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Resaerch Application Summary

Using system of rice intensification practices to mitigate climate change effects on rice production in Western Kenya

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Abstract

The increasing impacts of climate change and the demand for food threaten the productive and service capacity of agro-ecosystems. Consequently, adoption of irrigation alternatives that enhance water use efficiency in crop production is vital. The System of Rice Intensification (SRI) increases crop water productivity through intermittent wetting and drying of rice paddies, under specific soil and agronomic management practices. The main objective of this study was to determine the level of adoption, replication and up-scaling of SRI practices among rice farmers in three western Kenya irrigation schemes. The study used the Farmers Field Schools (FFS) strategy for extending SRI practices to the farmers and optimizing crop water productivity using reduced inputs. Two FFS sites were identified from among individual farmers' fields in each of the three irrigation schemes (Ahero, Bunyala and West Kano). Individual irrigation scheme farmers' participation involved Ahero (40), Bunyala (50) and West Kano (52), respectively. The results indicate a steady increase of 18 percent of farmers from 120 farmers during the second year to 142 farmers by the end of the third year of the project work. Comparison of SRI and conventional rice growing reveals that the SRI strategy leads to higher grain yield through increase in numbers of effective tillers per hill as opposed to the conventional system. Rice production costs under SRI when compared to the conventional system are also much lower due to reduced amount of seedlings and its lower water demands. The need for systematic promotion of SRI as an integrated approach is recommended.

Key words: Farmers Field Schools, rice farmers, rice production, SRI adoption, SRI up-scaling

Résumé

Les impacts croissants du changement climatique et la demande alimentaire menacent la capacité de production et de service des agro-écosystèmes. Par conséquent, l'adoption d'alternatives d'irrigation améliorant l'efficacité de l'utilisation de l'eau dans la production agricole est essentielle. Le Système d'Intensification du Riz (SRI) augmente la productivité de l'eau des cultures en humidifiant et en asséchant les rizières de façon intermittente, dans le cadre de pratiques de gestion agronomiques et de sol spécifiques. L'objectif principal de cette étude était de déterminer le niveau d'adoption, de réplication et d'extension des pratiques du système SRI chez les riziculteurs de trois périmètres irrigués de l'Ouest du Kenya. L'étude a utilisé la stratégie FFS (Champs Écoles d'agriculteurs) pour étendre les pratiques du SRI aux agriculteurs et optimiser la productivité de l'eau des cultures en utilisant des intrants réduits. Dans chacun des trois périmètres d'irrigation (Ahero, Bunyala et West Kano), deux sites pour FFS ont été identifiés parmi les champs des agriculteurs. La participation d'agriculteurs à des systèmes d'irrigation individuels a impliqué respectivement Ahero (40), Bunyala (50) et West Kano (52). Les résultats indiquent une augmentation régulière de 18% d'agriculteurs passant de 120 durant la seconde année à 142 d'ici la fin de la troisième année du projet. La comparaison entre le riz du système SRI et le riz du système conventionnel révèle que la stratégie SRI conduit à un rendement en grain élevé grâce à une augmentation du nombre de talles efficaces par colline, par opposition au système conventionnel. Les coûts de production de riz sous le système SRI par rapport au système conventionnel sont également beaucoup plus bas en raison de la quantité réduite de plantules et de ses faibles besoins en eau. La nécessité d'une promotion systématique de SRI en tant qu'approche intégrée est recommandée.

Mots-clés: Champs Écoles d'Agriculteurs, riziculteurs, production de riz, adoption du SRI, extension du SRI

Introduction

Demand for rice in Kenya continues to soar as more people show progressive changes in their eating habits, coupled with urbanization. Rice is currently the third most important cereal crop after maize and wheat in the country. Most of the rice in Kenya is grown in irrigation schemes established by the Government. These include Mwea in central Kenya and three irrigation schemes (Ahero, West Kano and Bunyala) in western Kenya (GoK, 2008). However, a smaller quantity of rice is produced along major river valleys, located in the coast and the lake basin regions. The System of Rice Intensification (SRI) approach will unlock farmers' opportunities through increased rice productivity by changing the management of plants, soil, water and nutrients and reducing external inputs like fertilizers and herbicides (Ndiiri *et al.,* 2017). Through intermittent watering (up to vegetative period), System of Rice Intensification (SRI) offers opportunities to increase crop production, boost incomes, save water and improve food security (Mati, 2010).

