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Comparing the Economic Performance of Two Rice Technologies in West Kano Irrigation Scheme, Kenya

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Abstract

The contributions of rice in alleviating hunger and poverty among rural households in Kenya has led to the belief that better rice technologies can contribute in enhancing the role of rice in poverty reduction. It is for this reason that this study attempts to analyse the economic performance of rice technologies and their effects to rural households in West Kano Irrigation Scheme (WKIS) of Western Kenya. The study involved a survey of 123 households on their rice farming activities and field experimental trials on Conventional paddy and Systems of Rice Intensification (SRI) technologies. Conventional paddy system is a method of rice production where about 21 days or older seedlings are transplanted. Random planting and smaller spacing, usually 20cm by 15cm spacing or less is maintained, with 2 to 3 seedlings per hill, while on the other hand, SRI is rice production technology which involves transplanting 8-12 days old seedlings to the main field in order to maximize the tillering potential with single seedling per hill, with a wider spacing. Results of the study indicated that 89% of the households produced rice for both consumption and commercial purposes. Findings also indicated that the SRI system saved about 64% of water compared to the conventional paddy system. Experimental results showed that the yield difference between Conventional paddy method and SRI when 12 days old transplanted seedlings for SRI were compared with 21 days old seedlings for Conventional paddy system, the yields for IR2793 rice variety when SRI was used increased by up to 33.4 % compared to Conventional paddy method. In the case of basmati 370 rice variety, SRI increased grain yield of up to 53.3 % compared to Conventional paddy method. The study reveals that SRI method of rice production saves about 64% of water compared to the Conventional method. Furthermore, net revenue margins for SRI was higher by KSh. 58,275 (US 583) per acre of land. In conclusion, therefore, there is need to adopt the SRI method of spacing 25cm by 25 cm, since water is a very scarce commodity in the study area. Hence, adoption of this SRI method of rice production would be an important instrument for poverty reduction among the rural households of West Kano irrigation scheme and Kenya at large.

Key Words: Rice, Technology, Conventional Paddy System, SRI, WKIS

Introduction

Besides maize and wheat, rice has transformed into the third most important staple food in Kenya (GOK, 2005). This new development is attributed to progressive change in local eating habits. Consequently, there has been an increasing demand for rice consumption at a rate of 12% as compared to 4% for wheat and 1% maize (GOK, 2008). However, domestic demand continues to exceed supply despite the existence of great potential for rice production in Kenya. As such, agriculture still offers more possibilities for poverty alleviation and employment creation than other sectors (Adofu, Shaibu & Yakubu, 2010). In agreement with this argument, Bola, Aliou and Omonona (2012) estimated that a 1% increase in agricultural productivity reduces the percentage of poor people living on less that 1 dollar a day by between 0.6% and 2%. Expansion of rice production is therefore, not only an opportunity to reduce the number of food insecure Kenyans that stand at 3.5 million, but also an opportunity to reduce unemployment (Olielo, 2013).

Rice in West Kano irrigation scheme is faced with high demand for the already scarce water resource, increased cost of inputs including heavy dosage of chemical, fertilizers and less returns causing negative effect on the livelihoods of the farmers (Mukumbu, 1987; Kipkorir, 2012b). Results from a study conducted in three irrigation schemes showed that over 93% of all the households in Ahero, West Kano and Bunyala irrigation schemes primarily depend on rice production as the main source of income (Kipkorir, 2012a). The national rice consumption is estimated at 300,000 metric tons compared to an annual production range of 45,000 to 80,000 metric tons. The deficit is met through imports which were valued at KShs. 7 billion in 2008 (Mati, 2010) and paid through tax-payers money, among them being the rice farmers of West Kano Irrigation Scheme. This therefore makes it important to increase the local production of rice in saving the country's import costs. This can be made possible through improvement of technological progress, including development of new rice production technologies (Kim, *et al*., 2012).

There are two main methods of rice production: Conventional paddy system, the main method applied at WKIS, and which requires a lot of water through flooding of the rice fields, with smaller spacing per hill; and SRI which requires little usage of water and wider spacing of rice hills. SRI has not been adopted in WKIS like conventional paddy system. It is against the foregoing background that the study was carried out on rice technologies to determine their economic significance and suggest the most productive technology to be adopted for increasing rice production. To the researcher, there is no known literature done on comparing economic performance of the two rice technologies in WKIS. Due to this limited literature, this study attempts to bridge the knowledge gap.

