Ruterana IWRM Model Site in Rwanda as a community based CC resilience, Experience from 2008 to 2013

Hakizimana Jean Pierre

Protos-Great Lakes Region, Kigali. Email: jeanpierre.hakizimana@protosh2o.org.

1. Background

On the eve of the Integrated Water Resource Management (IWRM) action in Ruterana sub-cathcment, the local community suffered the effects of CC in the forms of floods, landslides, draught, food insecurity and many diseases due to unclean water and lack of sanitation. Being a hilly region, Ruterana has fragile soils exposed to high erosion. The deforestation of the region, and soil degradation justified the food insecurity and vulnerable conditions of the local communities. PROTOS launched its IWRM action in 2008 with local partners as a coping mechanism to reduce the vulnerability of local beneficiaries. The multi-facet action addressed the issues of Soil conservation through different majors (radical terraces, trenches, etc), agroforestry, and Agriculture production (with Kitchen garden, draught resistant and high performance varieties), from upstream to downstream households of the sub-catchment.

The IWRM action evolved with the decentralisation approach that led to growing ownership and effective involvement of local communities and District. In the regards, of natural resources, the IWRM mechanisms led to sustainable and tangible effect including control of erosion, biodiversity improvement of the catchment with introduction for various species, natural formation of new sources emergencies resulting to the progress infiltration from upstream, increase of food production and reduction of water stress, etc.

Furthermore, it is important to note that the model site of Ruterana served as best experience, that is being duplicated in the sub-region due to visits and various knowledge exchanges in (Rwanda, Burundi and Uganda). Hence, this Rwanda experience is a tangible and good experience of applied IWRM principles, to share as coping mechanism for CC effects at community level.

2. Issues addressed

- The erosion and continuous soil degradation
- Food insecurity at households level due to small production and degenerated varieties
- Deforestation of the sub-catchment by reforestation with fruit and agro forestry trees
- Issues of households sanitation and hygiene by introducing PHAST approaches and HAMS at school level as well as supplying clean water.

Action/process taken

- Soil Erosion control and conservation mechanisms (Radical terraces, trenches, agro forestry, green manure, etc)
- Improving agricultural production of the households by introduction of high yield and draught resistant varieties: Rice, Beans, maize, etc), Vegetable production at households level
- Improving Hygiene and Sanitation through PHAST and HAMS/child to child approaches
- Local ownership of the project through various trainings, setting up Water Users comities and a structure of WRM managing the sub catchment, Ruterana Sub-catchment , Muhanga District, Rwanda

The action of IWRM in Ruterana sub-catchment is piloted and funded by PROTOS. It also involves partners in a synergy with complementary expertise:

- **UGAMA:** Expertise of Hillside management (Erosion control, agroforestry, etc.) and Local Community development (training, organization, etc.)
- **COFORWA:** Expertise of WASH (Water supply, Hygiene and sanitation)
- **DUHAMICADRI:** Expertise in Marshland management (Rice and vegetables)
- **Muhanga District:** the Client playing the role of coordination

Summary of issues/Results/challenge

The issues was low level of adaptation capacity of the communities to CC effects vis à vis to drought, floods, fluctuation of seasonal patterns that led to community vulnerability.

The results of IWRM integrated action carried out in synergy of partners was appreciated at different levels such as Improvement of food security of households, Erosion control and improvement of soil fertility, changing the landscape of the sub-catchment into green due to introduction of various species, etc. The action contributed enormously to the positive change of livelihoods of the communities.

However, on the way of action implementation the challenges were encountered such as limited funds compared to the local demand and needs, the slow pace of ownership by local communities and the local authorities as well as systematic approach of follow up of changes for the good knowledge management of the model sites achievements (that started a bit later/recently !)

Evidence of result or challenges

The evidence of the results is the physical change of the sub-catch in landscape (radical terraces, and trenches, as well as the green landscape) In the area of Water resources management, the new emergencies (new sources) at the foot of the protected zones as the results of infiltration process since 2008 associated with the growing surface of rice plantations in the dry season also remain convincing on the benefits of IWRM action.