In Kenya, shortage of water and land suited for rice production means that extensive expansion of rice growing is not a likely option. Therefore there is need to consider irrigation water saving alternatives and any interventions that can increase the water productivity of rice (Mishra 2009). SRI offers opportunity to improve food security through increased water productivity of rice, increased smallholder farmers' income and reduced national rice import bill (Mati, 2010). The main objective of this paper was to determine the level of adoption, replication and up-scaling of SRI practices among rice farmers in western Kenya irrigation schemes.

Materials and methods

Study area. The study was carried out in three National Irrigation Board (NIB) managed irrigation schemes that specialize in rice growing in Western Kenya, i.e., Ahero Irrigation Scheme (AIS), West Kano Irrigation Scheme (WKIS) and Bunyala Irrigation Scheme (BIS). The rainfall pattern of western Kenya is bimodal, governed by the movement of the Inter-Tropical Convergence Zone (ITCZ). The irrigated fields in the three schemes are underlain by deep black cotton soils (Vertisols) (Sombroek *et al.,* 1982). According to Jaetzold *et al.* (2005), black cotton soils are heavy with very high clay content that swell or shrink and crack accordingly when they are hydrated or dried. Bunyala is a flood plain with poorly drained alluvial sediments composed of deep, grayish brown to very dark grey, mottled, very firm, saline and sodic, cracking clay soils (Jaetzold *et al.,* 2005).

During the period of study, rice production in the three schemes mainly involved Sindano (IR2793) variety and each farmer was licensed to cultivate 1.6 ha of irrigated rice in four fields, each of 0.4 ha. Substantial research work on SRI has been done in Mwea Irrigation Scheme (central Kenya) one of the two main regions involved in rice production in Kenya. Due to the increasing demand and interest by farmers to embrace the SRI approach in western Kenya, there was need to carryout field experiments to establish the viability of this system.

Meteorological data. Climate data were collected in AIS and WKIS where experiments were done. Daily rainfall, daily maximum and minimum air temperature records from the AIS were collected for the period 1st August 2011 to 30th January 2012 while in WKIS it was collected during the period 1st September 2011 to 30th March 2012 during the 2011/2012 growing seasons.

Soil sampling. Soil sampling was done in the paddy plots to test soil pH, available of P, %N and %C at the beginning and end of the growing season. This process was done for all the three western Kenya irrigation schemes.

Carbonic gases emission. In this study the amount of carbonic greenhouse gases emission from rice field trials with and without SRI were evaluated in the WKIS site. The experiment was performed with four sampling times at different rice growth stages for IR2790-80-1 and for both SRI and conventional systems The chamber method and gas chromatograph technique was used to measure the emission of CH4 from the rice fields (Shin *et al.,* 2003). Laboratory analysis for the samples collected was done by injected 10 ml of the dissolved sample into the gas chromatograph (GC) machine, using GC 8A equipped with a Flame Ionization Detector (FID). This involved igniting the GC machine and setting a standard to the injected sample, i.e., for methane gas analysis, at temperature of 500^{o}C and a pressure of 4-5 atmospheres. Four samples were analyzed in each sampling day and quantitative data were obtained. The obtained data were used to compute the amount of methane produced from the rice field plots by observing the peaks and the area covered by the peaks.

Irrigation water regimes. Two irrigation water regimes were tested in the rice field trials as follows: (a) (i) Conventional paddy rice system, where a water layer of 5 cm 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 (ii) Intermittent water application 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) plot. With this water regime a total of nine irrigation events were applied after accounting for the rainfall events.