The overall objective of the study was to determine the economic performance and effects of two rice technologies used in rice production in West Kano Irrigation Scheme of Western Kenya in relation to improving livelihoods in the households in the scheme and other schemes in Kenya. The specific objectives of the study are to: (i) establish impacts of rice productivity on livelihoods among rural households in West Kano rice scheme (ii) determine effects of conventional paddy and SRI technologies on rice productivity in West Kano rice scheme and (iii) determine factors affecting adoption of System-of-Rice-Intensification (SRI) method in West Kano rice scheme.

Conventional and SRI Rice Production Technologies

Conventional paddy system is a method of rice production where about 21 days or older seedlings are transplanted. Seedlings are uprooted from the nursery; the nursery bed soil is removed from the root zone before binding and transporting to the main field. Random planting and smaller spacing, usually 20 cm by 15 cm spacing or less is maintained, with 2 to 3 seedlings per hill. This method prefers static water so as to help in weed suppression thereby eliminating weeding (Singh, Shankar & Bora, 2007). On the other hand, SRI is rice production technology where seedlings are raised in the nursery in a manner that they can be transplanted along with the seedbed soil without disturbing the root system. This involves transplanting 8-12 days old seedlings to the main field in order to maximize the tillering potential with single seedling per hill (Norman, 2013). A wider spacing is recommended in SRI to create better micro-environment for higher number of tillers unlike conventional paddy method. SRI method alternates wetting and drying from 14 days after transplanting to the end of vegetative stage unlike the Conventional paddy method (Mati, 2010). SRI requires frequent mechanical weeding, as opposed to chemical weeding. A sub-saturated to saturated soil-water environment is preferred. This assists in channelling the energy required to create aerenchyma (air pockets) in the roots under anaerobic conditions to better productivity.

Scarcity of resources (land, water, labour, capital inputs, finance to purchase the inputs) for rice production demands the need of an efficient rice production method. This justifies the need to analyze input use and rice yields of the two technologies of rice production. The communities of West Kano irrigation scheme stand to benefit from this study through better resource allocation and subsequent increase in rice yields that would better their livelihoods.

Materials and Methods

Study Area

The field study was conducted in West Kano Irrigation Scheme. West-Kano irrigation scheme is in Nyando River basin and located in the Kano plains between Nandi Escarpment and Nyabondo Plateau on the shores of Lake Victoria. It falls within Kisumu Sub-county in Kisumu County. The scheme has 782 households with a gross area of 1,780 Ha and farm size of 1-4 acres (GOK, 2013). The scheme also is divided in 17 blocks. The Nyando River basin covers an area of 3,500 km^2 of western Kenya, and has, within it, some of the most severe problems of agricultural stagnation, environmental degradation and deepening poverty, with its level in Kisumu sub-county being at 66 % (GOK, 2003). West Kano rice irrigation scheme is part of broader study funded by the National Council of Science and Technology (NCST) through the "3 Competitive Science, Technology and Innovative Grant" (Ref: NCST/5/003/3rd STI CALL/188) that ran from 01 January 2011 to 01 January 2014.

Production Effects and Livelihood Model

The production of rice requires a combination of factors: land, labour, water, capital inputs, entrepreneurship and finance to purchase the inputs; all these combinations affect output (Clayton, 1995) of rice production. Consequently, the effect of rice production on rural livelihoods will be measured by mode of truncated normal distribution (i.e., T_i) assumed to be a function of rice productivity factors as shown in the relationship below (also refer to Ogundele & Okoruwa, 2006):

$$T_i = \beta_1 K_{1_i} - \beta_2 K_{2i} + \mu \quad \text{........ (1)}$$

Where T_i is rice incomes of rural households, K_{1i} is rice yields in Kgs, K_{2i} is rice inputs (water costs for maintenance and operations in KShs, organic and inorganic fertilizers in Kgs, pesticides and herbicides in litres, land in acres, labour in person days*),* μ is error term, while β_0 - β_3 are parameters to be estimated.

Population and Sampling Procedure

The population of the study is rice farmers in West Kano irrigation scheme, Kisumu County, Kenya. The population size is 782 households. The sample size was derived based on equation 2 (Sumukwo, Adano, Kiptui, Cheserek & Kipkoech, 2013):

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad \text{..................... (2)}$$

Where n is sample size, N is population size, C is coefficient of variation (30%) and e is standard error (2.5% of target population). Therefore the computed sample size, n, was 123 households.

In determining the respondents (households and persons), the study was guided by the rice blocks and population per block, where a representative sample size from each of the 17 blocks was chosen based on equation

2. The records of farmers per block were obtained from National Irrigation Board Western regional office, Ahero. The 123 questionnaires were distributed in a systematic sampling method: the village to start with was determined through making a ruffle of the first 5 households, out of which household number 2 was picked. From household number 2, the administration was done, skipping 4 households to the 6th household being a respondent, through to the last household.

