Original Research Article

Optimizing Rice Yields: A Mahbubnagar Perspective

ABSTRACT

Aim: The main aim of this study is to calculate the potential yields of rice by using Oryza.apsim module and the yields gaps in Mahbubnagar district, for 30 years (1993-2022).

Study area : The study area for this research is Mahbubnagar district of Telangana State, India.

Methodology: Employing the crop simulation model- Agricultural Production Systems Simulator, specifically Oryza.apsim, this study assesses potential and actual yields over 30 years (1993-2022).

Results: Results highlight cultivar-specific potential yields and quantify two types of yield gaps. The decreasing trend in one of these gaps indicates progress but underscores persistent challenges.

Conclusion: This research provides valuable insights for improving rice productivity and addressing food security concerns in Mahbubnagar and similar regions.

Key words: Rice, Potential yield, Agricultural Production Systems Simulator, Oryza.apsim, potential farm yield, etc.,

Introduction

About half of the world's population, or over 3.5 billion people, depend on rice as a main diet. 515.3 million metric tons of rice was produced worldwide in 2022 (USDA, 2022).

According to Indiastat 2022–2023, India produced 314.51 million tons of food grains and 129.66 million tons of paddy in 2022–2023. Mahbubnagar produced 0.2 million tons of paddy, while Telangana produced 9.63 million tons. (Statistical abstract, Telangana, 2022).

Notwithstanding these successes, India's rice output is very low and needs to be increased in order to ~~fulfill~~ meet the country's expanding population's demands. Since there is little room for area expansion, increasing productivity is the key strategy for rice, the crop that millions of farmers choose for both the security of their income and the provision of food for their families. By 2050, there is expected to be a 60% rise in demand for agricultural production, which is a significant but achievable increase (FAO, 2020). There is a significant "yield gap," and bridging it could increase rice production's efficiency as well as productivity.

The difference between the average farmer's production and an estimate of a reference yield or potential output in a particular place in a given time is usually referred to as the "yield gap." The yield of experimental or on-farm plots under known management practices in a given environment at a given period, free from physical, biological, and financial restrictions, is known as the maximum attainable yield. Numerous techniques, including crop growth models, maximum yield trials, other research studies, and best yields from farmers' fields, can be used to define and assess potential yield. Farm level yield is the typical yield of a farmer in a particular location at a specific period within a specific environment.

There are yield gaps because the best production technologies are not being used in farmers' fields. This could be because of the farmers' personal traits (such as their lack of knowledge and skill or their ability to take risks), the characteristics of their farms (such as their soil quality, land slope, or poor roads), or the inadequacy of the technology given their circumstances (such as labor-intensiveness, high initial investment requirements, or limited access to inputs).

Numerous crop models are available that may estimate crop growth and potential yields for specific crop types, as well as for combinations of multiple crops, by incorporating physical variables unique to a given site. Crop simulation models can be used to assess the constraints on crop growth and production because they address the relationships between crop growth and climatic conditions, soil conditions, and agronomic management approaches (Ittersum et al., 2013; Liu et al., 2012). These crop models are a very helpful tool for creating agricultural systems that maximize production outputs since they are frequently constructed using field and experimental data, which provides accurate estimates of plant development and prospective yields. APSIM is one such model.

A ~~modeling~~modelling tool called APSIM (Agricultural Production Systems Simulator) is used to simulate biophysical processes in cropping systems, especially those that have to do with the ecological and production effects of management decisions made in the face of climate risk. It emerged from the necessity for research instruments that addressed long-term problems with natural resource management and offered precise projections of agricultural yield in connection to climate, genotype, soil, and farmer management parameters. A specific emphasis is on simulating agricultural rotations, crop sequences, and fallow times in response to daily soil and climate variables, as opposed to merely single crops (Akinseye et al., 2020). The plant, soil, climate, and management processes are described in multiple distinct modules that make up the modular framework known as APSIM.

