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Review

Narrowing the rice yield gap in East and Southern Africa: Using and adapting existing technologies

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ABSTRACT

The importance of rice production in sub-Saharan Africa (SSA) has significantly increased over the past decades. Currently, rice plays a pivotal role in improving household food security and national economies in SSA. However, current rice productivity of smallholder farms is low due to a myriad of production constraints and suboptimal production methods, while future productivity is threatened by climate change, water shortage and soil degradation. Improved rice cultivars and agronomic management techniques, to enhance nutrient and water availability and use efficiencies and to control weeds, have the potential to increase yields. The aim of this study was to assess the relative contribution of such technologies to enhanced rice productivity. Relative yield gains emanating from nutrient, water and weed management were surveyed and calculated from literature. Partial budgeting was used to evaluate viability of fertilizer technology under GAP. Substantial yield gains ranging from 0.5 t ha^{-1} to 2.9 t ha^{-1} are projected following the use of improved technologies. Relative yield gains decreased in the following order: weed management (91.6%) > organic fertilizer application (90.4%) > bunding (86.7%) > mineral fertilizer application (51.9%) > tied ridges (42.6%). Combining fertilizer with unimproved rice cultivars led to negative returns. The lack of integration of improved technologies, to increase synergies and alleviate socio-economic constraints, largely explained the existing yield gaps. The gains obtained through improved rice cultivars can be further enhanced through application of Good Agricultural Practices (GAP), improving nutrient, water and weed management technologies, based on the local resource availabilities of small farms. We therefore propose adapting technologies to local conditions and developing and using rice production decision tools based on GAP to enable rice farmers in SSA to improve resource-use efficiencies and crop productivity at the farm level.

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1. Introduction

The importance of rice as a commodity has significantly increased over the past decades in Sub-Saharan Africa (SSA) (Seck et al., 2010). Rice plays a pivotal role in African rural household food security and national economies. Since the 1990s urbanization and increased income associated with rural–urban migration (Kennedy and Reardon, 1994) has led to an increase in per capita rice consumption. In SSA rice grain yield per unit area and the total area under production have stagnated (Otsuka and Kalirajan, 2005). There are however still possibilities to expand area under rice and improve productivity given the positive land balance (FAO, 2010) and the relatively low level of adoption of modern technologies (Balasubramanian et al., 2007). Clearly, there is a need to study important yield reducing factors closely in order to determine strategies to help increase and maintain rice productivity on farmers' fields and, through that, overall regional rice production.

In East and Southern Africa (ESA), Madagascar and Tanzania are the major rice producing countries (Table 1), while Rwanda is the smallest producer (FAO, 2010; Kanyeka et al., 1996; Rodenburg and Demont, 2009). In terms of area under rice, the rain-fed lowlands are the dominant ecosystems in ESA, comprising 55% of the total area. Irrigated rice ecology (both highland and lowland) comprises 27% while rain-fed uplands comprise 18% of the area under rice. Though there are disparities across countries in the region, the biophysical conditions in ESA (topography, water reservoirs, rainfall distributions and soils), suggests that there is untapped potential for improving rice production.

Ferralsols, Acrisols, Arenosols, Nitosols and Lixisols are the dominant soil types found in the ESA region (Bationo et al., 2006; Bekunda et al., 2002; Hartemink, 1997; Nandwa and Bekunda, 1998). Due to erosion and degradation, soils on uplands are relatively less fertile and more acidic than those on lower positions on the catena, with the latter being accumulation zones for soil mineral sediments, nutrients, organic matter and (rain or run-off) water (e.g. Andriesse et al., 1994; van der Heyden and New, 2003). It is for this reason that there exist a relatively large agricultural potential in rain-fed lowland systems (inland valleys, also known as *mbuga* in East Africa and *vleis*, *dambos*, *mapani* or *matoro*, and *inuta* or *amaxhaphozi* in Southern Africa according to Acres et al. (1985)) in particular for rice production (e.g., Rodenburg et al., 2014). However, the lowland ecosystems should not be developed indiscriminately for the sole purpose of agricultural production, as they are often fragile or harbour a range of natural resources (e.g. biodiversity) linked to important ecosystems functions worthy of conservation (e.g., McCartney and Houghton-Carr, 2009; Sakane et al., 2011; Verhoeven and Setter, 2010).

There is a growing realization that rice production is important for advancing the agricultural contribution to the national GDP (e.g., Seck et al., 2012). In Madagascar for instance, rice is the main staple food crop and an important export commodity (Garenne, 2002), while Kenya, Mozambique and Uganda are net importers of rice (NPA, 2007). Improving domestic production can reduce imports. If production increases alongside quality, for instance through investments in post-harvest grain-quality infrastructure, it will augment the market share of locally produced rice (e.g., Demont and Rizzotto, 2012). However, major constraints to rice production are of biophysical (i.e. soil nutrient depletion, weed infestation, variable rainfall patterns, low and under-developed irrigation infrastructure), socio-economic, institutional and political (i.e. lack of financial resources, labour shortages, low levels of education, weak infrastructure, lack of conducive policies)nature. Solving these constraints could bridge the existing large gap between current farm level production and the potential production.

The term 'yield gap' is used to indicate the difference between the biological and climatic potential yield and the average actual crop yield produced by farmers (Lobell et al., 2009). Factors affecting crop growth and development are radiation and temperature (yield determining), water and nutrition (yield limiting); the attainable yield is the potential yield limited by these two factors in a given environment (Rabbinge, 1993). An additional factor affecting crop growth is pest and diseases (yield reducing). In addition, productivity is also determined by factors such as cultivar choice and crop management. The interaction between the above factors determines the actual yield level at a particular location. In irrigated areas productivity is primarily determined by radiation and temperature whereas in rain-fed areas, precipitation and soil moisture storage capacity are important factors (De Wit, 1992).

Table 1
Harvested area under cultivation (ha) and mean yields (kg ha^{-1}) for rice under rainfed upland (RU), rainfed lowland (RL) and irrigated ecosystems from 8 countries in East and Southern Africa.

Country	RU	RL	IR	Total Area (ha) × 1000	Rice yield (kg ha^{-1})
Burundi	4	74	21	21	3310
Kenya	0	0	100	19	3570
Madagascar	29	18	52	1300	2770
Malawi	0	72	28	53	1740
Mozambique	39	59	2	204	960
Rwanda	0	92	8	10	4400
Tanzania	23	73	4	665	1860
Uganda	45	53	2	119	1360
Regional share (%)	17.5	55.3	27.2	–	–
Total area under rice				2391	
Average yield (kg ha^{-1})					2496
Standard deviation of the mean					1204
Difference in yields (kg ha^{-1})					3440

FAO (2010).