Field Experiments/Trials

IR 2793 and basmati 370 rice varieties were cultivated in a field site comprised of clay soil during the 2012/2013 short rains growing season. The scheme receives a mean rainfall of 1100 mm, has a mean diurnal temperature of 23^{0}C, and a relative humidity of 68-70% (Kipkorir, 2012b). The four experimental plots for Conventional paddy system had a net area ranging from 298.2 to 399.3 m^2 each while the four plots under SRI had a net area ranging from 305.0 to 521.5 m^2 each.

Description of Experimental Factors

The experimental factors considered were: two irrigation water regimes, two rice varieties and two different spatial crop patterns.

Irrigation Water Regimes

Two irrigation water regimes were tested in the rice field trails as follows:

a) Conventional paddy rice system, where water layer of 5cm was maintained in the field and drained 2 weeks before harvesting. In total, 11 irrigation events were applied after accounting for the rainfall events; and
b) Intermittent water application of water up to a depth of 2 cm at irrigation intervals ranging from five to seven days referenced to when hair sized cracks were observed on the SRI plots. With this water regime, a total of nine irrigation events were applied after accounting for the rainfall events. The intermittent irrigation regime was only applied two weeks from transplanting till tillering process was complete at flag leaf stage of growth and thereafter a constant water layer of 2cm was maintained in the field till the final field drainage which was done two weeks before harvesting.

The applied water to a total of two blocks (of total area A=1419.3 m^2 for conventional and A=1584.8 m^2 for SRI) and each divided into four plots, under a give water regime was measured by determining the time (t in seconds) required to fill a 20-litres bucket by water flowing through a 75 mm in diameter plastic pipe installed in a feeder canal to supply irrigation water. Also, the amount of time (T) required to apply irrigation water to required depth in the fields in each block was measured. The flow rate during each irrigation event in each water regime was determined as $Q=20/t$ (lit/sec) and the corresponding applied water depth (d) was computed using the equation: $d = (Q\times T)/A$, and results are presented in Table 3 and Table 4.

Treatment Variables and Factor Combinations

The experimental field trials tested four treatment combinations under the two divergent irrigation regimes. The following were the main variables: i) two rice varieties which comprised of IR 2793 and basmati 370; and ii) two different spatial crop patterns for Conventional paddy and SRI method. The two spacing levels for Conventional paddy were at 15 cm×10 cm and 20 cm × 20 cm, while the SRI system was spaced at 25 cm × 25 cm and 35 cm × 35 cm. The fertilizer level used for SRI fields was a mixture of organic fertilizer (cattle manure) at the rate of 5 tons/acre plus inorganic nitrogen at the rate of 4.41 kgN/acre. The organic manure was applied before transplanting. The nitrogen application was split twice. The fertilizer level for Conventional paddy system was only in the form of inorganic nitrogen at the rate of 4.41 kgN/acre also split twice. Therefore, the experiment comprised of eight experimental plots: Four plots under Conventional paddy and four plots under SRI method.

Cultural Management

Hand transplanting in the trial plots for both rice varieties and for SRI and Conventional paddy system were planned to coincide on the same date. One seedling per hill was transplanted for the SRI plots while 2-3 seedlings according to the farmer's practices were adopted for the Conventional paddy system. Fertilizer was applied to all fields in the form of inorganic nitrogen at the rate of 4.41kgN/acre. Inorganic fertilizer was applied in two equal splits; the first was applied 14 Days after Transplanting (DAT) and the second split was applied 35 DAT. Weeding was done twice for Conventional paddy plots by manually pulling the weeds while it was done three times for SRI plots using hand weeding machine. The maximum root depth of the crop was measured after the mid-season as 0.15m. For all the plots, water application was stopped two weeks before harvesting. The crop was cut and harvested in the field 105 DAT (Conventional paddy) and 110 DAT (SRI) for basmati 370 variety and 120 DAT (Conventional paddy) and 130 DAT (SRI) for IR2793 variety. This was because the two rice varieties, basmati 370 and IR 2793, matured for harvest at different times, under the two different rice production methods with different conditions under which each rice production method applies. Yield for a plot in each treatment was determined from mean weight of field grain rice harvested from five quadrants and dried to 12.5% moisture content. The performance of the two rice varieties tested under two water regimes (Conventional paddy and SRI water regimes) and under two different spacing was collected for analysis.

Data Collection and Analysis

The study used questionnaires, interviews, focused group discussions, document analysis, observation, photography, field experiments/trials and secondary data, across all the specific objectives. The field experiments/trials done tested on inputs, spacing of seedlings, rice varieties, water regimes, fertilizer rates and rice yields per rice production method. The selection of these tools was informed by a pilot study in which pre-tests were done in the study area.

