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Modeling and Forecasting of Rice Yield in Western Uttar Pradesh

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A B S T R A C T

This findings of this research presents a new Integrated Farming System (IFS) ver. 1.1 developed model and data sets that can fulfil the requirement of the growing community of end-users which has been demonstrated by a set for rice crop growers. This farm simulation model has been utilized to analyze the effects of the nutrient amendment, pond soil on the yield of rice and the effect of climatic parameters like sunshine and rainfall on crop performance which was then used to calibrate the model for the experimental field of institute's experimental site. Using data the model was validated over the next year's crop cycle at the farm scale. The current study shows how development of integrated farming system (IFS) ver. 1.1 model has been undertaken by simulating the current scenario being confronted by the rice growing farmers of western Uttar Pradesh plain zone resulting in technological modifications that are required to enhance the farming community profitability and productivity. By controlling the management practices which are in control and practically feasible by farmers for example: like date of sowing and application of non-chemical nutrient amendments, farmers have scope to enhance income as well as increase the profitability resulting in use of less input and cost of cultivation thus an increase in cost-benefit ratio. The current study results reveal that technological interventions undertaken based on land use planning results in a system that can result in increased gains and sustainable livelihood through the farming system. This developed model shall act as an informative and innovative tool which can renovate a low paying farming production system into a high compensable farming system while utilizing existing farm resources on a sustainable basis. The suggested model in this study can also be useful in academic purposes which involve in the integrated farming system and its behaviour as well as output in response to variable inputs.

Introduction

This paper deals with the discussion that how the integrated farming system (IFS) ver. 1.1 model has been developed simulating the entire farm based situations faced by innovative farmers of western Uttar Pradesh with desired technological modifications needed to boost the farmers' productivity and profitability on sustainable basis. Through integration of potato crop and practically feasible farm enterprises, better net profitability with lesser annual cost of cultivation with overall holistic higher B: C ratio under (IFS) ver. 1.1 models can be obtained (Sunil Kumar, *et al.*, 2016). These results revealed that induction of IFS principles and technological interventions on the basis of land use planning, the system can fetch better gains and livelihood through their farms. IFS ver. 1.1 model can act as an innovative tool to transform less remunerative farm production systems into highly remunerative systems using available farm resources to generate better farm gains on sustainable basis towards a new generation of agricultural system data models (Miller, 2007).

An important role for crop models is the estimation of yield potential and yield gaps at the site, regional and national levels, identification of reasons for the gaps and evaluation of management options for closing those gaps. Yield potential (Yp), also called potential yield, is the yield of a crop cultivar when grown with water and nutrients non-limiting and biotic stress effectively controlled (Athanasiadis, I.N., 2015).

Crop phenology is the most important means to study the impact of weather on crop plants. It is the study of the timing of recurring natural phenomena such as flowering or senescence of a crop. Information of crop phenology is essential for evaluating crop productivity and crop management (Wheeler *et al.*, 2016).

Scientists involved in simulation studies aim for a new creation of agricultural systems models to quicken progress towards the goal of meeting sustainable global food security challenges. An objective is to develop a form of new, user-friendly analytical tool which can use the available or developed models and the outputs by a much more varied set of practices. Further, the current crop models should be able to simulate the effects of incremental increases in fertility and also to simulate the effects of changes in climatic factors. Farming systems model and statistics are required to yield the expected results that can be used to deliver farm-specific advice related to increase in rice productivity as well as to raise the economic and sustainability of the farmer. The farming system model also tries to address farming issues like labour, costs, risks of losses and managing new developed systems, as these are important and critical components for evaluating the overall sustainability. The simulation model encompassing all or majority of the above-said parameters might yield results that match with real-time crop data in case of simultaneous field experimentation. Otherwise, such model can still be able to predict exact changes in prediction trends even in absence of field experiments once the model is validated (Jones, 2016).