As far as Impact and beneficiaries are concerned, Ruterana households have improved their living conditions in hygiene and sanitation, food security and savings (The impact assessment is progress) the local population (households dwellers) who live on hillside are the one who grow rice in the marshland are the same beneficiaries of PROTOS action.

The success of the action was due to several factors:

1) Effective involvement of the beneficiaries from planning to evaluation phases of the project
2) Targeting the local needs expressed by the communities
3) Multistakeholders approach (coupling the expertises of local partners)
4) high involvement , leadership and ownership of the local authorities (District)
5) Putting in place a steering committee of IWRM action under District coordination

3. Innovative steps

- IWRM at local community level(in the households)
- The steering committee of IWRM action made of all stakeholders including donor organization, local authorities, local NGOs/Implementers and local Water Users Committees with the special mandate to monitor the action.

- The multi-stakeholders approach with complementary expertises in the same action and sub-catchment (4NGOs) in the same intervention area.

The most important thing in achieving the results at Ruterana was the local ownership of the action by the community and local authorities (local buildership). In first period (2008/2010), the ownership was low and the vision as not well shared, but this changed progressively with the tangible effect of the action in the sub-catchment.

4. Lesson from Ruterana experience

The success of the IWRM projects in the communities must rely on the full and effective involvement of the stakeholders and a good cooperative framework with a shared vision. A such action does not necessarily depend on heavy means but the based results oriented programs with full commitment of all parties including the communities.

The local action on IWRM in the sub-catchment of RUTERANA will be strengthened by a three year program of PROTOS and its partners (2014/2016) for consolidation, where too much effort will be invested in the Systematization of the action-research to evaluate the impact of IWRM practices on the community livelihoods vis à vis to climate changes effects. The base line has already conducted over 688 households of the sub-catchment submitted to the action-research.

Optimizing system of rice intensification parameters using AquaCrop model for increasing water productivity and water use efficiency in rice production

Katambara, Z. [1,]*, F.C. Kahimba[2], W.B. Mbungu[2], R. Paul, M. Maugo[3], F. Mhenga[2] and H.F. Mahoo[2]

[1]Department of Civil Engineering, Mbeya University of Science and Technology, Mbeya, Tanzania. [2]Department of Agricultural Engineering and Land Planning, Sokoine University of Agriculture, Morogoro, Tanzania. [3]Ministry of Agriculture, Food Security and Cooperatives, Dar es Salaam, Tanzania. *Corresponding author email: zkatambara1@gmail.com

Abstract

Producing more rice while using less water is among the calls in water scarce regions so as to feed the growing population and cope with the changing climate. Among the suitable techniques towards this achievement is the use of system of rice intensification (SRI), which has been reported as an approach that uses less water and has high water productivity and water use efficiency. Despite its promising results, the use of SRI practice in Tanzania is limited due to less knowledge with regard to the transplanting age, plant spacing, and minimum soil moisture to be allowed for irrigation, and alternate wetting and drying interval for various geographical locations. The AquaCrop crop water productivity model, which is capable of simulating crop water requirements and yield for a given parameter set, was used to identify suitable SRI parameters for Mkindo area in Morogoro region, Tanzania. Using no stress in soil fertility, plant spacings ranging from 5 cm to 50 cm were evaluated. Results suggest that the yield and biomass produced per ha increase with decreasing spacing from 50 cm to 20 cm. Preliminary field results suggest that the optimum spacing is round 25 cm. However, the model structure does not take into consideration number of tillers produced. As such, the study calls for incorporation of the tillering processes into AquaCrop model.

Keywords: SRI, rice cultivars, plant spacing, transplanting age, tillering.