This study administered questionnaires to the respondents from West Kano Irrigation Scheme that consisted of 123 sampled households in the 17 rice blocks. The questionnaire comprised of identity of respondent and rice production in terms of costs of farm inputs, rice yields, technology of rice production used, rice varieties used, experience of rice farming, exposure to trainings on rice production and constraints of SRI. In order to minimize bias in the analysis, random sampling technique was adopted. The technique involved identifying the crop area to be selected by not actually looking at the crop, but by throwing a piece of stone while facing away from the site in each plot, as equally applied by Kipkorir (2012b). The area of one square meter (quadrant) was taken for sampling in the place where the stone fell. In this manner, 40 samples were collected (i.e. 5 samples from each of the 8 experimental plots) from the experiment and several crop variables were measured.

The data obtained from field survey and field experiments/trials was subjected to descriptive and inferential statistical analysis such as multiple regressions and correlation analysis to show the degree of relationship between variables. Descriptive statistics for the data obtained in this study included frequency of occurrence, percentages of occurrence and means.

Results and Discussions

Socio-Economic Characteristics of the Households

The demographic information of the respondents was gathered from the structured questionnaire administered to 123 households in the study area. Results are presented in table 1.

Table 1. Descriptive Statistics of Socio-Economic Characteristics of the Households

Variable		**Count**	**Percent**
Gender:	Female	70	57
	Male	53	43
Household size	5 – 9 persons	67	54
	10 – 14 persons	37	30
	15 – 19 persons	19	16
	20 – 29	10	8
Age (Years):	30 – 35	21	17
	36 – 40	23	19
	41 – 49	46	37
	Over 50 years	23	19
Major source of income:	Fishing	1	1
	Trading	14	11
	Farming	108	88
Rice varieties:	IR 2793	92	75
	Basmati 370	31	25
Education:	No. formal schooling	18	15
	Primary school	52	42
	Secondary school	38	31
	Technical/college	15	12
Income per annum (KShs.):	30,000 – 59,000	8	7
	60,000 – 119,000	14	11
	120,000 and above	101	82
Irrigation land allocated by NIB:	2 acres	58	47
	4 acres	65	53
Rented Irrigated land from others:	0 acres	109	89
	2 acres	14	11

The females constituted 57% of the sample while the male represented 43% of the total households. Also, 56% of the rice farmers in West Kano Irrigation Scheme were beyond the productive age of 20 to 40 years. Considering that most of the farm operations in the rice cultivation, such as land clearing, tilling, weeding and harvesting, require a lot of strength and energy, the majority of the rice farmers, who were females and mostly beyond the productive age, may have to hire young and energetic people to do the work, hence incur more labour costs. However, with 84% of the households comprising of a size of between 5 to 14 persons, it was recommended that as the rice farmers engage their family labour, it should be done in a manner that would not lead to low uptake of formal education among the young ones. Majority (85%) of the respondents had formal education and among these, 42% had primary education. Education is an important instrument in new skill acquisition and technology transfer. The fact that about 43% of the respondents had secondary education and above means that it was possible for the farmers to adopt better high yielding rice technologies. Most (88%) of the respondents indicated that their major source of income was farming, meaning that if the efficiency of rice production was improved, there would be high probability of poverty reduction.

Effects of Technologies on Rice Productivity

In order to determine the effects of technologies, a paired t-test on the relationships between various costs of rice inputs was done. The Table 2 illustrates the findings.

Table 2. Paired Samples T-Tests of Rice Input Costs

Paired variables	**Mean (Kg)**	**St.dev**	**Std.error**	**Regression coefficient (t-value)**	**Sig.**
Water irrigation and fertilizers (DAP)	10427.3	5902.6	532.2	19.592	0.000
Top dressing and organic manure	15437.4	4524.1	407.9	37.844	0.000
Fungicides and pesticides	-448.78	518.73	46.77	-9.595	0.000

Note: Paired samples test significant level at 5%; St.dev means Standard deviation; Sig. shows Significance

Farmers applied more fertilizer during the planting season (average of 61 kg) than for top dressing (48 kg) while only 2% of the respondents used farm manure. On average, households spent about KShs.1,528 (US $15) in purchasing fertilizers for planting (DAP) per annum and KShs. 15,437 (US $ 154) in buying top dressing (sulphate of ammonia). Majority of the farmers (83%) spent between KShs. 3,500 (US $ 35) to 4,000 (US $ 40) per annum on irrigation water fee payable to NIB which was mainly used to cover the operation and maintenance costs of the irrigation infrastructure.