MATERIAL AND METHODS:

Details of Study Area

The Indian state of Telangana's Mahbubnagar district served as the study's location. Telangana is a state in south-central India. It is bordered to the north by Maharashtra, to the northeast by Chhattisgarh and Odisha, to the southeast and south by Andhra Pradesh, and to the west by Karnataka. Telangana lies between the latitudes 16.30°and 18. 50° north and between the longitudes of 77.30° and 79.30° east. Telangana belongs to north eastern part of Deccan Plateau. Selection of Mahbubnagar district was done on the basis of productivity (3t/ha), which is low compared to all other districts of Telangana.

Input data required by Oryza.apsim model

Some input data files like weather file, soil file, crop management data are needed for running this model. In Oryza.apsim model, the weather file should be in the form of met. file and the parameters required in this weather file are daily maximum & minimum temperature, solar radiation and rainfall of three selected districts for the selected period of 30 years (1993 to 2022). The soil parameters like bulk density, organic carbon, field capacity, saturation levels at different depths are needed for running this model. The crop management data like harvesting, dates of sowing and, date, amount of fertilizer application, dates of cultural operations are to be included in this model. The genetic coefficient file should also be needed for running this model. This data is collected by conducting survey in the selected district of Telangana and some secondary data is collected from the published literatures.

Model description (APSIM v7.10)

To mimic biophysical processes in agricultural systems, particularly as they relate to the ecological and economic implications of management techniques in the face of climate risk, a comprehensive model known as the Agricultural Production Systems Simulator (APSIM) was developed. It is also being used to look into options and fixes for the issues of food security, mitigating and adapting to climate change, and carbon trading. With features ranging from gene expression modelling to multi-field farms and beyond, APSIM has grown into a framework that comprises many of the fundamental models required to study changes in agricultural landscapes since it was first established 20 years ago.

APSIM is composed of modules for plants, soil, and management. These modules address a wide range of soil processes, including water balance, N and P transformations, soil pH, and erosion, in addition to a diverse selection of crops, pastures, and trees. APSIM was developed in response to the need for tools that provided accurate crop production projections based on soil, climate, genotype, and management factors, as well as those that addressed long-term resource management concerns. In APSIM, there are many modules like Wheat.apsim, Oryza.apsim, Millet.apsim, Agpasture.apsim, etc., In this study Oryza.apsim module was used to calculate the potential yields of the Mahbubnagar district of Telangana

For calculating yield gaps we need potential yields, potential farm yields and actual yields of farmers.

Potential yield (Y_p)

The potential yields are calculated for the selected district (Mahbubnagar) for 30 years (1993-2022) by using simulations of oryza.apsim in APSIM.

Potential Farm Yield (Y_d)

The best yield possible obtained by deftly utilizing the greatest technology currently accessible (research station yields or demonstration plot yields) is known as the "attainable yield" or "potential farm yield."). These attainable yields are obtained from the published sources like IIRR website, PJTSAU website, etc., The average potential farm yield is obtained by doing average of all the cultivars yield and it is found to be 6577 Kg/ha. These Potential farm yields are given in the table 1.

Table 1: Potential farm yield of different cultivars

Cultivar name	**Yield range(kg/ha)**	
	Min	**Max**

Cultivar 1	6400	6600
Cultivar 2	4390	4790
Cultivar 3	6000	6400
Cultivar 4	7000	7300
Cultivar 5	7500	7700
Cultivar 6	6500	7000
AVERAGE	6399	6756
MEAN	**6577**	

Actual yield/District average yield (Y_a)

It reflects the current condition of the climate and soils, as well as the average technological use and skill level of the farmers. It is defined as the average yield (in space and time) that farmers in the region achieve under the most commonly used management practices (sowing date, cultivar maturity, plant density, nutrient management, and crop protection) in order to represent variation in time and space within a defined geographical region. This data was collected from the Directorate of economics and Statistics office, Hyderabad, Telangana.

Total Yield Gap

It is the difference between the district average yield and the actual yield, or potential yield.

Total Yield Gap =Potential Yield (Yp) - Actual Yield / District Average Yield (Ya)

where Yp is the potential yield achieved using the model.

Ya is the harvest that farmers are able to obtain.

Yield gap I

It is the difference between the Potential farm yield and Potential yield

Yield gap I = Potential farm yield (Y_d) - Potential yield (Y_p) …….ii

Y_p is the potential yield achieved using the model.