Materials and Methods

The field experiments were done during *rabi* 2017 and 2016 by growing rice variety HD-343 at the IIFSR, Modipuram, farm (29° 08' N latitude and 77° 41' E longitude; msl 237 m) Uttar Pradesh, India. Rice was taken up in maize-rice-rice cropping sequence during both the years. Three treatments were evaluated: T1-Recommended dose of fertilizers, T2-Application of pond soil in the field and T3-Control. The experimental region is of a semi-arid subtropical climate. The average yearly temperature of the experimental area is 16.8°C. The month of May is having the highest mean monthly temperature (38.9°C) and January is having the lowest mean monthly temperature (4.5°C). The average annual rainfall is about 665 to 726 mm in which 80% is during the monsoon period. The soil texture of the experimental site is classified as sandy loam. Soil samples were collected (0–15 cm depth) and tested prior to application of treatments as per design. The soils were low in available nitrogen, organic carbon and medium in accessible phosphorus, potassium and alkali in nature (Fig. 1).

Statistical analysis

The data produced for two seasons by the field experiment was processed and analyzed to ascertain the parameters like grain, straw and above-ground biomass yield and phenological parameters i.e. number of days taken for each developmental stage of rice was recorded for using in model. Comparisons between simulated data were compared for similar parameters and comparison was also made through regression analysis corresponding observed data (Rai and Chandrahas, 1997).

Validation of the model

Validation is the comparison of the results of model simulations with observations from crop that was not used for the calibration. A model should be rigorously validated under widely differing environmental conditions to evaluate the performance of major processes in addition to its ability to predict yield (Timsima and Humphreys, 2006).

Before any model can be used with confidence, adequate validation or assessment of the magnitude of the errors that may result from its use should be performed. Model validation, in its simplest form is a comparison between simulated and observed values. Beyond comparisons, there are several statistical measures available to evaluate the association between predicted and observed values. Among them correlation coefficient (r) and its square, the coefficient of determination (R^2) are widely used parameters. (Willmott 1982) has pointed out that the main problem with this analysis is that the magnitudes of r and r^2 are not consistently related to the accuracy of prediction where accuracy is defined as the degree to which model predictions approach the magnitudes of their observed counterparts.

IFS Simulator ver.1.1 model

A computer based crop model IFSS (Integrated Farming Systems Simulators) was used to simulate the growth, development and yield of rice under middle Meerut agro-climatic region by taking into account the effects of weather, management and genetics. Since the focus of this research is on performance of selected cultivar and applications of this model under middle Meerut agro-climatic region, therefore Tuber yield, vegetative growth, and physiological maturity was switched off during simulation. Since the initial configuration of the model was suited to simulate the performance of longer duration cultivar of crop, it couldn't be fitted for above selected cultivar under this agro-climatic region as such. Efforts were made to create the required input files and to modify several initial values pertaining to the weather, soil, genotypes and management practices. Minimum crop performance data set are required for determining the values of the phonology coefficients initially and then the values of the coefficients describing growth and reproductive development include dates of emergence, beginning of maximum vegetation, Physiological maturity and tuber yield. The procedure for determining genetic coefficients involved in running the model using a range of values of each coefficient, in the order indicated above, until the desired level of agreement between simulated and observed values was reached. Iterations for the coefficients were stopped when the agreement reached ±10 % For the present study the cultivar genetic coefficients based on field experimental data of first crop season *spring*, 2017 for cultivar of rice had been carried out under experimentation.

IFSS Ver.1.1 consists of many different applications, including data programs, crop simulation models and analysis programs for Agro-technology transfer. The following is a very brief description of IFSS models (Fig. 2&3). The main elements in the design techniques are identification of critical inputs and their interactions, software engineering for developing algorithm, calibration, verification and validation of the developed computational model.

Software engineering for developing algorithm

The general methodology for computational modeling system is the design techniques are identification phase, conceptualization phase, formalization, system design & development, testing/evaluation and prototype revision phase. Theoretical concepts and computational methods that describe, represent and simulate the functioning of real-world processes; computer simulations in agriculture system are becoming a 'third way' of performing research, expanding thus traditional experimental and theoretical approaches: simulation can be regarded as a numerical experiment, but it often requires advancements in theory simulations can provide information which is impossible or too expensive to measure, as well as insights which are not amenable or too complicated for analytical theory methods models are simplified abstractions of reality representing or describing its most important/driving elements and their interactions simulations can be regarded as model runs for certain initial conditions (real or designed).

Traditional modelling placed emphasis on mathematical modeling with most models based on partial differential equations. As the vast majority of mathematical models are not solvable analytically, approximate methods and numerical methods are the alternative. Unless the solution behaves smoothly, it may be intractable even with approximate methods. In this case, the only feasible approach is numerical solution. However, even though we can in principle solve a complex system numerically; this does not mean it is trivial in practice. In fact, most research efforts in the last few decades have dedicated to finding the most efficient methods in solving complex systems.

