Smallholder System Innovations (SSI) in Integrated Watershed Management

Science for development decision makers

POLICY BRIEF

Rapidly increasing populations in the dynamic semi-arid agro-ecosystems in sub-Saharan Africa highlight the necessity to increase food production, while at the same time safeguarding other ecological systems that support human development and well-being.

In sub-Saharan Africa, where 95 percent of the total agricultural land is used for rainfed agriculture, productivity is often low, averaging around, or below, one ton per hectare, and the highly variable rainfall patterns make water availability a particular problem. Climate change will exacerbate this problem.

In the past, increases in crop production to keep pace with population growth were largely achieved through the expansion of cultivated area. But today, we must also consider ways of improving the productivity of already existing cropping systems. Intensification in many other parts of the world has taken place with investments in larger scale irrigation projects. These are however often associated with high costs and sometimes large environmental implications.

The identification and application of innovative technologies and management practices that improve water availability in rainfed agriculture offer opportunities to increase both food and environmental security. The impact of these innovations has been studied at field scale for some time. The SSI-programme takes on the challenge of exploring the effects of these innovations on watershed and river basin scales.

Science Messages for Smallholder System Innovation

Adoption of interventions. Working with 'adoption by the minority' through farmer to farmer extension approaches, and collaboration with partners outside the agricultural sector, are useful in many different social and biophysical contexts.

Outreach and knowledge sharing. There is a big difference between introducing and promoting a 'technology' and increasing the capacity of the community to adapt and solve problems.

Water source and delivery. To prevent crop damage from flood and drought where rainfall is intense and intermittent, control over water delivery and catchment planning are as important as water storage.

Restoring ecological systems. Well-designed small-scale water system innovations may restore overall productivity in agro-ecosystems by increasing crop water availability and stabilizing on-farm yield levels.

Hydrologic processes. Understanding linkages between surface and groundwater is vital when making water resource development decisions, to ensure benefit to, and/or proper attention to trade-offs between, both upstream and downstream water users.

Livelihood dependency. Understanding how people cope with stresses and shocks, particularly drought, is necessary to plan strategies to reduce the vulnerability and build resilience of farming communities.

IWMI International Water Management Institute

UNESCO-IHE Institute for Water Education

Universitet Stockholms

University of KwaZulu-Natal

SSI

Smallholder farmers practice subsistence farming in the Potshini catchment, while downstream land use is dominated by commercial agriculture and forest farming.

The Programme Catchments

The research is conducted in two different catchments in semi-arid to sub-humid regions where water is an important limiting factor for crop growth, smallholder agriculture dominates the landscape and local livelihoods are highly dependent on the annual crop production.

Thukela River Basin, South Africa

The Thukela River in KwaZulu-Natal province in South Africa is the largest river by volume in the country. It is a climatologically and socio-economically diverse watershed on the east coast of South Africa. It is hydrologically complex with high spatial and temporal variability and an unpredictable seasonal climate. Its streams are contaminated by high sediment concentrations and acid mine drainage. The Potshini catchment is characterized by a juxtapositioning of commercial agriculture and industrial economies with impoverished communities dependent on subsistence farming in degraded areas.

Pangani River Basin, Tanzania

The Pangani River Basin drains Mt. Kilimanjaro, extending from the northern highlands to the north-eastern coast. The Makanya catchment, located in the South Pare Mountains, in the mid-reaches of the Pangani, represents typical semi-arid to dry sub-humid rainfed agrarian conditions with strong signs of human induced land degradation where land use changes upstream are affecting hydrology and erosion downstream. Farmers have interesting community water storage in the middle of the watershed and river diversion water harvesting for maize at the lower part of the catchment.