Y_d is the research station yields

Yield gap II

It is the difference between the Actual yield/District average yield Potential farm yield and

Yield gap II = Potential farm yield (Y_d) – Actual yield/District average yield (Y_a) ……iii

where, Y_d is the yield realized on demonstration plots/ research station

Y_a is the yield realized on farmers' fields

RESULTS AND DISCUSSION

Results are obtained by using the oryza.apsim model and Excel. The results are represented as tables to throw light on the specified objectives of this study. The ~~obtained~~ results are interpreted and discussed under the following heads.

- Calibration and evaluation of model
- Potential yields Simulation
- Rice yield gaps estimation

Calibration and evaluation of model

Eight eco-physiological coefficients are needed for the Oryza.apsim model to simulate rice cultivar phenology, growth, and grain production. Since these values are unavailable, genetic coefficients were approximated using the method recommended by Jones et al. (2003) through repeated iterations until phenology, growth, and yield were closely matched between the simulated and observed data. The several cultivars that were employed in this investigation are listed in Table 2 and include Cultivars 1, 2, 3, 4, 5, 6, and 7. The genetic coefficients are computed using information gathered from the thirty farmers in Telangana's Mahbubnagar districts. Phasic coefficients (P coefficients) and growth coefficients (G coefficients) are two examples of these genetic coefficients. The length of the vegetative, grain filling stages, panicle initiation duration, critical photoperiod—the longest day length at which development proceeds at its fastest rate—potential spiklet number, single grain weight, and tillering coefficient are the definitions of the P1, P5, P2R, P2O, G1, G2, and G3 coefficients, respectively.

Table 2: Different cultivars used in this study

CULTIVAR NAME	DENOTED AS
RNR 15048	Cultivar 1
MTU 1010	Cultivar 2
JGL 1798	Cultivar 3
JGL 18047	Cultivar 4
JGL 24423	Cultivar 5
KNM 118	Cultivar 6

APSIM model validation and calibration are completed by checking with the RMSE, N-RMSE values and all the values obtained are inside the acceptable range. For calibration all the data obtained through the model is exported to excel and calculations are be carried out for each cycle. APSIM models mostly rely on rainfall rather than the other weather parameters like temperature, solar radiation, etc., for simulations. As for potential yields the irrigation water was given adequate there was no change in the potential yield for the 30 years.

Estimation of Potential yield

Simulation has been done for assessing the production potential of the rice crop in the selected district (Mahbubnagar) of Telangana under the normal conditions in oryza.apsim model incorporated in APSIM, the results are represented in the following T~~t~~able 3. This shows that the different cultivars~~ are~~ have~~ing~~ different production potentials,~~.~~ ~~The~~ cultivars 2 & 4 ~~are~~ have~~ing~~ more potential yield ~~compared~~ than the~~to~~ other cultivars. C~~The c~~ultivar 5 ~~is having~~has the lowest potential yield among all the cultivars. These potential yields are found to be the same for all the 30 years (1993-2022). The average of all cultivar potential yields was utilized to determine the potential yield employed in this study, and the result was 9208 kg/ha.

Table 3: Potential yield of different cultivars simulated from APSIM model

MAHBUBNAGAR						
Cultivar 1	**Cultivar 2**	**Cultivar 3**	**Cultivar 4**	**Cultivar 5**	**Cultivar 6**	**AVERAGE**
8595	10727	8255	10698	7767	9208	9208

Estimation of rice yield gaps

The difference between the farmer's yield and the potential yield is known as the yield gap. This yield gap is divided into two sections. They are known as Yield Gap I and II. ~~The following are these yield gaps.~~

Yield gap I

Yield gap I is the difference between potential farm yield (Yd) and potential yield (Yp). Potential yields were calculated from Oryza.apsim model (APSIM) for the selected district of Telangana state. The Potential farm yields were obtained by calculating average of all the major rice growing cultivars. Potential farm yields were mentioned in the ~~table~~ Table 1.

In Ttable 4, yield gap I is tabulated. The yield gap I is similar in all 30 years (1993-2022) and it is 2631 Kg/ha.

