Spatial water requirements of rice : Study under various crop establishment methods using GIS and crop models

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Abstract

Linking crop models with Geographical Information System (GIS) have demonstrated a strong feasibility of crop modeling applications at a spatial scale (Engel et al., 1997; Thornton et al., 1997). In the present study, spatial analysis of long- term simulations were carried out with DSSAT spatial analysis tool linked with GIS to estimate irrigation requirements, nitrate leaching under alternate rice establishment methods in the Wargal watershed, Andhra Pradesh, India. The rice yield was compared between two management scenarios- flooded and aerobic rice. Grain yield, seasonal water balance components, nitrate leaching, and water productivity(WP) was calculated, visualized and mapped with GIS. The rice productivity increased by 22% and 27% under aerobic and flooded management compared to rainfed system. The adoption of new water efficient aerobic rice in the watershed resulted in 36% water saving with a relatively smaller yield reduction of 4%, thus increasing the water productivity to 0.77 g kg^{-1} of water compared to 0.56 g kg^{-1} in flooded rice. The aerobic rice method reduced the overall water pumping hours to 88 h ha^{-1} during rice crop season compared to 299 h ha^{-1} with flooded rice cultivation resulting in 71% energy savings.

Introduction

Traditional rice transplanting method of cultivation faces severe yield limitations due to frequent monsoon rain failure, which results in water stress during critical periods of rice growth. To meet the water demands of traditional flooded rice crop farmers need to pump more water from the underground aquifers. This continuous pumping cause drying up of the underground water and creates serious ecological and environmental consequences hence necessitates the development of water saving rice production technologies.

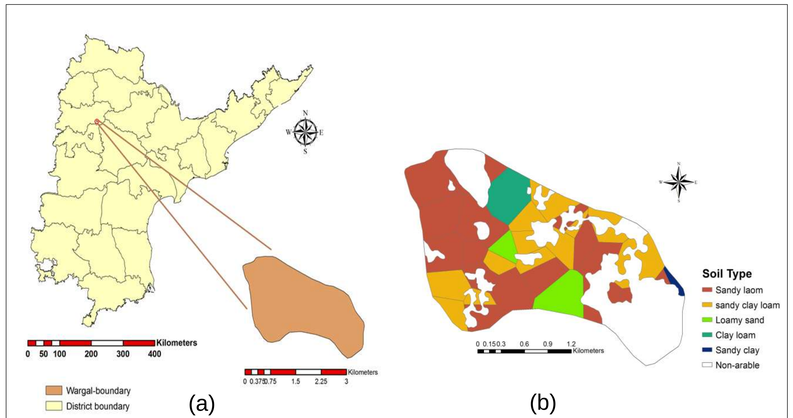

Fig 1(a). Location of study area- Kothakunta sub watershed, Wargal, Medak District, A.P, India, 1(b). Distribution of main soil types.

Methods

- The soil samples were collected from 34 locations across the watershed area (512 ha).The 34 soil reference points were converted into polygons using Thiessen method and were clipped with soil and crop area maps.
- The CERES-Rice model, embedded in DSSAT group models was calibrate and evaluated for rice and was used for the spatial analysis.
- The model was simulated with 180 kg N ha^{-1} for two scenarios- i) flooded rice (irrigation with 20 mm depth of standing water from transplanting to flowering and 50 mm depth of water from flowering to one week before maturity)- ii) aerobic rice (automatic irrigations with 40 mm, when soil available water (ASW) in top 30 cm equals to 60%).
- Simulation runs were performed using 35 years of historical weather data.

- The output results on grain yield, water and nitrogen balance components were mapped to visualize spatial and temporal variability for two scenarios.
- Annual leaching, irrigation withdrawals and drainage were calculated for each polygon and summed to obtain values for entire watershed.