(b) The field trials tested four treatment combinations under the two distinct irrigation regimes. The main variables included: i) two rice cultivars namely IR 2793-80-1 and basmati 370; ii) two different spatial crop patterns for conventional paddy and SRI systems. For conventional paddy, two spacing levels at 15 cm × 10 cm (C1) and 20 cm × 20 cm (C2) were considered, while the SRI system were spaced at 25 cm × 25 cm (S1) and 35 cm × 35 cm (S2). Fertilizer levels for organic and inorganic were also tested.

Up scaling SRI practices to farmers fields. Farmer Field Schools (FFS) were used in the three schemes to promote farmers interaction and knowledge sharing on SRI practice (Ashby *et al.,* 2000) having been introduced to the approach in the first year (2012) of the project using model field plots, at two sites (Ahero and West Kano). Bunyala irrigation scheme was only considered for farmer exchange visits where farmers were prepared to take it to individual farm level during the second year (2014) of the project. Farmers in the three schemes used the third year (2015) to further implement the findings from first year experimental results and their experiences to explore individual knowledge in enhancing the SRI technique.

Organization and management of FFS. As a strategy of up scaling the adoption of SRI technology during the second and third years of the research project, FFS approach was considered in the three irrigation schemes. The FFS approach provided farmers an opportunity for learning-by-doing, based on the principles of non-formal education. The rice farmers who participated in the FFS from the three irrigation schemes attended a minimum of six sessions per field trial site.

Spacing of rice seedlings. Most farmers in western Kenya rice irrigation schemes have adopted a spacing of (20×20 cm) however through experience some farmers still explore different spacing options. In BIS for instance about 33 percent of the FFS farmers have embraced a spacing of (25×10 cm) and 20 percent of farmers in AIS used a spacing of 30×10 cm, respectively. Most of these farmers argued that the SRI technique still saves on seed and productivity and is not affected much by varying the spacing between seedlings. Research has established spacing of 25 cm × 25 cm to be ideal for SRI (Reuben *et al.,* 2016).

Irrigation scheduling. The time of applying the first irrigation event varied from (7-17) days after transplanting for different schemes and farmers alike. However, data collected in the three schemes indicates that most farmers (AIS - 50%; BIS - 78% and WKIS - 65%) administered their first irrigation between days (12-15) after transplanting.

Alternate drying and wetting irrigation events. AIS and BIS had 1- 4 drying and wetting irrigation events throughout the season whereas WKIS had 2-10 irrigation events for different farmers spread over the season. The drying and wetting irrigation events depend on pumping schedule of water supply to farmers. Apparently more irrigation schedules were organized in WKIS as opposed to the other two schemes.

Inorganic fertilizer. The use of inorganic nitrogen fertilizer in the three schemes during the third year (2015 growing season) was assessed. Organic fertilizer is environmental friendly and affordable to rural small-holder farmers. The records reveal that the quantity of fertilizer used in western Kenya irrigation schemes was between 125-500 kg/ha. There were clear variations within and between the three schemes in terms of the quantity of fertilizer used. The FFS farmers in BIS applied the least fertilizer dose; 58.8 percent used 125 kg/ha, and 29.4 percent used 250 kg/ha. Approximately 98 percent of the farmers in AIS applied fertilizer, with amounts ranging between 250-500 kg/ha; out of which about 44 percent used 250 kg, 25.6 percent used 375 kg and another 25.6 percent used 500 kg respectively. In WKIS, about 51.2 percent farmers applied 250 kg/ha of fertilizer, while 11.5 percent used 375 kg/ha, and the rest of the farmers (34.6%) did not report on the use of fertilizer in rice growing.

Integrating SRI in irrigation system management in western Kenya

Integrating SRI in irrigation system management is a deliberate and synchronized capacity building strategy intended to promote, monitor and evaluate its benefits. Technical capacity building aimed at enhancing knowledge acquisition, skills development and change of attitude. In the three western Kenya irrigation schemes (BIS, AIS, WKIS), the focus was directed more on partial capacity building. Farmers were encouraged to practice both systems of rice production (SRI and conventional) in order to compare the benefits and make informed choices.

