The Small Reservoirs Project: Research to Improve Water Availability and Economic Development in Rural Semi-arid Areas.

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1. Introduction

In semi-arid areas of the developing world, rural water supply is increasingly insufficient. Supplying the rural population in semi-arid developing countries with water requires spatially distributed sources of different qualities and quantities of water. Access to clean drinking water is being improved with borehole programs, but the equally important large volume demand for non-drinking purposes is currently not addressed sufficiently. In many regions, small reservoirs act as multi-purpose water sources in support of irrigated agriculture and gardening, livestock watering and fishing, as well as personal hygiene, domestic uses, and building. They are as important for rural development, health improvement and poverty reduction as access to safe drinking water.

One of the key advantages of small reservoirs is their existence in large numbers, greatly improving the water availability at village level. They are often the only adequate and economically feasible source of large volume water supply for non-drinking purposes and important for economic development and the reduction of poverty.

While their small size, existence in large numbers, and widespread distribution leads to many desirable socio-economic effects, the same characteristics make hydrological impact assessments and scientifically sound development difficult.

The Small Reservoirs Project is conducting research in Ghana, Burkina Faso, Zimbabwe, and Brazil, to assess the impact of small reservoirs on the rural communities and to provide tools to improve their planning, operation, and maintenance.

2. Characteristics of water sources available to meet the rural non-drinking water demand

2.1 Ground water resources

Ground water is an important water source, especially for the supply of clean drinking water. While, depending on the region, ground water resources may be under-exploited (Martin and van de Giesen, 2005), its large volume use i.e. for irrigated agriculture is not feasible for most of the rural population due to insurmountable borehole drilling, pump acquisition, and pumping costs. Operating and maintenance costs require farmers to possess a fair amount of cash capital throughout the growing season, the time at which cash availability in farmers is often low.

Shallow, hand-dug wells are another water source that is utilized in some regions, but many a time they are not perennial. They are small or medium volume water suppliers and can support gardening on a small scale. Temporary wells dug into the beds of dried up rivers can be seen as a special form of shallow wells. They tap the riverine aquifers
and can supply enough water for small scale irrigation throughout the course of the dry season.

2.2 Natural surface water

Apart from agricultural use of the flood plains, free surface water of rivers is also used for irrigation purposes in the dry season. Irrigation at a considerable scale requires the acquisition and operation of pumps. In regions as the Upper East Region of Ghana, where most streams are only carrying water during the rainy season, this water source is only an option for a very small part of the rural population. Regions with river stretches downstream of hydroelectric dams benefit from the constant water release that is required for power generation, thereby turning seasonal into perennial streams. River stretches with extensive floodplains, however, are at times unfavorable for health reasons. In the Upper East Region of Ghana, for example, these areas where largely abandoned over the past decades in the struggle to eradicate river blindness and to restrict other vector borne diseases.

2.3 Rainfall

The most abundant and ubiquitous large volume water source for the rural population, however, is rainfall. Rainfed agriculture is usually producing the staple foods, largely for subsistence, but also for trade. Rainfed agriculture, however, is frequently subject to crop failure. Except for years of a meteorological drought, this is often not due to a lack of total rainfall, but due to extended dry spells between the rain events. This means that the timely distribution of the water availability is often the limiting factor to crop growth. Especially in light of global climate change that predicts a shift towards weather extremes, this calls for practices and technologies to level out the extremes. Some farming practices are utilized to improve rainfed agriculture. They are mainly aiming at water conservation which is achieved by maximizing soil infiltration and water holding capacity. Dry spells could also be bridged through supplementary irrigation of the rainfed agriculture by means of water harvesting systems that collect local surface runoff in small storage structures (Rockström et al., 2002).

2.4 Small reservoirs

Semi-arid regions are often associated with high intensity rainfalls. Their intensities often exceed the infiltration rates and capacities of the soils and cause surface runoff. Significant amounts of the rainfall are lost without replenishing the soil water that otherwise would be available to plants. Small reservoirs capture parts of this surface runoff and make it available for later use. Their water is used throughout the year, but their main importance is that they make water available for an extended time into the dry season.

The water captured in these structures serve local communities in many ways. They support livestock watering throughout the dry season when most other water sources are dried up. In households, reservoir water uses include washing of dishes and clothes, as
well as personal hygiene. The silt caught in the reservoirs can be molded to bricks, and reservoir water is also used during the construction of houses. The possibility of fishing adds a source of protein to the local diet.