The conventional method uses 94.8% chemicals (inorganic fertilizers), compared to SRI method that uses 5.2%, using lesser chemicals by 89.7% (Figure 3). This is because SRI uses 5,000 kg of compost (organic manure) per acre of land instead of the inorganic fertilizers (chemical fertilizer) for planting and top dressing.

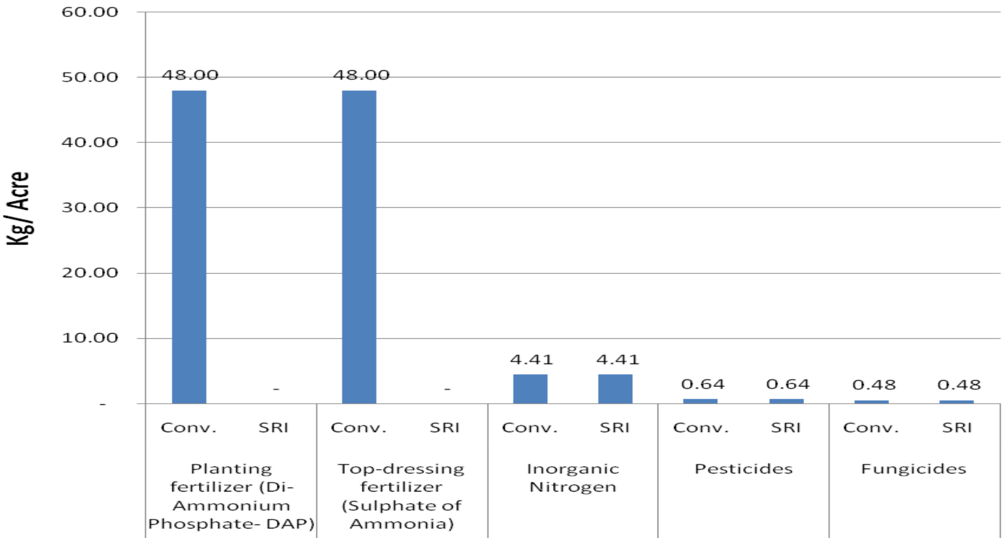

Figure 1. Chemical Application for Rice Methods per Acre of Land in WKIS

Findings therefore show that there is a significant difference between the population means of costs of irrigation and costs of dia-monium phosphate (DAP) fertilizers at 5% level as indicated by the ρ<0.000, indicating higher need for irrigation water and increased DAP fertilizer application. This is because the size of land irrigated would affect the amount of rice planted. The interesting results were that of the costs of fungicides and pesticides where increased costs of fungicide application led to reduced costs of pesticides. The reason is that basmati 370 - aromatic rice variety (planted by 25% of the sampled households), - is much prone to fungal disease, *blast*, hence requiring more application of fungicides and less pesticides, while the non-aromatic variety, IR 2793 (where out of the 123 sampled households, 92 planted IR 2793, which is equivalent to 75%), is more prone to pests, hence need for application of more of pesticides and less fungicides. The reason why most farmers (75%) planted IR 2793 instead of basmati 370 would be because the basmati variety is aromatic (sweet-smelling) hence prone to destruction by birds. These results are in concomitant with findings of Ogundele and Okoruwa (2006) where, from 1954 to 2002, a total of 54 blast-resistant rice varieties were released to serve different ecologies and other specific needs in Nigeria, to help reduce costs of pesticides and fungicides.

Table 3. Irrigation Water Application for Each Event for the Block under Conventional Paddy Method

Net block irrigate area (A) = 1,419.3 m^2

Irrigation event number	**Date**	**Flow rate (sec) to fill 20 litres container**			**Mean (secs)**	**Discharge (Lit/sec)**	**Time to irrigate block (min)**	**Irrigation depth (mm)**
		T1	T2	T3	T	Q	T	D=(QxT)/A
1st	30/11/2012	7.2	7.18	7.24	7.21	2.78	540	63
2nd	10/12/2012	7.87	7.52	7.66	7.68	2.60	540	59
3rd	17/12/2013	6.98	7.02	7.11	7.04	2.84	520	62
4th	24/12/2013	7.13	6.68	6.99	6.93	2.88	500	61
5th	02/01/2013	7.78	7.81	7.56	7.72	2.59	600	66
6th	15/01/2013	8.12	7.76	7.98	7.95	2.51	660	70
7th	21/01/2013	8.11	8.02	8.24	8.12	2.46	660	69
8th	03/02/2013	9.37	9.78	9.91	9.69	2.06	720	63
9th	10/02/2013	9.12	8.64	9.34	9.03	2.21	720	67
10th	25/02/2013	9.44	9.86	9.65	9.65	2.07	720	63
11th	01/03/2013	9.81	9.74	9.80	9.80	2.04	720	62
	Total							**706**