Results and Discussion

Meteorological data collection. Daily rainfall, daily maximum and minimum air temperature records from the AIS were collected during the 2011 growing season and FAO Penman–Monteith method (Allen *et al.,* 1998) was used to calculate daily reference crop evapotranspiration (ET0) for the stations. The total ETo during the season was estimated as 617 mm while rainfall received during the same period was 729 mm, indicating a wet season with spaced dry spells. For WKIS the total ETo during the field trials period (growing season) was estimated at 488 mm while rainfall received during the same period was135 mm, indicating a dry and hot growing season.

Soil analysis. The results indicate that pH which is a measure of acidity of the soil was near neutral in the three sites; however the values in WKIS were slightly higher than those for BIS and AIS. The pH ranges are suitable for most crops but there is need for further monitoring in WKIS to confirm the upward trend and necessary remedial measures to be taken. Phosphorus is involved in the photosynthetic processes in plants and results indicate that the soils showed a level of P that was much higher than the critical value of 10 in both AIS (greater than three times the limit) and WKIS (greater than ten times the limit). In BIS the P level was slightly higher than the limit value of 10. It would be important to identify mainly for WKIS the cause for the soil to exhibit such very high levels of P. Nitrogen is essential for growth and protein synthesis, in the plant. A value of 0.2% obtained is acceptable for most plants. Except for start of season data points in BIS, all the others were below this critical value by the end of the growing season and in some cases at the start of the season.

Generally a value of 2% carbon is considered adequate. While the values in the samples from the three sites were adequate with the exception of two data points, it is important to maintain the level of carbon in the soil as this improves the soil structure. Practices such as leaving/ incorporating trash and adding composted organic manure (as recommended for SRI) into the soil are encouraged. The finding during the field trials in the 1st year that fertilizer has no significant effect on grain rice yields can be explained from the soil analysis results. The only deficient element in the soils was nitrogen which was corrected by addition of recommended level of nitrogenous fertilizers supplied in the form of Sulphate of Ammonia 21% N commonly used in the two rice irrigation schemes.

Influence of cultivation method on carbonic gases emission. The results of flux of CH_4 measured on four days distributed within the various growing stages of crop, from the active tillerring stage, primordial and flowering stage indicated that applying water intermittently using SRI saves water as earlier discussed, more over based on the limited data collected, it mitigates methane emission compared to conventional paddy method. Analysis of results indicate that the higher the methane emission, the more the peaks and the larger the areas under the peak and the longer the peak heights. During the growing period, amount of methane emissions in SRI method was lower (36.6%) compared to conventional method (63.4%) indicating 26.8% emission reduction by adopting SRI. This inference can be used to conclude that the SRI growing system had lower methane emission compared to the conventional system. The obtained results compared closely to those of Shin *et al.* (1995) that found that SRI can reduce methane emissions by 36% compared to the continuous flooding method. For the IR2798-80-1 crop variety considered, crop spacing and fertilizer levels and types used, SRI plots had reduced methane production, efficient water use and higher grain yields thus high crop water productivity than the conventional paddy system. Analysis on the fertilizer effect on methane gas production was however not done due to logistical reasons but all factors held constant, methane emission was more reduced in SRI than conventional system. However, not all the methane gas emitted originated from rice fields.