1. Introduction

Against the background of increasing water demands to produce more food such so as to feed the overgrowing population the challenge has further been worsened by climate change (Ndiiri et al., 2012). Rice is among the most commonly grown cereal crops which requires large amount of water when grown under conventional practices. Apart from being one of the important staple crops consumed by the majority of the population (approximately >70%), much of the rice is produced by smallholder farmers in irrigated fields with high production costs. However, this is likely to become a difficult challenge with dwindling water resources, competition in the use of the water as well as problems posed by the impacts of land use/cover and climate change. To improve food security, Tanzania as well as other countries in East Africa and Sub-Saharan Africa has to increase the resilience of the resource base and intensify rice productivity. To counteract this, good water management and agronomic practices must be tested for their suitability in the local environment.

System of rice intensification (SRI) which originates from Madagascar is an approach that provides a new avenue that significantly increases the rice yield per hectare (Vishnudas, 2009). The suitability of SRI has been reported in various studies. In Kenya SRI practices indicate that the yield of rice under SRI practices range from 6 to 8 ton/ha, water saving could be up to 25%, healthy grains which weigh 100-110 kg per bag, and it produces quality grains with stronger aroma (Mati, 2012; Ndiiri et al., 2012). In Madagascar it has been reported that SRI can increase the rice yield by 25% - 50% while reducing the amount of water use by an equivalent amount and is considered as an incentives to a rice grower (Satyanarayana et al., 2007). In China it has been reported that up to 46% of water saving has been attained under SRI practices and yield increase of similar value (Xiaoyun et al., 2005). All these studies provide evidence on the suitability of SRI practices in saving water use while increasing yields to feed the growing population.

From the agronomic point of view, SRI practice is considered as a representation of empirical practices that vary in a manner that significantly reflect local conditions (Dobermann, 2004). Therefore, the knowledge on the principles and the bio-physical mechanisms are imperative under a range of different agro-ecological environments (Stoop et al., 2002). On-farm participatory research activities under well defined farming-systems approach are necessary so as to adequately validate the practical relevance and risks associated with practising SRI under local conditions (Stoop et al., 2002). Among the parameters that need to be tested are transplanting age, spacing of the seedling, minimum soil moisture to allow irrigation, alternate wetting and drying interval, and cultivars for various geographical locations. All these require adequate time and resource so as to make appropriate decisions.

In Tanzania SRI practices is not popular and this merits a need to test these parameters using a less resource dependent approach such as the use of crop simulation model. This study attempts to simulate rice yield and water requirements using AquaCrop model, a crop water productivity model. The suitable parameter set obtained is thereafter compared to the first season yield from Mkindo area in Morogoro region, Tanzania.

The AquaCrop Model and its Application

The Food and Agriculture Organization's model, the AquaCrop Model is a result of the scientific and experimental progress in water relation as well as the necessity to improve water productivity so as to cope with water scarcity (Raes et al., 2009a; Raes et al., 2009b). The model is capable of simulating yields of several herbaceous crops as function of water consumed under any of the four conditions, which include rainfed, supplemental, deficit, and full irrigation (Steduto et al., 2009a; Steduto et al., 2009c). Therefore, the crop growth engine considered in the model is water-driver and calculates the transpiration from crop cover which is further translated into biomass that is related to evaporative demand and CO_2 (Steduto et al., 2009d).

The crop yield is determined as the product of biomass and Harvest index. Further information is given in (Steduto et al., 2009b). The major strength of the model lies in its ability to balance simplicity, accuracy, and robustness while using fewer parameters (Izzi et al., 2009; Steduto et al., 2009a; Steduto et al., 2007; Steduto et al., 2009b; Steduto et al., 2009c)..

The AquaCrop Model has been tested with crops such as maize, cotton and quinoa. In Spain, the model was evaluated using maize crop (Steduto et al., 2009a). The model was noted to simulate the crop water use (ET) under very high ET and wind conditions satisfactorily. In addition, the model performed well in simulating the growth of above ground biomass, grain yield, and canopy cover (CC) in the non-water-stress treatments and mild stress conditions (Steduto et al., 2009a). With respect to cotton, the model has been reported as it accurately simulated the canopy cover, evapotranspiration, biomass and yield within acceptable ranges (Izzi et al., 2009).

