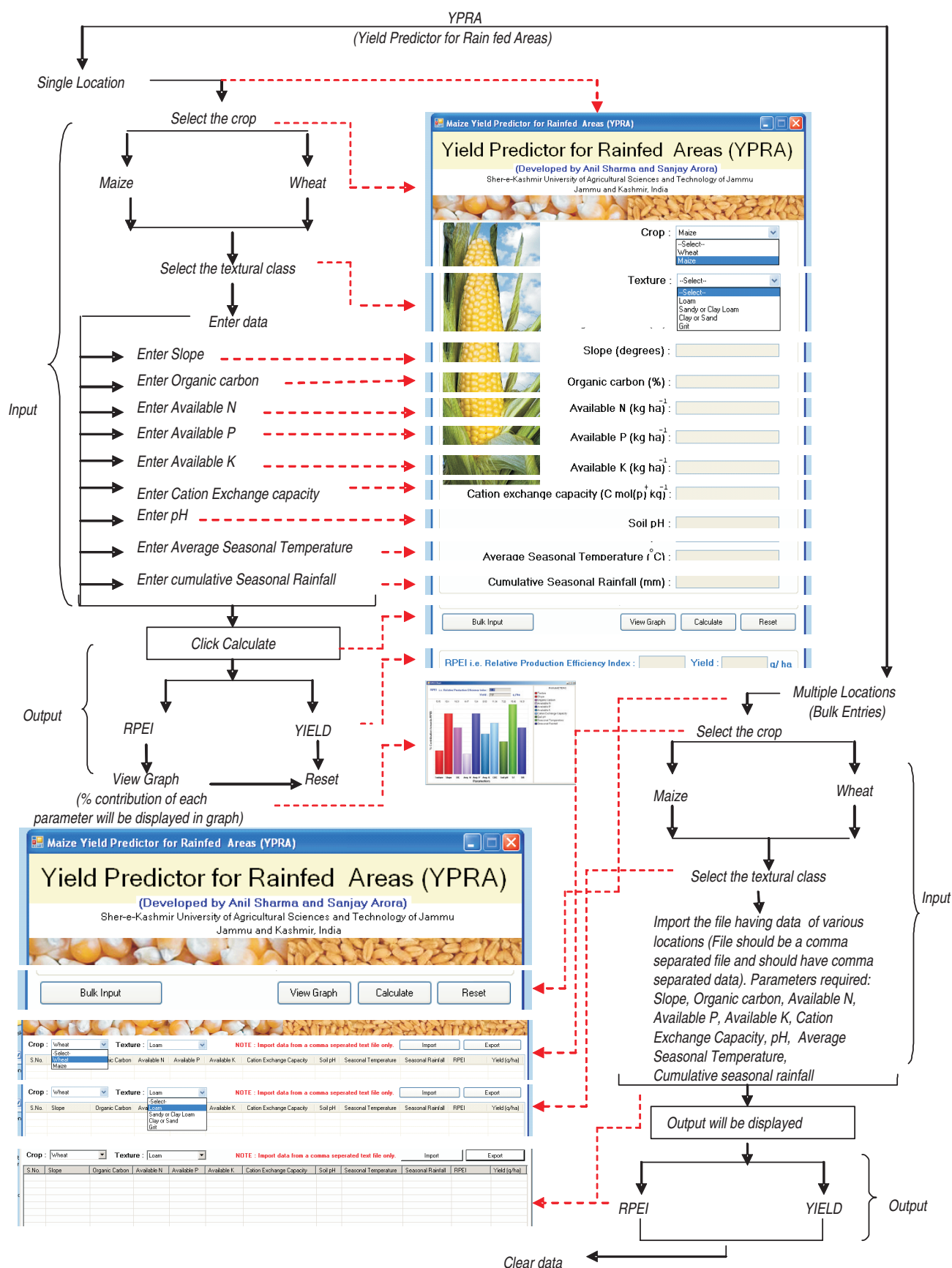


Fig 2 Operational diagram of YPRA.

use and crop contingency planning to meet inauspicious climatic situations.

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