Influence of irrigation water regime on rice grain yield

Ahero site. Field trials in the site tested 12 treatment combinations under three distinct irrigation regimes, mainly: (i) two rice cultivars namely IR 2793-80-1 and Basmati 370; (ii) two different crop spacing patterns for conventional paddy and SRI systems, and (iii) three fertilizer levels (organic and inorganic). From comparison of the eight days old transplanted seedlings for SRI with 21 days old seedlings for conventional plots, the results reveal that crop grain yield performance for Basmati 370 rice variety increased. For SRI irrigation interval of 7 days the yield range of 4.1 – 5.1 tons/ha was achieved while for SRI with cracks of 2 cm wide, the yield range of 3.8 to 5.1 tons/ha was achieved. The SRI increase in grain yield of up to 4.6% was achieved compared to conventional system. The Water savings of SRI compared to conventional indicated that SRI irrigation interval of 7 days resulted in 11.6% water savings while SRI with cracks of 2cm wide resulted in 12.5% water savings. On the other hand different fertilizer types and levels showed no significant effect on grain rice yields.

West Kano site. Field trials in the site tested four treatment combinations under two distinct irrigation regimes, mainly: (i) two rice cultivars namely IR 2793-80-1 and basmati 370 and (ii) two different crop spacing patterns for conventional paddy and SRI systems. For the 12-days old transplanted seedlings for SRI compared to 21-days old seedlings for conventional, samples were collected from five randomly selected quadrants in each of the eight field trial plots and computed mean values used to represent crop performance during the short rains of the 2011- 2012 growing season. The results reveal that crop grain yield performance for Basmati 370 rice variety increased with conventional paddy yield ranging from 3.9 to 4.0 tons/ha and SRI with cracks of 2cm wide yield range of 6.0– 7.1 tons/ha was achieved and SRI increased grain yield up to 53.3 % compared to conventional. Water savings of SRI compared to conventional system indicated that SRI with cracks of 2cm wide resulted in 64 % water savings compared to conventional paddy system. Further, adopting SRI growing system will result in reduction in methane emission of 26.8% compared to conventional paddy system.

Adoption of SRI practices

Adoption of SRI practices has continued to grow since the inception of the project activities in the three schemes. However, due to farmers' innovativeness some of the practices tested through the initial experimentation have slightly been adjusted to suit their requirements. Among those practices are age of transplanting seedlings, spacing, type and amount of fertilizer, weeding and irrigation scheduling. Studies have shown that transplanting younger seedlings at age of 8 to 12 days increases rice grain yield with suitable soil conditions and agro ecological characteristics (Reuben *et al.,* 2016). Farmers in the three schemes appreciate the contribution of the preliminary experiments carried out during the first year since this is the basis of selecting the options during up-scaling phases in the second and third year of the project.

Field days evaluation. Field days were organized in each of the three schemes to mark the end of FFS SRI seasonal learning activities during the second and third years of the project. The discussions during these events were farmer-driven to try and interrogate the knowledge acquired through FFS trainings and continuous interaction with the research team. In all the three schemes (AIS, BIS and WKIS), it was evident that the solutions to crop and water management problems encountered by farmers emanated from fellow farmers. Therefore, the initiatives set to build capacity by first training facilitators have now spread to FFS members who can competently train their peers.

Number of tillers by rice production method. The results obtained show that 46.6 percent of the SRI farmers attained 11-40 tillers per hill, particularly in AIS and BIS. About half of farmers practicing conventional rice growing attained between 21-30 tillers per hill. A number of farmers practicing SRI farming obtained up to 61-80 tillers and more in BIS (20) and WKIS (19). Transplanting rice seedling at its youngest possible age contributes to higher tillering (Menete *et al.,* 2008) that translates to higher yields.

Yield of rice produced in western Kenya irrigation schemes. The yield obtained from the three schemes was variable, ranging from 1,250 to 7,500 kg/ha of rice grain. Results revealed that 45 percent of the FFS farmers in AIS harvested between 3751-5000 kg/ha, while four farmers obtained 5001-6250 kg/ha from the conventional methods, 34 percent of the farmers in BIS harvested 1251-2,500 kg/ha, and the highest yield of 6251-7,500 kg/ha was achieved in WKIS by 67.3 percent of the farmers due to higher dosage of fertilizer, whereas a few farmers (3.8%) obtained more than 7,500 kg/ha (WKIS). Most studies have shown that SRI water management practices produce considerably higher rice yields as well as saving on water usage compared to conventional continuous-flooding water management practice irrespective of rice variety (Ndiiri *et al.,* 2017).