Table 4. Irrigation Water Application for Each Event for the Block under SRI Method

Net block irrigate area (A) = 1,584.8 m^2

Irrigation event number	**Date**	**Flow rate (sec) to fill 20 litres container**			**Mean (secs)**	**Discharge (Lit/sec)**	**Time to irrigate block (min)**	**Irrigation depth (mm)**
		T1	T2	T3	T	Q	T	D=(QxT)/A
1st	30/11/2012	8.81`	9.02	9.12	8.98	2.23	720	30
2nd	15/12/2012	9.33	9.87	9.14	9.45	2.12	660	26
3rd	24/12/2012	9.11	9.72	9.64	9.49	2.11	660	26
4th	02/01/2013	9.31	9.14	9.33	9.26	2.16	660	27
5th	22/01/2013	10.02	10.17	10.67	10.29	1.94	680	25
6th	04/02/2013	8.37	8.14	9.11	8.54	2.34	720	32
7th	10/02/2013	9.81	9.42	9.68	9.64	2.08	720	28
8th	15/02/2013	9.77	8.99	9.42	9.39	2.13	720	29
9th	01/03/2013	9.48	9.52	9.61	9.54	2.10	720	29
	Total							**253**

The results from Table 3 and Table 4 show that the conventional paddy system used 706 mm, while the SRI used 253 mm of water, holding all other factors, constant. This therefore indicated that SRI system saved about 64% of water compared with the conventional paddy system.

The total cost of irrigation water (which was ranging between KShs. 3,500 to 4,000 per annum on irrigation water fee payable to NIB) had a positive and significant effect on the costs of hired labour in nursery bed preparation, transplanting, top dressing, cutting, transportation and spraying (correlation of 0.517, 0.710, 0.512, 0.665, 0.512 all at 95% level). This means that when costs of water for irrigation go up the general costs of labour also increases. The reason for this is that the NIB base charges of irrigation water per unit area of land, such that as the land under irrigation is increased, the water charges were increased, and subsequently the other costs like labour costs were increased by virtue of the increased land size under rice production. This is in agreement with the fact stated above that water charges were based on acreage of land.

In order to understand the effects of different irrigation water regimes on rice grain yield, the SRI and Conventional paddy methods were applied, and their performance compared based on their marginal yield means. Results show (Table 5) that by varying irrigation water regimes, the SRI irrigation water regime exhibited significant increase in rice yield compared to Conventional paddy, at a rate of 2.26 tons/ha, irrespective of the rice variety and spacing used.

Table 5. Effect of Different Irrigation Water Regimes on Rice Grain Yield (Tons/ha)

Irrigation water management technology	Mean	Std.Error	Lower Bound	Upper Bound
Conventional Paddy	6.31	0.126	6.05	6.57
SRI	8.57	0.126	8.32	8.83

Pair wise comparisons of rice grain yield for the two water regimes

Irrigation water management		Mean difference	Std. Error	Sig.[a]	95% confidence interval	
					Lower Bound	Upper Bound
Conventional	SRI	-2.26*	0.177	0.000	-2.63	-1.90
SRI	Conventional	2.26*	0.177	0.000	1.90	2.63

*The mean difference is significant at 0.05 level.

From Table 5, it can be observed that the SRI method is more superior in yield performance compared with the Conventional paddy method. To test further the other factors that influence rice productivity, the experiment had an interaction effect of rice variety, plant spacing and irrigation water regimes. Out of 11 comparable irrigation events, Conventional method used a total of 706 mm depth of water, while SRI used 253 mm depth of water, indicating that SRI system saved about 64% of water compared with the Conventional rice production method. Table 6 illustrates the findings. Majority (99%) of the farmers practised Conventional paddy method of rice production. The results are in concordance with Kipkorir, (2012a), which indicates that though SRI was introduced in Mwea, Kenya in 2009, the technology has not yet been adopted in WKIS.

Table 6. Interaction Effect of Variety, Plant Spacing and Irrigation Water on Rice Yield

Plant spacing	Rice variety	Irrigation water management	Mean	Std. error	95% Confidence Interval	
					Lower Bound	Upper Bound
Conventional (15cmx10cm)	IR 2798	Conventional	8.39	0.251	7.88	8.90
or SRI (25cmx25cm		SRI	11.19	0.251	10.68	11.71
	Basmati 370	Conventional	3.88	0.251	3.37	4.39
		SRI	7.12	0.251	6.61	7.63
Conventional (20cmx20cm)	IR 2798	Conventional	9.01	0.251	8.50	9.52
Or SRI (35cmx35cm)		SRI	10.03	0.251	9.52	10.54
	Basmati 370	Conventional	3.96	0.251	3.45	4.47
		SRI	5.95	0.251	5.44	6.46