Calibration, verification and validation

Shaalan Khaled *et al.,* (2004) studied that these three steps, calibration, verification and validation are the important steps to bring accurate simulation models. A base model should be created and calibrated so that it matches the area being studied. The calibrated model should then be verified to ensure that the model is operating as expected based on the inputs. Verification is a set of techniques for determining the validity of computational models predictions relative to a set of real data. To verify a model the models predictions are compared graphically or statistically with the real data.

Input identification and their interactions:

Critical inputs and their interface among themselves for optimum output are defined in this phase. In the course of identifying the inputs, it is always advisable to take the minimum but most critical inputs for the simplicity of the model as well as to begin proper interactions among the selected critical inputs. Interaction of the critical inputs should conceptualize the behaviour and mechanism of the projected systems for a particular set of objectives. After founding the idea behind a set of objectives, using the concept of software engineering, algorithmizing the interactions is the next phase for developing of computational model. As per (Shaalan Khaled *et al.,* 2004) calibration, verification and validation are the three important steps to bring accuracy in simulation models. A base model should be formed, calibrated and tested so that it complements the area under study.

The standardized model should then be confirmed to ensure that the model is functioning on the anticipated lines based on the critical inputs. For authentication of a model, the developed model's predictions should be compared statistically/ graphically using the real data.

Results and Discussion

The highest grain yield (5839 kg/ha) was recorded in T_2 in the *khraif* 2017. The mean grain yield of rice during 2016 & 2017 was found higher in T_2 followed by T_1 and T_3. In general higher grain yield of rice was observed in *khraif* 2017 over the *khraif* 2016.The test weight (g/1000 seeds) of rice was recorded higher in treatment T_2. The range of mean test weight of rice was 27.1g to 30.8g. In the *khraif* 2017, test weight was higher in comparison to *khraif* 2016. The trend of grain yield was similar as in the trend of the test weight (Table 1).

Data pertaining to phenological observation *viz*, days taken to panicle initiation (PI), days to flowering, days to milking stages, days to dough stages and days taken to physiological maturity in days are presented in table 2. In the crop season *kharif* 2016, the highest days taken to PI was recorded in treatment T_2 (49.3 days) followed by T_1 (44.7days) and T_3 (41.0days). The similar trend in case of crop season *kharif* 2017 was also recorded. The mean days to PI stage recorded highest in T_2 followed by T_1 and T_3.

The highest days to flowering (63.7days) was recorded in T_2 which was followed by T_1 (58.0days) and T_3 (52.7days) in *kharif* 2016. During *kharif* 2017, a lower day to flowering was recorded in compression to *kharif* 2017. The results of mean days to flowering showed that treatment T_2 has taken higher days (61.3 days) in flowering over the T_1 (56.8days) and T_3 (52.5days). Mean days taken to attained the milking stage by the crop were 71.1days in T_2, 61.2days in T_3 and 60.7days in $T_{1.}$ The highest days taken to milking stages in *kharif* 2016 and 2017 were in the similar fashion among the treatments. Mean days taken to achieve the dough stage by the crops was recorded higher (81.7days) in T_2 followed by T_1 (76days) and T_3(71.5days). The trends of days taken to milking stage were similar in *kharif* 2016 and *kharif* 2017 (Table 2).

Out of 7 parameters related grain yield of rice *viz*, test weight, PI, flowering, milking stage, dough stage and physiological maturity significantly contributed in the determination of grain yield, the coefficient of determination R^2=0.938 is calculated following the stepwise regression analysis. The regression equation {Grain Yield (kg/ha) = 809.7 + 71.3*(test weight) + 160*(PI)-100.3*(Flowering)-21.5*(Milking Stage) + 16*(Dough Stage) + 7.6 *(Physiological Maturity)} was fitted in the model for development of the software for decision support systems as a rice component/module (Table 3 & 4).

