International Journal of Agriculture and Food Science Technology.
ISSN 2249-3050, Volume 4, Number 6 (2013), pp. 553-560
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http://www.ripublication.com/ ijafst.htm

Simulation of Crop Growth Model for Agricultural Planning

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Abstract

The three villages in Dhenkanal Sadar block of Odisha i.e. Khallibandha, Nuagaon and Mandapala villages has been taken as study area. Simulation of growth and yield of a low duration paddy crop has been done using AquaCrop model for the Dhenkanal district situations. Scenario analysis using the AquaCrop model showed that paddy yield can reduce drastically in case of prolonged dry spell. Increase in maximum temperature upto 4^{o}C did not have any adverse effect on the paddy growth and yield. The economical height of the bunds in paddy field was found as 20 cm. The model simulation showed that in a drought affected year, one or two life saving irrigations can reduce the loss of yield in paddy substantially.

Keywords: dry spell analysis, aquacrop model, model simulation.

1. Introduction

In the backdrop of a burgeoning population where food and nutritional security is a constant challenge, agriculture has emerged as a key component for the growth of the Indian economy. The changes in climate parameters are being felt globally in the form of changes in temperature and rainfall pattern. There is also a global trend of an increased frequency of droughts as well as heavy precipitation events over many regions. The IPCC (2007a) projected that temperature increase by the end of this century is expected to be in the range 1.8 to 4.0°C. For the Indian region (South Asia), the IPCC projected 0.5 to 1.2°C rise in temperature by 2020, 0.88 to 3.16°C by 2050 and 1.56 to 5.44°C by 2080, depending on the future development scenario (IPCC 2007b). These environmental changes are likely to increase the pressure on Indian agriculture, in addition to the on-going stresses of yield stagnation, land-use, competition for land, water and other resources and globalization. It is estimated that by 2020, food grain requirement would be almost 30-50% more than the current demand (Paroda and Kumar, 2000). Rainfall contributes to an estimated 65% of global food production, while the remaining 35% global food is produced with irrigation. Not all rainfall that falls in a field is effectively used in growing crops; a part of it is lost by runoff, seepage and evaporation. Only a portion of the heavy and high intensity rains can enter and be stored in the root zone, and therefore effectiveness of this type of rainfall is low. Even though Odisha is endowed with a good amount of annual rainfall, droughts are common phenomenon. There is a loss in crop yield due to irregular rainfall and occurrence of drought. There are several crop models are developed to simulate yield response to water. AquaCrop, a recently developed model by FAO (Doorenbos and Kassam, 1979) is a relatively less complex model and has been used in the current study. The AquaCrop model is a user friendly and practitioner oriented type of model, because it maintains optimum balance between accuracy, robustness, and simplicity, and requires a relatively small number of input parameters. The objective of our study is to simulate the effect of climate change and other parameters on the growth and yield of paddy using AquaCrop model.

2. Materials and Methods

2.1 Study Area

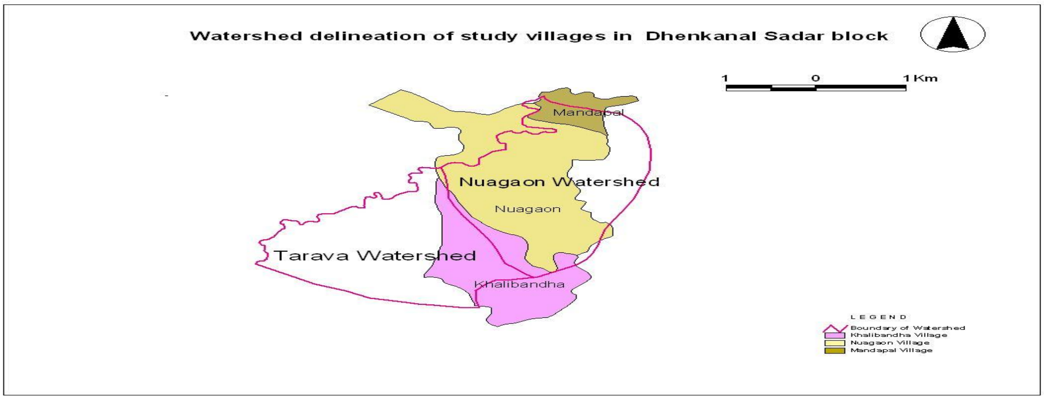

Fig. 1: A View of the Study Area.