Smallholder System Innovations

Runoff diversion from gullies, footpaths, and small streams - roof, household compound, and catchment water harvesting and storage - treadle pumps - conservation and deep tillage with organic soil amendments, and back sloped terracing to capture water on site - are amongst the interventions being studied to supply supplemental irrigation to maize during dry spells and vegetable gardening during the dry season. Institutional innovations are as important as technical innovations. Larger scale storage requires communities to organize and agree on allocation. SSI explores not only the potential of these innovations, but also changes in water cycling, and the impacts widespread adoption may have on downstream water users and the environment.

Science Messages for Development from SSI Research

Outreach and knowledge sharing

There is a big difference between introducing and promoting a 'technology' and increasing the capacity of the community to adapt and problem solve. Demonstrations, complemented by ongoing learning processes within the 'Farmer Learning Groups' in the two basins, reveal a positive impact on farmers' capacity to experiment, solve problems and adapt water system innovations. In "Co-learning" experiments, all farmers involved are given a rain gauge, and jointly with researchers analyze data they collect on precipitation and yields. Continuous engagement of government departments, local extension workers and non-government agencies in the research process added value when they incorporated some of the emerging SSI research findings on conservation agriculture and rainwater harvesting into their design and planning processes.

Adoption of interventions

These catchments differ culturally, in their degree of water stress, their social (government) support systems, the reliance of the population on agriculture for livelihood security, and the sources of technical innovations that exist (indigenous and exogenous). Despite these different biophysical and social conditions, adoption dynamics are very similar in both catchments. Common features were seen to be adoption by a minority who are able (already possessing greater biophysical, financial and social assets than others), and the importance of both successful technology and socio-economic support. Farmer to farmer extension is seen to play a big role in continued adoption. In Tanzania, primary education is an important determinant of adoption of new technologies, suggesting that the Ministry of Education could be an important partner in out-scaling efforts.

Water source and delivery

Water delivery is as important as water harvesting. In semi-arid areas of Tanzania rainfall is intense and intermittent, and flooding through poor delivery control can be as big a problem as drought. Field trials indicate that the main determinant of yield, when water is limiting, is the area of the catchment for rainwater harvesting. Farmers' strategy to continue to expand cultivated area (thus reducing the ratio between runoff catchment to cultivated area) is a mal-adaptation to the environment, necessitated by extremely poor yields. This is part of traditional knowledge in arid agricultural systems, but less well integrated into development planning and farmer strategy in semi-arid zones. In South Africa bore wells provided for drinking water are often the most practical source of water for home gardens (see Figure 1). Planning for this use is important when designing water delivery to households.

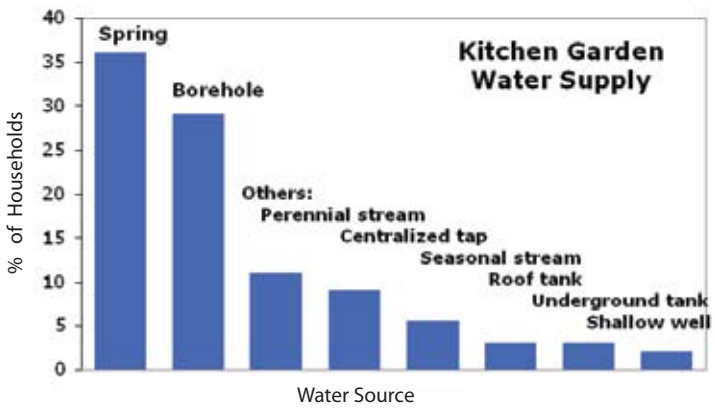


Figure 1. Boreholes and springs are the most common source of water for kitchen garden irrigation in the Potshini catchment. Source: Kosgei et al, 2006.

