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Can soil bunds increase the production of rain-fed lowland rice in south eastern Tanzania?

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ABSTRACT

Rain-fed lowland rice is by far the most common production system in south eastern Tanzania. Rice is typically cultivated in river valleys and plains on diverse soil types although heavy soil types are preferred as they can retain moisture for a longer period. To assess the effects of soil bunds on the production of rain-fed lowland rice, the crop was cultivated in bunded and non-bunded farmers' plots under the common agronomic practices in the region, in three successive seasons on Grumic Calcic Vertisols (Pellic). For the three seasons and for the two plot types, crop transpiration was simulated with the BUDGET soil water balance model by using the observed weather data, soil and crop parameters. Comparison between the observed yields and the simulated crop transpiration yielded an exponential relationship with a determination factor of 0.87 and an RMSE of 0.15 tonnes ha^{-1}. With the validated soil water balance model crop yields that can be expected in bunded and non-bunded fields were subsequently simulated for wet, normal and dry years and various environmental conditions. Yield comparison shows that soil bunds can appreciably increase the production of rain-fed lowland rice in south eastern Tanzania in three quarters of the years (wet and normal years) when the soil profile is slow draining (K_{SAT} equal to or less than 10 mm day^{-1}). In normal years a minimum yield increase of 30% may be expected on those soil types. In wet years and when the soil hardly drains (drainage class of 0–5 mm day^{-1}), the yield may even double. In dry years the yield increase will be most of the time less than 10% except for plots with a percolation rate of 0–5 mm day^{-1}.

1. Introduction

South eastern Tanzania borders with the Indian Ocean to the east and Mozambique in the south. In the coastal area, the reference crop evapotranspiration (ETo) is fairly constant throughout the year ranging from 3.5 mm day^{-1} in the dry months to 5.5 mm day^{-1} at the start of the rainy season. The rainfall pattern is uni-modal (Fig. 1). December–April are wet months and the period sets the length of the cropping season (Griffiths, 1972).

Rice is next to maize a popular staple food crop in south eastern Tanzania and ranks third in importance for food

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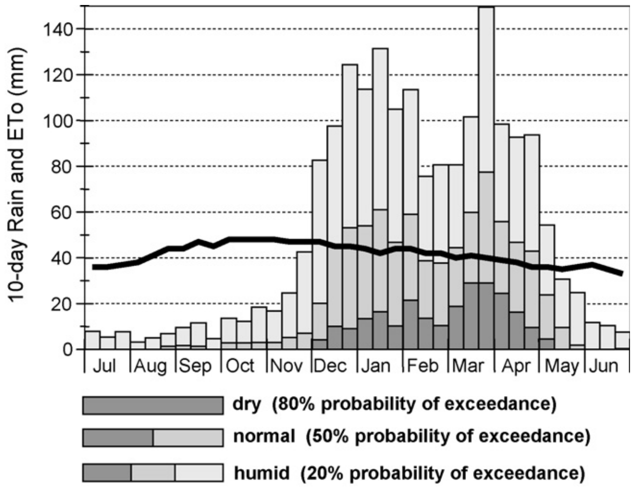

Fig. 1 – Average 10-day reference evapotranspiration (ETo, line) and 10-day rainfall (bars) for various probabilities of exceedance for Mtwara in the coastal area of south eastern Tanzania.

security after maize and cassava (Ministry of Agriculture, 1992). About 94% of the crop is cultivated on smallholdings of about 0.5–2.0 ha. Rain-fed lowland rice is by far the most common production system. In the lowlands rice is typically cultivated in river valleys and plains on diverse soil types although heavy soil types are preferred as they can retain moisture for a longer period. Due to increasing demand for rice consumption, an average of 10–25% of the total consumption is imported annually to cover the shortfall (Kafiriti, 2004).