Ramdoss and Subramaniam (1980) reported similar result and documented that the number of sunshine hours had positive effect on grain yield of rice. The higher average daily wind speed (4.7 kmph) might be grain yield reducing factor by affecting the flowering phase of the crop during crop season 2016 than the crop season 2017 (4.4 kmph). (Viswambharan *et al.*, 1989) reported the similar result and documented that excessive wind speed during flowering and maturation produces high spikelet sterility and low grain yield. The lower maximum temperature and higher mean vapour pressure and rainfall also might be conducive meteorological factors for higher grain yield in all treatments during crop season 2016 over the 2017. Hoa *et al.*, (1993) reported similar result during study of influence of agroclimatic elements on the grain yield of the rice. (Vkannanagri, 2011) reported that the total rainfall during the crop season was highly correlated positively with yield of paddy. The highest yield among the cultivars of rice irrespective of dates of transplanting during the crop seasons as well as on pooled data basis. It might be due to dual effects of higher accumulation of photosynthesis in to biomass from higher leaf area index during longer crop duration as well as longer grain filling duration.

The comparison of the results of grain yield during 2016 and 2017 separately as well as pooled basis revealed that differences in yield due to differences in the microenvironment created due to different dates of transplanting. Consistency in the best performance of the second date of transplanting was observed in all the four cultivars of aromatic rice and this was mainly attributed to more congenial weather that prevailed during this period as compared the weather that prevailed during the T_1 and T_3 transplanting. The prevalence of the lowest average maximum temperature in T_2 (31.4°C) during end of anthesis to beginning of grain filling (around 100 DAS) in 2016 crop growing season and 30.5 to 31.0°C during same crop phase i.e., around 90 DAS (as early anthesis was recorded in second crop year) during 2017 for same transplanting helped in maximizing the grain yield. (R Kumar 2009) similar result corroborated the findings. The average minimum temperature in the second date of transplanting during both the years was the lowest viz., 17.5°C in 2016 and 23.5°C in 2017 in comparison with that which correspondingly prevailed in the treatments T_1 and T_3.

The lowest value of the average maximum temperature throughout the growing season and relatively low values of average minimum temperature during panicle initiation to beginning of grain filling of treatment T_2 proved themselves congenial for higher grain yield. The average mean temperature i.e., 25.9 and 27.4°C in 20016-17 respectively, was also lower in T_2 in comparison to other date of transplanting during both the crop season. Considerably lower mean temperatures prevailed during the flowering and grain filling stages of the crop grown under T_2 and their beneficial effect was reflected in the grain yield during both the crop year.

Table.1 Yield and test weight of rice during *kharif* 2016 and 2017

Treatments	Grain Yield (kg/ha)			Test weight (g/1000 seeds)		
	2016	2017	Mean	2016	2017	Mean
T_1	4578	5114	4846	26.7	30.8	28.8
T_2	4611	5839	5225	30.0	31.6	30.8
T_3	4248	4617	4433	24.1	30.1	27.1

Table.2 Phenological parameters of rice during *kharif* 2016 and 2017

Treat-ments	Panicle initiation (Days)			Flowering (Days)			Milking stage (Days)			Dough stage (Days)			Physiological maturity (Days)		
	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
T_1	44.7	44.3	44.5	58	55.7	56.8	61.7	59.7	60.7	77	75	76	86	88	87
T_2	49.3	49.7	49.5	63.7	59	61.3	74	69.3	71.7	82	81.3	81.7	91	88	89.5
T_3	41.0	41.0	41.0	52.7	52.3	52.5	63.3	59	61.2	71.7	71.3	71.5	83	79	81

Table.3 ANOVA table of rice crop grown during *kharif* 2016 and 2017

ANOVAc						
	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3800050.378	6	633341.73	5.808	.006a
	Residual	1199462.067	11	109042.006		
	Total	4999512.444	17			

Table.4 Regression models for estimation of the grain yield of rice

Coefficients						
	Model	Unstandardized Coefficients	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	809.68	2762.89		0.29	0.78
	Test weight	71.28	38.93	0.38	1.83	0.09
	Panicle initiation	159.91	107.94	1.08	1.48	0.17
	Flowering	-100.34	49.96	-0.77	-2.01	0.07
	Milking Stage	-21.53	27.08	-0.23	-0.80	0.44
	Dough Stage	15.93	87.44	0.13	0.18	0.86
	Physiological Maturity	7.58	38.09	0.06	0.20	0.85