Restoring ecological systems

By increasing crop water availability and stabilizing on-farm yield levels well-designed small-scale water system innovations may restore overall productivity in agro-ecosystems. Land degradation is a major constraint to productivity in many semi-arid agro-ecosystems. Problems at field scale, for example, surface crusting, reduced water holding capacity, and declining nutrient levels, limit the productivity of water and lead to declining harvests. At larger scales, land degradation has to do with expansion of farming land into marginal areas, deforestation, or unsustainable grazing management. There seems to be a significant potential to shift unproductive evaporation to productive transpiration and biomass production, and mitigate degradation, by using water system innovations to restore water balances. In the Potshini no-till plots retained more moisture and produced less seasonal runoff than conventionally tilled plots. In Makanya, constructed fanya juus terraces result in increased soil moisture availability and have contributed significantly towards better maize yields.

Supplemental irrigation to bridge dry spells makes the difference between success and failure of the maize crop. This farm had access to the limited supply of water stored in a community reservoir. Cultivated area has now far outstripped the capacity of the reservoir, and less than 1 in 20 farmers will get the required water at the critical time.

Hydrologic processes

Understanding linkages between surface and groundwater is vital when making water resource development decisions. In the Potshini catchment in South Africa surface and groundwater systems are very closely linked, and stream base flow is coupled to this shallow groundwater. It can be expected that the different technologies tested will have a direct and relatively easy to predict effect on water flows out of the catchment (see Figure 2). In the Makanya catchment in Tanzania, geology is more complex. While surface streams are also coupled closely with shallow groundwater, sub-surface water can follow fault lines to emerge in catchments other than those where the rain fell, complicating simple water balance modeling. Water use impacts of interventions upstream may be disconnected from downstream impacts in both space and time, but are unlikely to have significant impact on spate irrigation directly downstream which is dependent on large flood events.

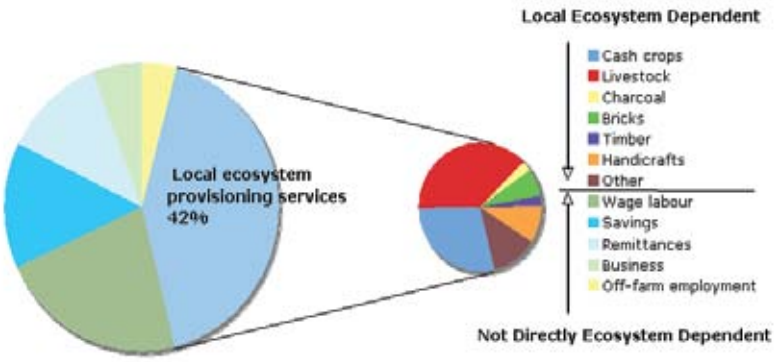


Figure 3. After two seasons of severe drought, 42% of household income in Makanya catchment came directly from ecosystem services, and almost 75% of that from activities other than cropping, most importantly livestock rearing which is dependent on grazing uncultivated lands, and small enterprises.

Livelihood dependency

Understanding how people cope with stresses and shocks, which in semi-arid smallholder agro-ecosystems often are related to drought, is necessary to plan strategies to reduce the vulnerability of these farming communities. In the Tanzanian catchment people rely heavily on savings and the surrounding natural ecosystem for resources in times of drought. These resources are often used to provide temporary income when crops fail (see Figure 3). Without functioning institutions that protect the ecosystem from excessive use, there is a risk that this "ecosystem insurance capacity" becomes reduced, compromising the coping capacity of the local population. In South Africa, people also use a wide range of resources in their livelihoods, but they have a substantially larger and more varied set of social support systems. Increasing capacity to mediate and navigate these options is an important entry point for increasing the adaptive capacity of the community.

Figure 2. Due to close hydrologic linkages, interception of rainfall in water harvesting structures is likely to have a rapid impact on groundwater levels and steam flows in the catchment. (2a) Groundwater level responds very rapidly to rainfall, illustrating the close linkage between rainfall and groundwater. (2b) Electrical Resistivity Tomography demonstrates the linkage between groundwater and stream flow.