Table 4: Yield gap I of Mahbubnagar district

District	**Potential yield** **(Y_p) kg/ha**	**Potential farm yield** **(Y_d) kg/ha**	**Yield gap I (kg/ha)**
Mahbubnagar	9208	6577	2631

Yield gap II

Yield gap II is the difference between district average yield (Y_a) and potential farm yield (Y_d). Potential farm yields were obtained by average of all the major rice growing cultivars and the value is 6577 kg/ha. Potential farm yields are mentioned in the table 1. Decreasing trend is observed in the yield gap II over the years. Yield gap II of Mahbubnagar district were mentioned in the table 5, for all the 30 (1993 to 2022) years. Yield gap II values for the years 1996 and 2022 are 4959 kg/ha and 3273 kg/ha, respectively, at its peak and lowest points. For all 30 years, the average Yield gap II is 4207 kg/ha.

Total Yield Gap

Total yield gap is the difference between District average yield (Y_a) and potential yield (Y_p). Potential yields are simulated through the model,(APSIM) Oryza.apsim for the Mahbubnagar district of Telangana state. Total yield gap of Mahbubnagar district for all 30 years (1993 to 2022) is mentioned in the table 6. The mean total yield gap for 30 years for Mahbubnagar district is 6558 kg/ha. The highest total Yield gap is 7602 kg/ha in 1994 year. The lowest total yield gap is 5450 kg/ha in the year 2019.

Conclusion

This study in Mahbubnagar, Telangana, focuses on rice production's pivotal role and emphasizes the need to enhance productivity. Using the APSIM model over 30 years, it assesses potential and actual yields, identifies cultivar-specific potential yields, and quantifies yield gaps. Results reveal a decreasing trend in one type of yield gap, suggesting progress but underscoring persistent challenges. This study highlights the importance of closing yield gaps for food security, providing insights for informed decision-making and interventions in Mahbubnagar and similar regions, stressing the ongoing need for targeted interventions and improved farming practices.

Table 5: Yield gap II of Mahbubnagar district

Mahbubnagar			
Year	**Potential farm yield (Y_d) kg/ha**	**District average yield (Y_a) kg/ha**	**Yield gap II kg/ha**
1993	6577	1932	4645
1994	6577	2383	4194
1995	6577	1766	4811
1996	6577	1618	4959
1997	6577	1754	4823
1998	6577	2134	4443
1999	6577	2628	3949
2000	6577	1930	4647
2001	6577	1986	4591
2002	6577	1659	4918
2003	6577	2592	3985
2004	6577	2389	4188
2005	6577	2018	4559
2006	6577	2318	4259
2007	6577	2265	4312
2008	6577	2501	4076
2009	6577	2444	4133
2010	6577	2872	3705

2011	6577	2910	3667
2012	6577	2448	4129
2013	6577	2775	3802
2014	6577	2305	4272
2015	6577	2683	3894
2016	6577	2839	3738
2017	6577	2601	3976
2018	6577	2233	4344
2019	6577	2698	3879
2020	6577	2448	4129
2021	6577	2676	3901
2022	6577	3304	3273
Mean		**2370**	**4207**

Table 6: Total Yield gap of Mahbubnagar district for 30 years

Mahbubnagar			
Year	**Potential yield (Y_p) kg/ha**	**District average yield (Y_a) kg/ha**	**Total yield gap kg/ha**
1993	9208	2362	6846
1994	9208	1606	7602
1995	9208	1755	7453
1996	9208	1863	7345
1997	9208	2235	6973
1998	9208	2076	7132
1999	9208	1989	7219
2000	9208	1872	7336
2001	9208	2463	6745
2002	9208	2123	7085
2003	9208	2730	6478

2004	9208	2548	6660
2005	9208	2031	7177
2006	9208	2503	6705
2007	9208	1993	7215
2008	9208	2900	6308
2009	9208	2699	6509
2010	9208	3032	6176
2011	9208	2885	6323
2012	9208	2800	6408
2013	9208	3562	5646
2014	9208	2970	6238
2015	9208	3391	5817
2016	9208	3653	5555
2017	9208	3274	5934
2018	9208	2849	6359
2019	9208	3758	5450
2020	9208	3331	5877
2021	9208	3245	5963
2022	9208	3000	6208
Mean	**9208**	**2650**	**6558**