The results of the influence of rice variety, irrigation water regime and spatial plant arrangement interactions on rice grain yield indicated that these variables had significant influence on grain yields attained as shown in Table 5. Hence, the rice variety, SRI method and rice spacing affected rice yields. These results indicate that SRI method of irrigation significantly improved rice yields. The yield difference between Convention paddy system and SRI showed that when 12-days-old transplanted seedlings for SRI were compared with 21-days-old seedlings for conventional paddy system, the yields for IR2793 rice variety, when SRI was used, increased by upto 33.4% compared to when Conventional paddy system was used. In the case of basmati 370 rice variety, SRI increased grain yield of upto 53.3% compared to Conventional paddy method.

Impacts of Rice Productivity to Rural Households

From the results shown above, the conventional paddy system of rice production that is cultivated in the scheme creates a high demand for irrigation water, increases cost of inputs including heavy dosage of chemical fertilizers and pesticides and causes less returns negatively effecting on the livelihoods of the farmers. Majority (62%) of these farmers had been growing rice for about 15 years and hence were experienced in rice production. However, the level of education and experience of farmer in rice production did not have any significant effect on the rice productivity because irrespective of level of education and experience of the rice farmer, all of them had not known about SRI technology, except for only 1 farmer. Table 1 shows that few (1%) of the households supplement their income by fishing, while the about 11% exploit wage labour opportunities and basic trading such as kiosk trade. Therefore, these other supplementary income sources contributed minimally (12%) when compared with rice production that was at 88%. Apart from the main income sources, households in study area have invested in productive assets such as livestock keeping that enable them to diversify their income options, and cushion themselves against livelihood shocks that were associated with reduced yields. About 55% of households have on average between one to nine herds of cattle, five goats, two to eight sheep and 10-14 chicken/ducks. These self-insurance strategies were important to these households as many had low incomes, and therefore constantly faced income and consumption risks. As long as the percentage of those with livestock was high, then the 55% of households could afford to use organic manure in replacement of the chemical fertilizers which would enhance rice production and reduce environmental degradation through the reduced chemical inputs.

Farmers sell about 83% of rice harvested (on average about 3,500kg) and retain 500kg of the rice produced for domestic use. This means that most of the rice produced by the farmers is for sale. The findings also show that rice is generally a commercial crop, and little consumed within the household indicates that rice is not a basic food for most of the respondents. Like in many parts of Kenya, maize is the basic food for domestic consumption. Though the grand cost (input) was high for SRI method, at KShs. 91,360 (US $ 914) for an acre, compared to KShs. 79,980 (US $ 800) for Conventional paddy method, the profit for SRI method surpassed that of Conventional paddy method by a margin of KShs.58,275 (US 583) for an acre size of land.

The price at which the farmers sell the rice varies depending on the season and outside demand. One kilogram of rice offered to farmers ranged between KShs. 37-44 (US $ 0.37 – 0.44) per kg to 65% of households while about 19% of respondents' sold for between KShs. 45-52 (US $ 0.45 – 0.52) per kg, and the rest 4% sold in the range of KShs. 53-60 (US $ 0.53 – 0.60) per kg. Business process and marketing skills determined the price the household fetched in the market place. The rice farmers received, on average, KShs. 272,566 (US $ 2,726) in sales yearly. Since the total average revenue was KShs. 283,396, it means that the rice consumed within the household was worth only KShs. 10,830 (US $ 108). These results show that the rice was mainly consumed by people outside the local community. Hence, low rice consumption means that there was no local market to sale the rice. These findings imply that the farmers were totally dependent on outside market for their produce and therefore, the rice farmers are faced with stiff competition in the outside market on prices, which is disadvantaged by their low yields per acre and high costs of rice production.

In order to analyze the main factors that affected the household revenue levels, analysis of variance (ANOVA) tests were done (Table 7).

Table 7. Analysis of Variance (ANOVA) of Factors Affecting Household Rice Revenue

Grand Rice Revenue	Sum of squares	Df	Mean square	F	Significance
Total costs of Fertilizers (DAP)	7.629 2.36	35 122	2.180 1.840	1.185	0.260
Total cost of fungicides	2.710 3.435	35 122	774243.912 83371.648	9.287	0.000
Educating from rice production	262.825 265.659	35 122	7.509 0.033	230.579	0.000

Table 7 shows that the F-ratios for the variables were significant at 5% level which means that these factors act differently in their effects on household rice revenues. In other words, total costs of pesticides and educating children from rice production were the main factors that caused revenues to reduce or increase. However, total costs of DAP fertilizers was not really significant, meaning that this factor affected rice revenues merely out of chance.