Figure 2a

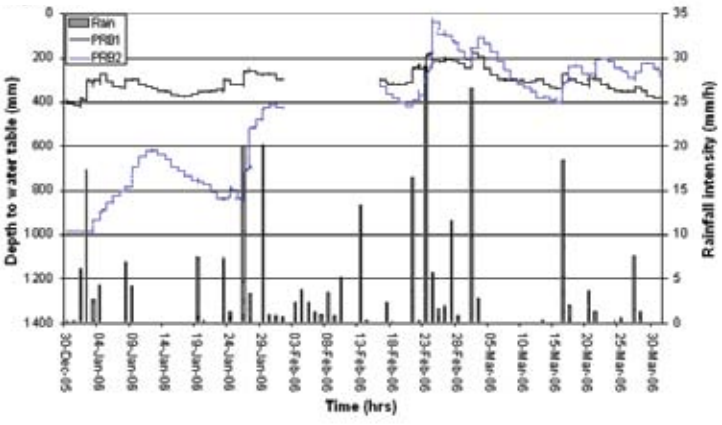
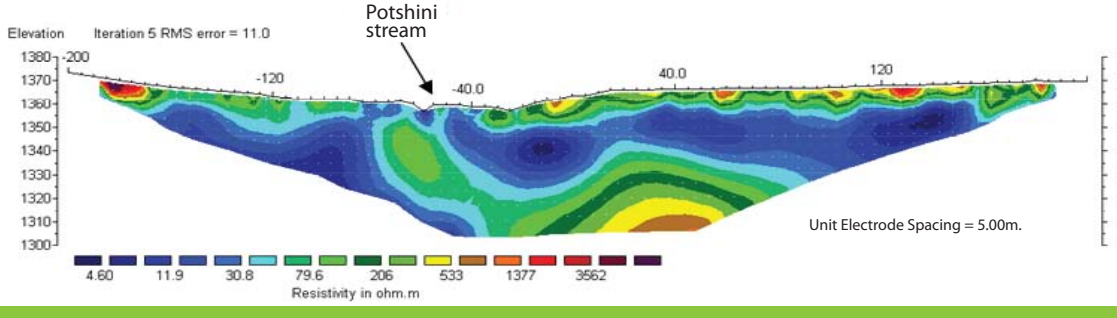


Figure 2b



The participatory catchment monitoring network at Potshini has the potential to become an integral part of the decision making process, from farm to national level, on water and agricultural policy development. Community members monitor daily rainfall, soil moisture, and runoff discharge.

The Programme

SSI is a research programme that aims to produce high quality science that can improve the livelihoods of the rural poor in semi-arid agro-ecosystems of sub-Saharan Africa. To do this, the programme brings together a set of PhD students and Post Doctoral Scientists from Africa, Asia, and Europe to undertake interlinked research projects in two catchments in sub-Saharan Africa. The research is carried out in a participatory manner, in collaboration with field-based action research organizations, supported by an outreach programme.

The Thukela Basin research in South Africa is hosted by the University of KwaZulu-Natal (UKZN), is assisted by the Farmer Support Group of UKZN and collaborates with the Agricultural Research Council (ARC), through its LandCare initiative. This initiative carried out demonstrations together with farmers on soil best management practices including soil fertility management, inter cropping, conservation farming and liming. The SSI partnership added the elements of water management, social, economic and hydrologic research.

The research in the Pangani is hosted by Sokoine University of Agriculture (SUA) which has a long track-record of research in the Makanya watershed, focusing on soil and water management and participatory rural development. The Soil-Water Management Research Group (SWMRG) at SUA has a research field station in the vicinity of the watershed. The SSI partnership added the elements of water management, hydrology, livelihoods and resilience research.

Acknowledgments

The work reported here was undertaken as part of the Smallholder System Innovations in Integrated Watershed Management (SSI) Programme funded by the Netherlands Foundation for the Advancement of Tropical Research (WOTRO), the Swedish International Development Cooperation Agency (Sida), the Netherlands Directorate-General of Development Cooperation (DGIS), the International Water Management Institute (IWMI) and UNESCO-IHE Institute for Water Education and Stockholm University (SU).