In Bolivia, the quinoa crop was simulated and satisfactory results were obtained for the simulation of total biomass and seed yield with values of Nash-Sutcliff efficiency being higher than 0.79 (Geerts et al., 2009). All these studies recommends on the model's ability to satisfactorily simulate crop yield and water use efficiency under rainfed conditions, supplementary and deficit irrigation, and on-farm water management strategies. However, limited studies have been done on the suitability of the model in simulating rice crop in a manner that attempts to identify appropriate parameters for the SRI practices and this study is a contribution towards the that direction.

2. Methodology

The AquaCrop Model was setup to simulate paddy rice under conditions of unlimited soil fertility and no water stress for Mkindo experimental area. The general soil characteristic is clay loam with clay 44%, loam 37%, and sand 19% (Kombe, 2011). The climatic files were generated using ETo Calculator. The data include air humidity, wind speed, and maximum and minimum temperature.

The meteorological station of Morogoro was used for the estimation of evapotranspiration and effect of distance between Mkindo and Morogoro was considered to be not significant. The rainfall data used was from Dakawa rainfall station which is close to Mkindo area. The rice breed used is TXD 306 (SARO 5) and the study examined the effect of transplanting spacing on the yield. Three treatments were used as indicated in Table 1.

Table 1: Treatments for the experimental sites

Treatment	Spacing
T1	25cm x 25cm
T2	30cm x 30cm
T3	35cm x 35cm

3. Results and Discussion

The suitability of a model in simulating a process depends on how realistic the results represent the actual biophysical process. As such, results obtained from simulations using the AquaCrop Model were compared to first season yield of January 2013. The grain yield obtained from the experimental filed and by using the AquaCrop model are shown in Figure 1. The yield from the experimental plots and the model yield indicate some significant variation for T1 whose spacing is 25cm x 25cm. The grain yield obtained was 9.91 tons/ha for the experiment plots and 7.682 tons/ha for the simulated, suggesting that the model underestimated the yield by 22%. For other treatment of T2 whose spacing is 30 cm x 30xm and that of T3 whose spacing was 35cm x 35cm there is an insignificant difference in the yields.

Considering the plant spacing, each single and widely spaced plant ensures enough space for tillering (Stoop et al., 2009). However, the model structure and mechanism takes less consideration of the variation in the number of productive tillers as well as the number of panicles which are influenced by the spacing. Spacing has been noted to substantially increase the yield as reported in several studies (Mati, 2012; Satyanarayana et al., 2007; Xiaoyun et al., 2005). Figure 2 and Figure 3 shows the variations of the number of panicles and tillers per hill. The number of panicles and the number of tiller per hill increases with spacing which is contrary to the grain yield which increases with decrease in spacing. These suggest that for

Mkindo study area, the spacing of 25 cm or less was considered to be the optimum spacing which led to higher grain yield, though this needs to be further investigated with lower spacing.

In addition, SRI has been reported to likely produce health grains that are suitable for being used as seeds Katambara et al. (2013), however, the effect that the spacing have on the quality of the seeds produced requires some further investigation. The variation of the grain yield, number of tiller and number of panicles provide evidence that SRI is really empirical and call for the application of some modelling approach which are less data dependent, incorporate uncertainties and capable of incorporating human reasoning and include the fuzzy based approach. The fact that the yield of the model being similar to that of SRI for T2, suggest that AquaCrop model can be used by water basin officers for water allocation purposes in which SRI practices must be implemented.