Profits accrued from rice production. The benefits obtained from rice farming vary within and between the western Kenya irrigation schemes. Profits of between 735 US$-980 US$ /ha were recorded by 25.8 percent and 980 - 1225 US$/ha by 32.2 percent of the FFS farmers in AIS. In BIS, 50 percent of the FFS farmers failed to report on the profit level achieved while 10 percent recorded loss. Another 20 percent of the farmers obtained between 980 and 1470 US$/ha. Farmers from WKIS received the highest profits; out of which 12.5 percent got profits ranging from 1225 - 1470 US$/ha, and 63.4 percent received 1470 - 1715 US$/ha, while the rest of the farmers got more than 1710 to 2450 US$/ha. These results indicate that benefits from conventional rice systems are quite variable.

Cost of rice production per rice cultivation method. The profits generated from rice farming are reduced due to high production costs. The total production costs for about 65 percent of SRI FFS farmers varied from 490 - 735 US$/ha to 980 - 1225 US$/ha. The results reveal that farmers in the three irrigation schemes of AIS, BIS and WKIS respectively were correspondingly affected. Depending on the size and timing of the seasonal crop production activities, the costs incurred can exceed 2450 US$/ha. Most of the farmers who practice conventional rice farming incur expenses of 491 - 735 US$/ha to 735 – 980 US$/ha.

Farmers Field School participants feedback. The ranked practices starting from the most accepted are: transplanting at wider spacing (at least 25×25 cm), planting only one seedling per hill and shallow planting, transplanting young seedlings, frequent weeding using simple tools, keeping soil moist during the first 15 days after transplantation and panicle formation, intermittent watering (up to vegetative period) and transplanting quickly within 30 minutes of uprooting without damage of roots. For WKIS it is encouraging to note that the practice of transplanting of young seedlings had improved in ranking from rank 7 in the 1st year to 4 in the 2nd year. The participants further listed key challenges in adopting SRI as: transplanting young seedlings (8-12 days) and damage of young seedlings by birds; levelling of fields; increase in number of weedings; and unreliable water supply at the block level due to frequent failure of pumping machines and electricity interruption.

Status of SRI integration in western Kenya. The adoption of SRI was at two levels, i.e., partial and full adoption by the end of the third year of the project. Adoption rates were 50% and 20% for West Kano irrigation scheme followed by 30% and 15% for Bunyala irrigation scheme, while for Ahero irrigation scheme there was the least adoption rate of 40% and 11% partial and full adoption, respectively. The low integration of SRI was attributed to irregular cropping pattern due to teething problems of participatory integrated management (PIM) and the weak rice value-chain development in the region.

Conclusion and Recommendations

Up scaling of SRI practices through the FFS strategy has greatly enhanced the productivity of rice farming in western Kenya rice irrigation schemes by increasing the number of farmers adopting SRI approach by 18 percent from 120 farmers during the second year to 142 farmers by the end of the third year of the project work. Farmers have the ability to make decisions on field practices in terms of line transplanting of one rice seedling per hill and at a wider spacing, with varying options between 20×20 cm to 30×10 cm, and the choice of fertilizer. The ideal SRI spacing is square pattern at whatever spacing selected, which ranges from 15x15 cm to 25x25cm for ease of crop husbandry operations such as weed management. Most farmers prefer the use of inorganic fertilizer due to ease of application and accessibility compared to organic manure which is not readily available and labour intensive in terms of its transportation and application in the field. Farmers appreciate the fact that transplanting young seedlings of 8-12 days old increases grain yield through improved rooting and setting of effective tillers. However, logistical challenges such as the shortage of manpower during the transplanting period lead to increase of the transplanting age to 13-14 days. The age of transplanting generally varies between 9-22 days in western Kenya rice growing schemes, compared to the old practice of 18-28 days. Comparison of SRI and conventional rice growing revealed that the SRI strategy lead to higher grain yield through increase in numbers of effective tillers per hill as opposed to the conventional system. The results further revealed that SRI reduce methane production by 26.8% compared to conventional paddy system and promotes efficient water use through water savings of 64 % compared to conventional paddy system. This resulted into increased grain yields by up to 53.3 % compared to conventional paddy system thus high crop water productivity. The production costs of SRI rice are also much lower due to reduced amount of seedlings and its lower water demands.