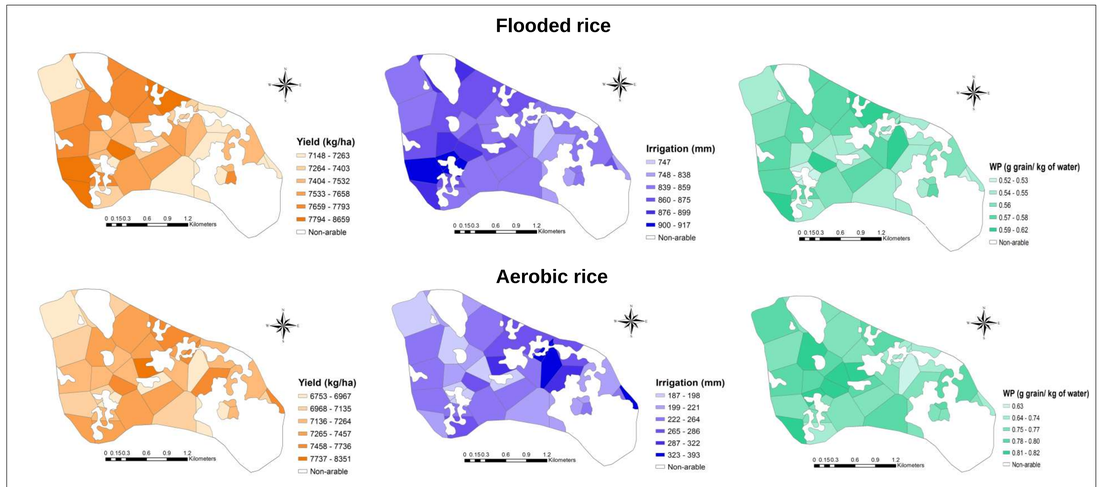

Fig 3. Simulations of CERES-Rice model for grain yield, irrigation amount and water productivity (WP) for flooded and aerobic rice scenarios.

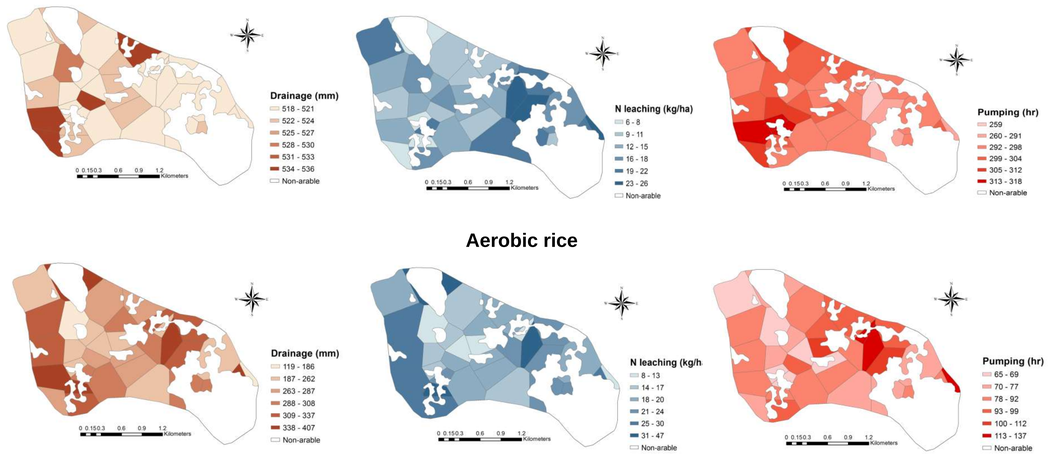

Fig 4**.** Simulations of CERES-Rice model for seasonal drainage, N leaching and pumping hours for flooded and aerobic rice scenarios.

Results

- The adoption of new water efficient aerobic rice in the watershed showed 36% water savings compared to traditional flooded rice cultivation with 4% yield reduction.
- The seasonal irrigation volumes in flooded rice ranged form 747 -917 mm compared to 187 -393 mm for aerobic rice.
- The WP (g grain kg^{-1} of water applied) of aerobic rice (0.63 – 0.82) was higher compared to flooded rice (0.52-0.62).
- Increased irrigation volumes for flooded system resulted in higher runoff and drainage and were lost form the system.
- In aerobic system irrigation was applied at 53% of ET, while it was 198% of ET for flooded rice.
- The nitrogen leaching was ranged from 8 - 47 kg ha^{-1} and 6-15 kg ha^{-1} in aerobic and flooded scenarios, respectively.

Observation	Units	Flooded rice (Mean±SD)	Aerobic rice (Mean±SD)
Production	(1X 10^3 MT)	2.78±0.10	2.65±0.10
Irrigation	(1 X 10^5 m^3)	31.7±3.0	8.70±1.4
Deep drainage	(1 X 10^5 m^3)	19.1±0.6	10.5±2.3
Pumping hours	(1 X 10^4 hrs.)	10.9±1.0	2.98±0.5
N leaching	(MT $season^{-1}$)	5.21±0.19	7.54±2.6

Table 1. Simulations for entire watershed (35 years) for total rice production, irrigation amount, deep drainage and pumping hours for different rice crop establishment scenarios.

Watershed level

- The mean seasonal irrigation applied for entire watershed for flooded rice scenarios were 264% more than aerobic rice method.
- To meet this increased irrigation demand for flooded system, irrigation pumping hours were increased to 2.65 times than the pumping hours for aerobic system.
- In flood rice scenario 60% pumped irrigation resulted in drainage, indicating loss of energy resources for pumping.
- Aerobic method of rice cultivation resulted in 2.33 tons more nitrate leaching per season compared to flooded system.

Conclusions

- This study on spatial and temporal water requirement demonstrated the capability of DSSAT models coupled with GIS for presenting the spatial patterns of simulated results.
- Higher water productivity and water savings are possible in rice cultivation by adopting aerobic rice method.
- Rice cultivation in Wargal area can be converted to the aerobic system to reduce over exploitation of groundwater resources.
- Application of crop simulation models in combination with GIS can be used as a decision support tool for policy makers in deciding maximum allowable irrigation withdrawals at a particular location.

References

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