Factors Affecting Adoption of SRI Rice Production Method

There were a number of factors that determined adoption of the SRI method in

WKIS. Inadequate knowledge of SRI was cited as one of the constraints that led to slow adoption of the technology. Rice farmers had not known the comparative profit margins of the two rice production methods. The rice farmers needed more trainings and exposure tours to understand and appreciate more of SRI rice production method. For instance, while SRI only required 1m by 1m size nursery served by 5 to 8kgs of seeds only, which would serve a whole acre of transplanted rice, Conventional paddy required 1/8 of acre size nursery served by 25kgs of seeds, that would serve an acre of transplanted rice. The comparative analysis revealed that SRI nursery cost KShs. 500 (US $ 5), while Conventional paddy nursery cost KShs. 2,500 (US $ 25).

Secondly, pertaining to land preparation, levelling of farms was said to be very difficult. The young seedlings at age 8 – 12 days, as practiced in SRI, would immerse in water and would not grow if land levelling was not properly done. The other challenge was on transplanting of the rice seedlings. Farmers transplanted at different times, hence young seedlings would easily be flooded because by the time a farmer had just transplanted, the neighbour would be requiring a lot of water in his/her farm because his/her crops would for instance, be at booting stage, hence leading to flooding of the young seedlings, that would lead to drowning. This would be worsened by a scenario where an interested SRI farmer had a neighbour still practising Conventional paddy.

The other constraints of adopting SRI apart from low knowledge on SRI method among rice farmers and levelling of rice fields included: planting of one seedling per hill, transplanting at wider spacing, keeping soil moist during the first 15 days after transplantation and panicle formation, intermittent watering, transplanting quickly within 30 minutes of uprooting without damage of roots and transplanting young seedlings of between 8 to 12 days (Table 8).

Table 8. Ranked Practices Based on Adoption of SRI

SN	Practice	Group Scores			Total Score	Easiness Rank
		1	2	3		
1	Planting only one seedling per hill and shallow planting	3	2	2	7	1
2	Low knowledge on SRI method among rice farmers	1	3	4	8	2
3	Transplanting at wider spacing (at least 25 × 25 cm)	4	4	6	14	3
4	Keeping soil moist during the first 15 days after transplantation and panicle formation	5	6	3	14	3
5	Intermittent watering (up to vegetative period)	6	5	7	18	5
6	Transplanting quickly within 30 minutes of uprooting without damage of roots	8	7	5	20	6
7	Frequent weeding using simple tools	7	9	8	24	7
8	Transplanting young seedlings (8 to 12 days)	9	8	9	26	8
9	Levelling of rice fields	9	9	9	27	9

Key: 1- Easiest to practice; 9- Hardest to practice

Conclusions and Recommendations

The findings indicated that the SRI method of rice production saved about 64% of water compared to the Conventional paddy method. Hence, there is need to adopt the SRI method of spacing 25cm by 25 cm, since water is a very scarce resource especially due to climate change. Considering the water usage by the Conventional paddy method, which was being practised by 99% of the rice farmers, there was need for policy attention to be directed towards providing water-saving rice production method, considering scarcity of the water resource. Water is a natural and scarce resource, essential for agriculture in many regions of the world. To achieve sustainability in production systems, improved efficiency of rice productivity in Western Kenya is important, considering its contribution to the improved food security, increased small holder rice farmers' income and poverty alleviation, creation of employment in Western region, reduction of the national rice import bill and optimization of the scarce water resource. High dosage of chemicals by Conventional paddy method is a great threat to water quality of the adjacent Lake Victoria, its fish and other biodiversity therein, hence need for government to develop specific policies to safeguard the Lake from eutrophication. To facilitate faster adoption of the SRI method, the NIB should promote SRI technology in West Kano Irrigation Scheme and other rice schemes in the country.

It can be observed that rice farmers practising Conventional paddy method were not getting maximum returns from the resources committed to the rice production. SRI method was found to be more profitable than Conventional paddy method, by a margin of KShs. 58,275 (US 583) per acre. In order to ensure increase of rice production and to be equipped with market competitiveness, it is important to improve productivity by removing inefficiency of rice production. The low rice yields by the Conventional paddy method as practised by rice farmers in WKIS may undermine Kenya Vision 2030 social pillar (Social equity and Poverty reduction), hence need for adoption of rice production method with high yields.

Pertaining to the constraints of adopting SRI method cited by rice farmers, the following are the recommendations: The rice farmers need to take agriculture/farming as a business and not just as a way of life. Rice farmers need training on SRI through Farmers Field Schools and exposure tours. There is also need of identifying SRI-method interested farmers so as to organize a joint-effort in levelling of their land.

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