To further increase the level of SRI adoption there is need to enhance extension services to reach out to all rice farmers. All the 142 participants in the project are trained farmer trainers whose vast experience should be integrated into NIB (National Irrigation Board) programmes in disseminating research findings from the diverse studies carried out within the western Kenya rice irrigation schemes. Importantly, NIB needs to invest in field days and make them a mandatory seasonal irrigation water use and crop production event so as to promote participatory sharing of new innovations amongst farmers themselves. The necessary resources required to promote best practices for sustainable agriculture should be made available and accessible to farmers. The desire for farmers to embrace the use of organic manure should be accomplished by providing the necessary infrastructure and resources.

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References

Allen, R., Pereira, L.S., Raes, D. and Smith, M. 1998. Crop evapotranspiration- guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No 56. Rome, Italy. 300pp.

Ashby, J.A., Braun, A.R., Gracia, T., Guerrero, M.P., Hernández, L.A., Quirós, C.A. and Roa, J.I. 2000. Investing in farmers as researchers: Experience with local agricultural research committees in Latin America Cali, Colombia: Centro Internacional de Agricultura Tropical.

Government of Kenya (GoK). 2008. National Rice Development Strategy 2008-2018. Ministry of Agriculture, Nairobi, Kenya.

Jaetzold, R., Schimidt, H., Hornetz, B. and Shisanya, C. 2005. Farm Management Hand Book of Kenya. Natural conditions and farm management information, VOL. II, 2nd Edition, Ministry of Agriculture Kenya, In cooperation with the Germany Agency of Technical Cooperation (GTZ).

Mati, B.M. 2010. System of rice intensification (SRI): growing more with less water, Promoting the adoption of SRI in Kenya. *Agron. J.* 101:438–447.

Menete, M.Z.L., van Es, H.M., Brito, R.M.L., DeGloria, S.D. and Famba, S. 2008. Evaluation of system of rice intensification (SRI) Component practices and their snergies on Salt-Affected Soils. *Field Crops Research* 109: 34-44. www.elsevier.com/locate/fcr http://dx.doi.org/10.1016/j.fcr.2008.06.003

Mishra, A. 2009. System of rice intensification (SRI): A quest for interactive science to mitigate the climate change vulnerability. *Earth and Environmental Science* 6: 24: 20-28.

Ndiiri, J.A., Uphoff, N., Mati, B.M., Home, P.G. and Odongo, B. 2017. Comparison of yields of paddy rice under system of rice intensification in Mwea, Kenya. *American Journal of Plant Biology* 2 (2): 49-60. doi: 10.11648/j.ajpb.20170202.12

Reuben, P., Katambara, Z., Kahimba, F.C., Mahoo, H.F., Mbungu, W.B., Mhengal, F., Nyarubamba, A. and Maugo, M. 2016. Influence of transplanting age on paddy yield under the system of rice intensification. *Agricultural Science*s 7 (3):154-163.

Sombroek, W. G., Braun, H.M.H and Van der Pouw, B.J.A. 1982. The exploratory soil map of Kenya and agro climatic zone map of Kenya scale 1:1million. Exploratory Soil Survey Report No. E1. Kenya Soil Survey, Nairobi, Kenya.

Shin, Y.K., Lee, Y.S., Ahn, J.W., Koh, M.H. and Ecom, K.C. 2003. Seasonal change of rice mediated methane emission from rice paddy under different water management and organic amendments. *Korean J. Soil Sci. Fert.* 36 (1): 41-49.