The three cluster of villages Khallibandha, Nuagaon and Mandapala in the Dhenkanal Sadar block in the National Agricultural Innovation Project (NAIP) ‘Sustainable Rural Livelihood and Food Security to Rainfed Farmers of Orissa’ were selected as study area in the current study. The three villages are mostly covered under two watersheds namely Tarava and Nuagaon watersheds. The total area under Tarava and Nuagaon watersheds are 481.74 ha and 510.39 ha respectively. The total area of Khallibandha, Nuagaon and Manadapala villages are 247.26 ha, 448.19 ha and 58.92 ha respectively. The rainfall data of Dhenkanal Sadar block was collected from district agricultural office of Dhenkanal. Daily rainfall data of 37 years (1975-2011) was collected to study the rainfall characteristics of the study area.

2.2 Dry and wet spell analysis

The dry and wet spell analysis was done by Markov chain method described by Pandarinath (1991), who considered less than 20 mm rainfall as dry week and 20 mm or more rainfall as wet week. Basing upon the experience, the concept used by Pandarinath (1991) was followed.

2.3 Crop growth simulation by AquaCrop model

Aqua Crop model version 3.1 was used for growth and yield simulation of paddy crop in the Dhenkanal district in the current study. The model was run for a kharif paddy cycle for the year 2007 for which climate data was available. Modeling was done for the short duration Naveen variety of paddy whose crop growing period is 115 days. The crop calendar considered was 5^{th} July to 27^{th} October. Based on the climatic data, field condition and available literature, the input parameters for the model were decided. Soil type was considered deep uniform clay loam profile and soil fertility was considered near optimal (80% level). The model was run for rainfed situation with a field bund height of 30 cm.

2.4 Scenario analysis using AquaCrop Model

2.4.1 Simulation of effect of climate change: - Effect of dry spell on paddy was simulated by considering that in one of the four months of July to September, there was no rainfall at all. Effect of temperature on paddy was simulated by increasing the daily maximum temperature by 2^o and 4^o C respectively. Effect of evapotranspiration on paddy was simulated by increasing the daily evapotranspiration by 1mm and 2 mm respectively.

2.4.2 Simulation of effect of soil fertility: - The effect of soil fertility on the paddy growth and yield was studied by simulating the model for non-limiting (100% level) and moderate (60% level) soil fertility conditions and comparing with the near optimal (80% level) condition.

2.4.3 Simulation of effect of field bund height: - The simulation of effect of bund height on paddy growth and yield was studied by considering a field bund height of 25 cm and 20 cm respectively and comparing with 30 cm bund height.

2.4.4 Simulation of effect of supplementary irrigation: - Effect of supplementary irrigation on paddy growth and yield was studied by providing supplementary irrigation during dry period. The model was simulated for three scenarios i.e.

1. 20 mm irrigation on 28th July.

2. 30 mm irrigation on 28th July.
3. 20 mm irrigation and 28th July and 10 mm irrigation in 11th August.

3. Result and Discussion

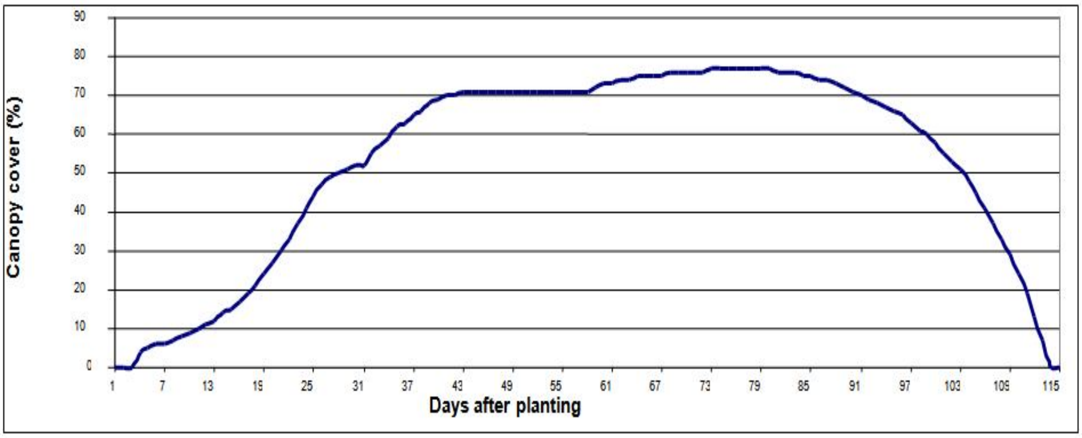

Fig. 2: Variation of simulated canopy cover (%) of paddy over the crop growth period.

The canopy cover reaches to 71% at 43 days after planting, remains constant at that level for about a fortnight and then reaches to a maximum of 77% during the period 73 to 80 DAP.