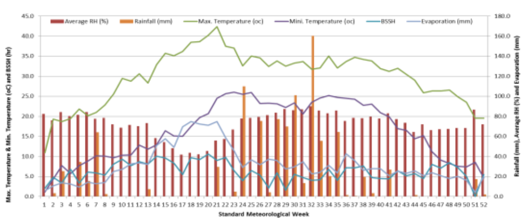

Fig. 1a. Metrological condition of the season 2016

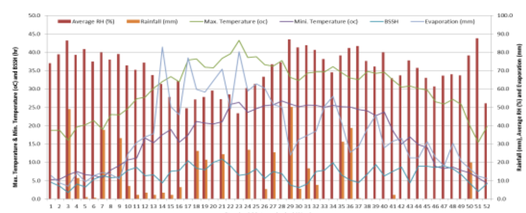

Fig. 1b. Metrological condition of the season 2017

Fig.2 Frontend flowchart of IFSS model

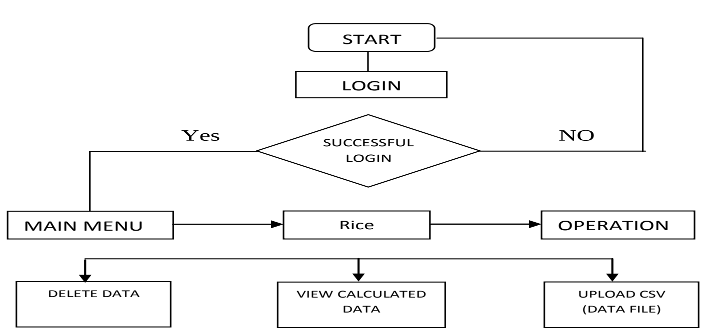

Fig.3 Database structure flowchart of rice model

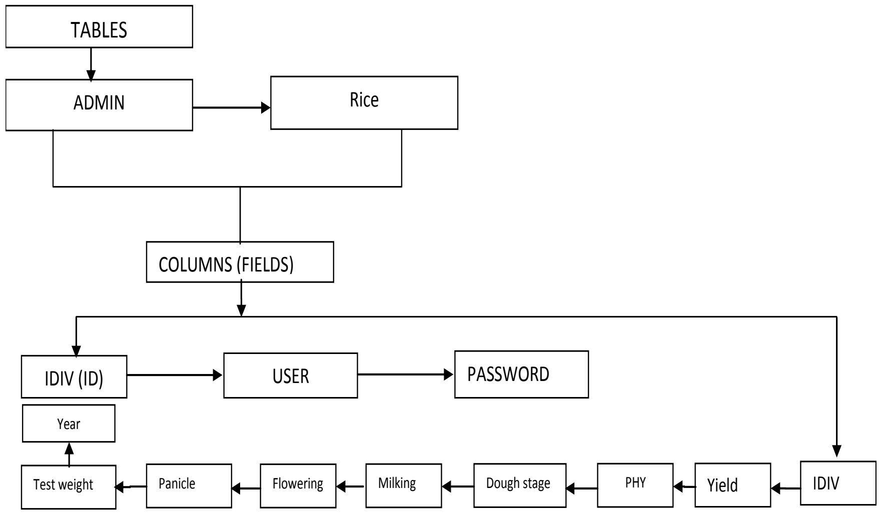

Fig.4 Coding of rice crop algorithm

```
Algorithm - 1:- (Grain Yield (kg/ha) = 809.7 +71.3 *(test weight) + 160 * (PI) -100.3 *
(Flowering) - 21.5*(Milking Stage) +16*Dough Stage+7.6*Physiological Maturity)
//=========================Rice======================
$sql="select * from $category where year='$year'";
$query=mysqli_query($conn,$sql);
if(mysqli_num_rows($query)>0)
$i=1;
while($row=mysqli_fetch_array($query))
{ echo $i;
echo $row['grain_yield'];
echo $row['test_wt'];
echo $row['panicle_initiation'];
echo $row['flowering_day'];
echo $row['milking_stage'];
echo $row['dough_stage'];
echo $row['physiological_maturity'];
 $i++;}
$query1=mysqli_query($conn,"select * from rice where year='$year'");
$count=mysqli_num_rows($query1);
while($row1=mysqli_fetch_array($query1))
{ @$sum+= $row1['grain_yield'];
@$sum1+= $row1['test_wt'];
@$sum2+= $row1['panicle_initiation'];
@$sum3+= $row1['flowering_day'];
@$sum4+= $row1['milking_stage'];
@$sum5+= $row1['dough_stage'];
@$sum6+= $row1['physiological_maturity'];
}echo number_format($sum/$count,2);
echo number_format($sum1/$count,2);
echo number_format($sum2/$count,2);
echo number_format($sum3/$count,2);
echo number_format($sum4/$count,2);
```