One of the main problems associated with rain-fed lowland rice in south eastern Tanzania is the erratic rainfall pattern (De Pauw, 1989). The onset, cessation and length of the rainy season, as well the occurrence of long dry spells during the growing season, are extremely variable (Kafiriti et al., 2001). When rainfall is low in a particular decade, it covers only about half of the 10-day ETo (Fig. 1). Hence crop water stress and yield depression occurs often during the rainy season. Even in years with abundant rainfall, average rice yields in farmers' fields are only 2 tonnes ha^{-1} as a result of dry spells and the absence of fertilizers applications. In normal years on average 1 tonnes ha^{-1} rain-fed rice is produced, and in dry years the rice yield drops to 0.5 tonnes ha^{-1} or farmers might even fail to harvest (URT, 2000). Kafiriti et al. (2003) reported average rice yields of 3.2 tonnes ha^{-1} in smallholdings when fertilizers and irrigation are applied. This is still about 50% of the 6 tonnes ha^{-1} that can be obtained under fully controlled conditions in experimental stations.

To reduce crop water stress during the growing season, there have been calls by extension services to promote on-farm rainwater harvesting techniques. Such techniques consist of retaining surface runoff rainwater within the field thereby altering the soil water status within the root zone (Lal, 1995). In rice fields the technique consists of building soil bunds around the fields to store excess rainwater. As bunds around the fields limit surface runoff and therefore raise the efficiency of the rainfall, one would expect a positive effect on the yield of rice. A Benefit–Cost analysis (Senkondo et al., 2004) indicates that rice production with rainwater harvesting is profitable. By considering the magnitude and frequency of the rainfall storms in the region, Maertens (1999) found that 0.15 m is the theoretical optimal height for the soil bunds. However given the roughness of the soil surface, the Gilgay micro relief of the land and the risk of damage by excess rainfall, a height of 0.3 m is recommended for plots of maximum 0.10 ha. Although the extension service has started to promote bunds in the region, the practice is not yet adopted by most of the farmers because of lack of awareness of the importance of bunds in relative flat areas, specific guidelines for where to apply it and the labour involved in the construction of the bunds. No information is yet available for which environmental conditions soil bunds might be effective.

To understand the profitability of soil bunds on the production of rain-fed lowland rice in south eastern Tanzania an experiment was set up in the smallholdings in the region. Rice was produced in bunded and non-bunded farmers' plots in three successive seasons. In this paper the results are analyzed and used to calibrate and validate a simulation model. Rice yields that can be expected in bunded and non-bunded fields for various environmental conditions were subsequently simulated with the calibrated model. The results are currently used to formulate guidelines for farmers.

2. Material and methods

2.1. *Classification of years*

Long series of daily rainfall were collected for three locations in the region (Table 1). To classify the years in wet, normal and dry years, the total rainfall during the five wet months (December–April) was analyzed with the RAINBOW software (Raes et al., 1996, 2006b). Although series of wet years alternates with series of dry years in cycles of about 10-years, the homogeneity test revealed that the analysed periods can be considered as more or less homogeneous. The statistical tests in RAINBOW revealed that the total rainfall for Lindi and Masasi and the square root of the total rainfall for Mtwara during the five wet months are normal distributed. By means of a frequency analysis the total rainfall that can be expected with various probabilities of exceedance in the wet months were estimated (Table 2).

2.2. *Observations in farmers' fields*

In the lowland close to Mkwaya (39°39′E, 10°08′S, 40 masl), rain-fed rice is cultivated for over 20 years in a large number of small plots of 100–500 m^2. In the growing seasons 2002/2003, 2004/2005 and 2005/2006 about 30 farmers scattered over the cultivated area were selected. Each farmer was requested to cultivate rice in a bunded and a non-bunded plot by respecting identical agronomic practice. The average bund height was 0.30 m. Water from the non-bunded plots, was drained to plots which did not belong to the experimental set-up. Land preparation with a hand hoe started typically in October. Ploughing in of crop residues and weeds was done in wet fields. When the fields are still too dry to plough, the residues