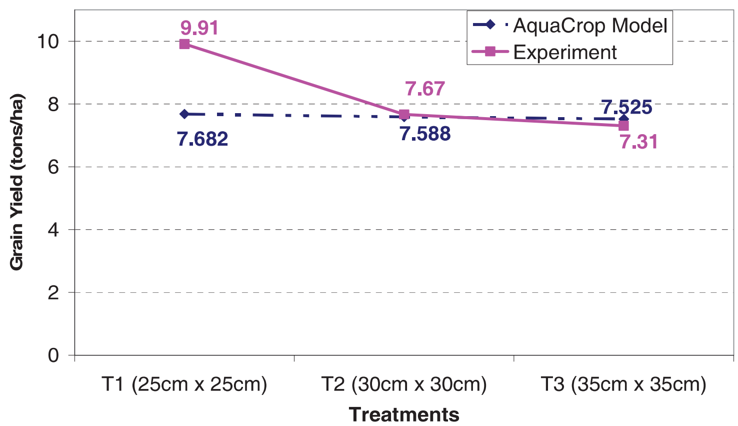
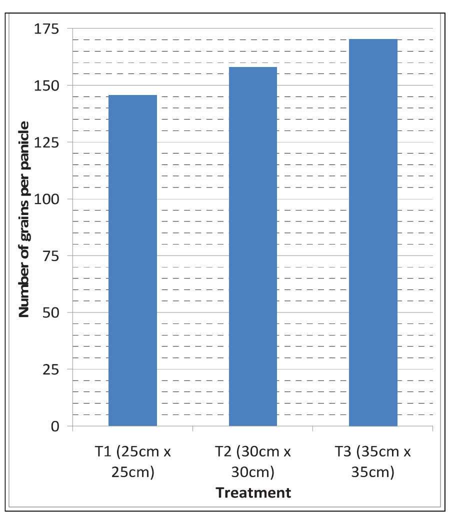


Figure 3: The rice yield per hectare



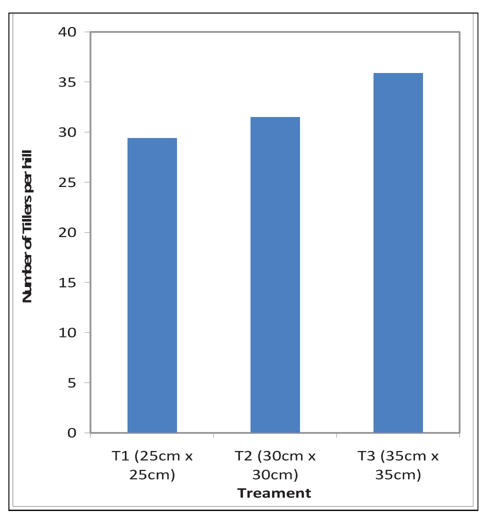


Figure 1: Number of panicles per tiller

Figure 2: Number of tillers per hill

4. Conclusion and Recommendations

The performance of AquaCrop and SRI practices has been compared for Mkindo area in Morogoro Tanzania. At higher spacing above 30cm x 30cm, the grain yield has been noted to have insignificant differences, but at a spacing of 25cm x 25cm the SRI produced more than the model estimates. This finding calls for more investigation on spacing smaller than 25cm by 25cm so as to identify the optimum spacing, since the number of tillers per hill and the number of panicles increased with increase with spacing. Modelling approaches such as fuzzy inference system approaches which are capable of incorporating human reasoning are less data intense, incorporate uncertainty constitutes further study. The AquaCrop model estimates suggest that the model can be used in water allocation process for rice irrigation water rights.

Acknowledgement

The authors acknowledge the financial support received from the Commission of Science and Technology of Tanzania (COSTECH).

References

Dobermann, A., 2004. A critical assessment of the system of rice intensification (SRI). Agricultural Systems, 79(3): 261-281.

Geerts, S. et al., 2009. Simulating Yield Response Of Quinoa To Water Availability With Aquacrop. Agron. J., 101(3): 499-508.

Izzi, G., Farahani, H.J. and Oweis, T.Y., 2009. Parameterization and evaluation of the AquaCrop model for full and deficit irrigated cotton. Agronomy Journal, 101(3): 469-476.