Ethical approval: Not applicable

REFERENCES

1. Akinseye, F., Hakeem, A., Traore, C.S., Samuel, O and Birhanu, Z. 2020. Improving sorghum productivity under changing climatic conditions: A modeling approach. *Field Crops Research*. 246. https://doi.org/10.1016/j.fcr.2019.107685.
2. Boling, A.A., Bouman, B.A.M., Tuong, T.P., Konboon, Y and Harnpichitvitaya, D. 2011. Yield gap analysis and the effect of nitrogen and water on photoperiod-sensitive

Jasmine rice in north-east Thailand, *NJAS: Wageningen Journal of Life Sciences.* 58: 11-19. DOI: 10.1016/j.njas.2010.05.

3. Dilla, A., Smethurst, P.J., Barry, K., Parsons, D and Denboba, M. 2018. Potential of the APSIM model to simulate impacts of shading on maize productivity. *Agroforestry System*. 92: 1699-1709. https://doi.org/10.1007/s10457-017-0119-0.
4. FAO. 2022. World Food and Agriculture –Statistical Yearbook 2022. https://doi.org/10.4060/cb4477en
5. Fernando, M.E.K.K., Amerasekara, D.A.B.N., Amarasingha, R.K., Suriyagoda, L.D.B., Marambe, B., Galagedara, L.W., Silva, G.L.L.P., Punyawardena, R., Parsons, D and Meinke, H. 2015. Validation of APSIM for long duration rice varieties in different agro-climatic zones of Sri Lanka. *Building Productive, Diverse and Sustainable Landscapes*. www.agronomy2015.com.au.
6. Gaydon, D.S., Singh, B., Wang, E., Poulton, P.L., Ahmad, B., Ahmed, F., Akhter, S., Hochman, Z., Choudhury, B.U., Das, A and Subash, N. 2017. Evaluation of the APSIM model in cropping systems of Asia. *Field Crops Research.* 204: 52-75. https://doi.org/10.1016/j.fcr.2016.12.015.
7. Heinemann, A.B., Oort, P.A.J.V., Fernandes, D.S and Maia, A.H.N. 2012. Sensitivity of APSIM/ORYZA model due to estimation errors in solar radiation. *Agrometeorology*. 71(4): 572-582.
8. Ittersum, M.K., Cassman, K.G., Grassini, P., Wolf, J., Tittonell, P and Hochman, Z. 2013. Yield gap analysis with local to global relevance-A review. *Field Crops Research*. 143: 4-17. http://dx.doi.org/10.1016/j.fcr.2012.09.009.
9. Jing, S.J., Qing, Z.W., Guo, Z.Z., Kang, D., Jie, K.L and Hua, W.Y. 2021. A new feasible method for yield gap analysis in regions dominated by smallholder farmers,

with a case study of Jiangsu Province, China. *Journal of Integrative Agriculture*. 20(2): 460–469.

10. Jones, J.W., Hoogenboom, G., Porter, C.H., Boote, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W., Singh, U., Gijsman, A.J and Ritchie, J.T. 2003. The DSSAT cropping system model. European Journal of Agronomy. 18: 235-265. http://www.uwyo.edu/plantsciences/afri-cap-legumeadoption/_files/pdfs/dssat.pdf.
11. Kumbar, P.C., Patil, R.H., Kubsad, V.S and Naik, R. 2020. Yield gap analysis of major crops grown in northern transition zone of Karnataka. *Journal of Farm Sciences*. 33(4): 464-469.
12. Liu, Z., Yang, X., Hubbard, K.G and Lin, X. 2012. Maize potential yields and yield gaps in the changing climate of northeast China. *Global Change Biology.*doi: 10.1111/j.13652486.2012. 02774.x.
13. Nirmala, B. 2009. Yield gap analysis of rice in Raichur district of Karnataka. *Karnataka Journal of Agricultural sciences.* 22(1): 238-239.