This brief was based on selected publications from the research work of the SSI programme:

Bhatt, Y., Bossio, D., Enfors, E., Gordon, L., Kongo, V., Kosgei, J., Makurira, H., Masuki, K., Mul, M., Tumbo, S. 2006 Smallholder System Innvations in Integrated Watershed Managemetn (SSI). IWMI Working Paper 109, pp 60.

Chikozho, C. 2005. Policy and institutional dimensions of small-holder farmer innovations in the Thukela River Basin of South Africa and the pangani River Basin of Tanzania: A comparative perspective. Physics and Chemistry of the Earth, Parts A/B/C, Volume 30, Issues 11-16, 2005, Pages 913-924

Enfors, E.I. and Gordon, L.J. (2007) Analyzing resilience in dryland agro-ecosystems: A case study of the Makanya catchment in Tanzania over the past 50 years. Land Degradation and Development, in press. Published Online: 15 May 2007

Enfors, E.I., Gordon, L.J. Strategies to deal with drought among smallholder farmers in semi-arid Tanzania A study from the Makanya catchment of climate related poverty traps and water system innovations. Global Environmental Change, submitted

Hendriksson, J. 2005. Mapping small-holder farmers use of ecosystem goods in Potsheni, Thukela Drainage basin, South Africa. Focus on times of Crop failure . MSc thesis, Stockholm University, Sweden

Kongo V.M., Lorentz S.A., Jewitt G.P.W. 2006. Surface and subsurface water interactions in the Potshini catchment, South Africa. In Proceedings of the 7th WaterNet/WARFSA/GWP-SA Symposium, 1-3 November 2006, Lilongwe-Malawi.

Kosgei, J.R., Jewitt, G.P.W., Kongo, V.M., Lorentz, S.A. 2007. The influence of tillage on field scale water fluxes and maize yields in semi-arid environments: A case study of Potshini catchment, South Africa. Physics and Chemistry of the Earth 32, 1117-1126.

Kosgei, J.R., Jewitt, G.P.W. 2006. Potential impacts of tailored policies on food security among smallholder farmers in semi-arid Potshini catchment, South Africa. Paper presented at the 10th Annual SearNet conference, 4th - 6th December, 2006; Mombasa, Kenya.

Makurira, H., M.L. Mul, N.F. Vyagusa, S. Uhlenbrook, H.H.G. Savenije, (2007). Evaluation of community-driven smallholder irrigation in dryland South Pare Mountains, Tanzania: A case study of Manoo micro dam. Physics and Chemistry of the Earth 32 (2007) 1090–1097.

Makurira, H., Savenije, H.H.G., Uhlenbrook, S., Rockström, J., Senzanje, A., (2007). Towards a better understanding of water partitioning processes for improved smallholder rainfed agricultural systems: A case study of Makanya catchment, Tanzania. Physics and Chemistry of the Earth 32 (2007) 1082–1089.

Masuki, K.F.G; M. C. Shetto; K.D. Mutabazi; E. M., Nkonya; A. Z. Mattee; H.F. Mahoo; J. M. Wickama and M.N. Kingamkono, 2007. Potentials and uptake of Water and Moisture System Innovations: the case of Makanya Watershed in Tanzania. Working Paper submitted to CPWF SG on Enhance Adoption of High Potential Interventions for Increasing Agricultural Water Productivity. SUA, ALERT and IFPRI. August 2007. 13pp

Mul, M.L., Mutiibwa, R.K., Foppen, J.W.A., Uhlenbrook, S., Savenije, H.H.G., 2007. Identification of groundwater flow systems using geological mapping and chemical spring analysis in South Pare Mountains, Tanzania. Physics and Chemistry of the Earth Volume 32, Issues 15-18, Pages 1015-1022.

Website: www.unesco-ihe.org/ssi