Katambara, Z. and Ndiritu, J.G., 2010. A hybrid conceptual-fuzzy inference streamflow modelling for the Letaba River system in South Africa. Physics and Chemistry of the Earth, Parts A/B/C, 35(13-14): 582-595.

Katambara, Z., Kahimba, F. C., Mbungu, W. B., Maugo, M., Mhenga, F., and Mahoo, H. F. (2013), Optimizing the system of rice intensification parameters using AquaCrop model for increasing water productivity and water use efficiency in rice production in Tanzania,

Katambara, Z., Msambichaka, J. and Mkisi, J., 2013. Estimation of Extreme Flows in Nkana River to Verify the Adequacy of Naming'ongo Bridge Waterway. Engineering, 5(3): 299-302.

Kombe, E. (2012), The system of rice intensification (SRI) as a strategy for adapting to the effects of climate change and variability: a case study of Mkindo Irrigation scheme in Morogoro, Tanzania, Masters Dissertation, Sokoine University of Agriculture, Morogoro, Tanzania.

Mati, B., 2012. System of Rice Intensification (SRI): Growing More Rice While Saving on Water Kenya_SRI_Manual.

Ndiiri, J.A., Mati, B.M., Home, P.G., Odongo, B. and Uphoff, N., 2012. Comparison of water savings of paddy rice under system of rice intensification (SRI) growing rice in Mwea, Kenya. International Journal of Current Research and Review 4(6): 63-73.

Raes, D., Steduto, P., Hsiao, T.C. and Fereres, E., 2009a. AquaCrop-The FAO crop model to simulate yield response to water. AquaCrop reference manual. In FAO, Rome.

Raes, D., Steduto, P., Hsiao, T.C. and Fereres, E., 2009b. Aquacrop the Fao Crop Model To Simulate Yield Response To Water: Ii. Main Algorithms And Software Description. Agron. J., 101(3): 438-447.

Satyanarayana, A., Thiyagarajan, T. and Uphoff, N., 2007. Opportunities for water saving with higher yield from the system of rice intensification. Irrigation Science, 25(2): 99-115.

Steduto, P. et al., 2009c. AquaCrop: a new model for crop prediction under water deficit conditions. Options Mediterraneennes, Series A: 285-292.

Steduto, P. et al., 2009d. AquaCrop: a new model for crop prediction under water deficit conditions. FAO, Rome.

Steduto, P., Hsiao, T., Evett, S., Heng, L.K. and Howell, T., 2009a. Validating the FAO AquaCrop model for irrigated and water deficient field maize. Agronomy Journal, 101(3): 488-498.

Steduto, P., Hsiao, T.C., Fereres, E. and Raes, D., 2007. AquaCrop: The FAO field-crop model to predict yield response to water.

Steduto, P., Hsiao, T.C., Raes, D. and Fereres, E., 2009b. Aquacrop -The Fao Crop Model To Simulate Yield Response To Water: I. Concepts And Underlying Principles. Agron. J., 101(3): 426-437.

Stoop, W.A., Adam, A. and Kassam, A., 2009. Comparing rice production systems: A challenge for agronomic research and for the dissemination of knowledge-intensive farming practices. Agricultural Water Management, 96(11): 1491-1501.

Stoop, W.A., Uphoff, N. and Kassam, A., 2002. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. Agricultural Systems, 71(3): 249-274.

System of Rice Intensification website (http://sri.ciifad.cornell.edu/countries/kenya/index.html).Accessed on

Vishnudas, C.K., 2009. System of rice intesification (SRI) in Wayanda: Experiences of RASTA. http://www.indiawaterportal.org/node/359.

Xiaoyun, L., Xiuli, X. and He, L., 2005. A socio-economic assessment of the System of Rice Intensification (SRI): A case study of Xinsheng Village, Jianyang County, Sichuan Province. Report for College of Humanities and Development, China Agricultural University, Beijing.