Fig. 3: Cumulative simulated biomass (ton/ha) and yield of paddy.

The final biomass of the paddy crop is 13.85 ton/ha and harvest index is 40%. The yield of paddy starts at 73 DAP and reaches to a final value of 5.541 ton/ha at the end of the cropping period.

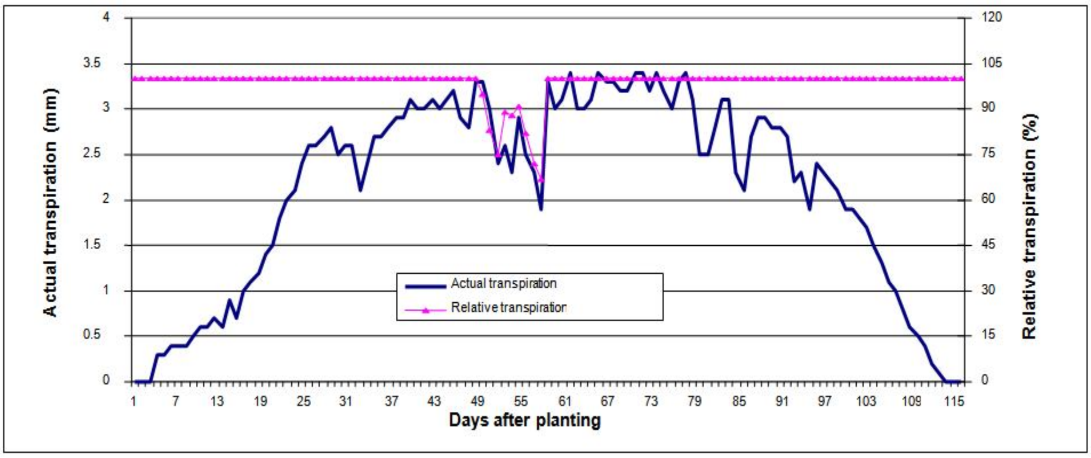

Fig. 4: Simulated actual (mm) and relative transpiration (%) over the crop growth period.

The relative transpiration (%) remains mostly at 100% level except the duration of 49-57 DAP. It indicates that water shortage was faced by the crop only during this 9 days period and at other times; the actual transpiration (mm) was same as that of maximum transpiration.

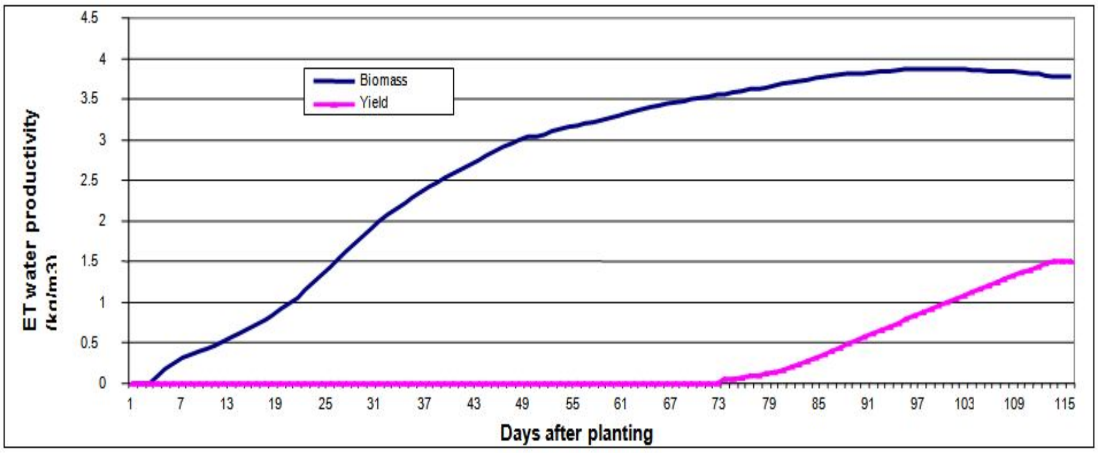

Fig. 5: Simulated ET water productivity of biomass (kg/m3) and yield of paddy.

The ET water productivity of biomass increases from zero at the start of the planting period to reach a maximum of 3.87 kg/m^3 at 95 DAP. It starts decreasing from 103 DAP and reaches to 3.87 kg/m^3 at the end of the cropping period.

Table 1: Simulated biomass and yield of paddy at different dry spell Scenarios.