These results were in good agreement with the findings of (Yoshida and Parao, 1976) for the grain yield of rice. They reported that the relatively lower temperature during reproductive stage had remarkable effects on increasing spiklet number and hence grain yield. The highest yield of T_2 transplanting might be also due to more or less constant lower mean vapour pressure and wind velocity encountered by the same date of transplanting during reproductive phase in both the crop year. These results highly strengthened the findings of the (Viswambharan *et al.*, 1989) during the study of effects of humidity and wind speed on grain yield, respectively. (Munakata, 1976) had also reported similar result in the case of rice. Reddy (1992) reported similar results and documented that grain yield was negatively correlated with maximum temperature and humidity (vapour pressure) during reproductive phase of the rice crop. Similar results were reported by (Shi and Shen, 1990) and (Samui, 1996) for rice crop.

Coding of rice crop algorithm

Equation

Gr = 809.7 +71.3 *(test weight) + 160 * (PI) - 100.3 * (Flowering) - 21.5*(Milking Stage) +16*Dough Stage+7.6*Physiological Maturity

In the Algorithm:

```
$sql="select * from $category where year='$year'";
$query=mysqli_query($conn,$sql);
```

We use the query to fetch the data on the behalf of selecting category and year then the data will be fetched from the database according to the field which is used in the equation and the equation calculate the prediction for the yield (Fig. 4).

And also display all the data of uploaded csv file through the while loop

```
while($row1=mysqli_fetch_array($query1))
{ @$sum+= $row1['grain_yield'];
@$sum1+= $row1['test_wt'];
@$sum2+= $row1['panicle_initiation'];
@$sum3+= $row1['flowering_day'];
@$sum4+= $row1['milking_stage'];
@$sum5+= $row1['dough_stage'];
@$sum6+= $row1['physiological_maturity'];
}echo number_format($sum/$count,2);
echo number_format($sum1/$count,2);
echo number_format($sum2/$count,2);
echo number_format($sum3/$count,2);
echo number_format($sum4/$count,2);
echo number_format($sum5/$count,2);
echo number_format($sum6/$count,2);
```

in this algorithm we also used the number_format function which is used to print the values 0-infinite after decimal.

```
echo 809.7 +71.3 *($sum1=$data[test_weight]) + 160 * ($sum1=$data[pi]) -100.3 * ($sum1=$data[flowering]) - 21.5*($sum1=$data[milking])
+16*$sum1=$data[dough]
+7.6*$sum1=$data[physiological])
```

The entire calculation sum will be print and display on the screen.

Comparison of model for rice

After examined the rice crop result presented in Table 3 and 4. It was evident from the table that during 2016 crop performed well as compared to 2017 irrespective of transplanting dates during experimentation. It might be due to better weather condition prevailed during crop season 2017 than the crop season 2016 i.e. sunshine hours, maximum temperature, rainfall intensity and equally distribution of rains during the entire crop season and relative humidity. The daily sun shine hours were higher (6.4 h) during the year crop 2016 than the crop season 2017 (5.8 h), however, its obtained more yields of rice cultivars in the year 2016 than 2017. These results were found better than other statistically software analysis of rice crop. Therefore our present trial model was found much better result for other (excel) programme because accuracy of the existing model result was R^2=0.938 than other model accuracy due to R^2=0.889. The coefficient of determination was calculated under the following steps by regression analysis parameters *viz*, test weight, PI, flowering, milking stage, dough stage and physiological maturity that affect the significant contribution in the determination of rice crop yield. Under the study area model used during experimentation was performed better accuracy as compared to other software. However, existing model is used more easy to predict the experimental finding elaborate or explained the crop performance.

Farmers were benefitted by the use of such model on their fields, use of models in farming was done to increase productivity and in turn livelihoods. Modeling technology like IFSS (Integrated Farming System Simulator ver.1.1) was developed for rice crop computational modeling for yield predictions in integrated farming system, which benefitted the entire farmer community in western Uttar Pradesh and also became popular in other regions of India.

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