Scenario	Biomass (kg/ha)	Yield (kg/ha)	Decrease in biomass (%)	Decrease in yield (%)
Calibrated	13.852	5.541	--	--
No rainfall in July	12.172	4.869	12.13	12.13
No rainfall in August	10.067	4.027	27.32	27.32
No rainfall in September	8.772	1.579	36.67	71.50
No rainfall in October	13.832	5.526	0.14	0.27

Table 2: Simulated biomass and yield of paddy at different evapotranspiration scenarios.

Scenario	Biomass (kg/ha)	Yield (kg/ha)	Decrease in biomass (%)	Decrease in yield (%)
Calibrated	13.852	5.541	--	--
1 mm increase in daily evapotranspiration	12.663	5.065	8.58	8.59
2 mm increase in daily evapotranspiration	11.516	4.606	16.86	16.87

However, increase in daily maximum temperature values by either 2^o C or 4^o C did not affect the biomass or yield of the paddy crop. Therefore it indicates that increase in maximum temperature upto 4^o C does not have any adverse effect on paddy.

Table 3: Simulated biomass and yield of paddy at different fertility scenarios.

Scenario	Biomass (kg/ha)	Yield (kg/ha)	Change in biomass (%)	Change in yield (%)
Calibrated – (Near optimal fertility-80%)	13.852	5.541	--	--
Non-limiting fertility (100%)	16.073	6.429	+16.03	+16.02
Moderate fertility (60%)	11.064	4.425	-20.12	-20.14

3.1 Simulation of effect of bund height

The simulation of the model with a field bund height of 30 cm, 25 cm and 20 cm indicated that there is no change in biomass and yield of paddy due to change in field bund height. It shows that even a bund height of 20 cm is sufficient in the paddy field.

Table 4: Simulated biomass and yield of paddy at different supplementary irrigation scenarios.

Scenario	Biomass (ton/ha)	Yield (ton/ha)	Increase in biomass (%)	Increase in yield (%)
Calibrated	13.852	5.541	--	--
Scenario-1	14.023	5.609	1.23	1.23
Scenario-2	14.044	5.618	1.38	1.39
Scenario-3	14.269	5.708	3.01	3.01

Table 4 shows that there has been marginal increase in biomass and yield of the crop due to supplementary irrigations. In the monsoon season, sufficient water is available through rainfall. Hence the effect of supplementary irrigation on plant growth and yield is minimal. However, in scenario 3 there is better increase in biomass and yield of the crop in comparison to scenario 2 even though same amount of water has been applied as supplementary irrigation. In scenario 3, the division of total 30 mm irrigation into 2 irrigation events resulted in better increase in biomass and yield of paddy.

Table 5: Simulated biomass and yield of paddy at different supplementary irrigation levels in a drought affected year.

Scenario	Biomass (kg/ha)	Yield (kg/ha)	Increase in biomass (%)	Increase in yield (%)
Drought affected year	8.772	1.579	--	--
With one supplementary irrigation	10.093	3.742	15.06	136.99
With two supplementary irrigation	11.088	4.364	26.40	176.38

Table 5 shows the effect of supplementary irrigation on the biomass and yield of paddy in a drought affected year. The table shows that there is substantial increase in yield (137 to 176%) due to one or two one or two supplementary irrigations in a drought affected year. It shows the importance of creation of water resources like pond, open well or tubewell so that with one or two life saving irrigations, a significant amount of yield loss can be saved in a drought affected year.

4. Summary and Conclusions

The dry spell and wet spell analysis by Markov Chain model was done and it was found that there is high probability of availability of assured water for irrigation water during the 24th to 38th week.

- Simulation of AquaCrop model indicated that paddy yield can reduce drastically in case of prolonged dry spell. Increase in maximum temperature upto 4^{o}C does not have any adverse effect on the paddy growth and yield.
- An increase in paddy yield upto 16% was simulated under non-limiting fertility condition, whereas a decrease in paddy yield upto 20% was simulated under moderate fertility condition.
- Field bunds of 20 cm height can be optimum in paddy fields.
- In a drought affected year, one or two life saving irrigations can save a significant amount of loss in paddy yield.

References

[1] Doorenbos, J. and Kassam, A.H. (1979). Yield Response to Water. FAO Irrigation and Drainage paper 33, FAO, Rome.pp: 193

[2] IPCC (2007a) Summary for Policymakers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[3] IPCC (2007b) Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22

[4] Pandharinath. N. (1991). Markov chain model probability of dry, wet during monsoon period over Andhra Pradesh, Mousum, 42(4): 393-400.

[5] Paroda, R.S., Kumar P. (2000) Food production and demand in South Asia. Agriculture of Economic Research: 1-25.