The most important use, however, is dry season irrigated agriculture. The water captured in the rainy season is released on the irrigation fields in a controlled way, which diminishes crop damage through drought stress. In contrast to the staple food producing rainfed agriculture, the produce from the irrigation fields is mainly marketed for income. Engaging in both irrigated and rainfed agriculture levels out the seasonality of workload and income, and vastly reduces the risk of total crop loss. It leads to a diversification of incomes, and a more stable and reliable financial basis for the rural population.

3. Scope of the Small Reservoirs Project

3.1 General scope

The Small Reservoirs Project seeks to develop tools to aid the planning and improve the operation of small reservoirs. It will provide watershed planners with the technical means to inventory and monitor storage volumes, and to assess the hydrological impact of reservoirs on different scales. The lack of knowledge on ensembles of small reservoirs is addressed by conducting research on local and regional levels. The principal output will be a Reservoir Ensemble Toolbox. The toolbox will be comprehensive and include analytical instruments, and a set of process oriented tools for improved participatory decision making. The set of tools will come in two parts, the Basin/Watershed Tools for the regional scales and the Community/Reservoir Tools for the local scale. The research is conducted in collaboration with local researchers and institutions. The process of developing the tools relies on the collaboration of local stakeholders and policy makers. The results are disseminated through numerous local institutions that are involved in developing the toolbox.

3.2 Focus in the Volta Basin, Ghana and Burkina Faso

Within the Volta Basin, the Small Reservoirs Project has its main focus on hydrological, biological, and health aspects. The hydrological research is conducted in the Upper East Region in northern Ghana, a semi-arid region with a single rainy season, high population density, and a great demand for water in support of agriculture and livestock. On a local level, the hydrological functioning of small reservoirs is being studied in the Tanga watershed in the Upper East Region, where water use, and the filling and draining of reservoirs is being observed. The 21 km² watershed features a branch with a single reservoir, and a branch with two cascading reservoirs. An undammed subwatershed can serve as a non-impact reference. Special attention is being given to water losses from the storage and through inefficient use. The water use efficiency was determined at two irrigation schemes. Institutional and sociological aspects are covered in respective studies.

On the regional scale, remote sensing techniques are being used to make up-to-date reservoir inventories and to monitor the reservoir storage over time. Algorithms are
sought for automated extraction of reservoir surfaces which can help in monitoring regional water availability.

In Burkina Faso, water quality and health studies are conducted at numerous sites. The impact of small reservoirs on water quality is being studied on ensembles of small reservoirs, which are monitored for algal blooms. They are indicators of aquatic stress, regularly attributed to excessive nutrient loading or pollution. Health aspects are studied in school children of schools in proximity to reservoirs, as well as control schools more than 5 km away from the nearest reservoir. The health indicators studied are prevalence and incidence of malaria, urinary and intestinal schistosomiasis. Potential vector breeding sites are identified in an ecological study. Around the select schools, different types of water bodies (e.g. reservoirs, canals, drains, seepage areas, borrow pits, rain puddles) are identified and mapped and a selection of these water bodies is monitored monthly for mosquito larvae and snails.

4. Small reservoirs addressed at regional and local scales

4.1 Small reservoirs on a regional scale

Large numbers of small reservoirs can be found throughout semi-arid areas, but efficient watershed management and the planning of further dam development is hindered by a lack of basic information. Reliable, up-to-date information on the number, location and storage volumes of existing reservoirs is hardly ever available from official sources, as their planning and construction is oftentimes neither coordinated nor inventoried.

In the Upper East Region of Ghana we have shown that the evaluation of satellite images is a useful tool in making region wide, up-to-date reservoir inventories. Even reservoir storage volumes can be determined as a function of reservoir surface areas using regional area-volume relations. Such relations can be derived from few bathymetric surveys of reservoir basins (Liebe et al., 2005).

While the hydrological impact of small reservoirs is individually quite small, the existence of several hundreds of such structures may have a notable impact on a regional scale. Through repeated coverage with weather independent Radar satellites, regional storage volumes can be monitored and the hydrological state of a region can be determined in near-real-time. The conclusions drawn from studying the functioning of ensembles of reservoirs on a local and regional scale will be combined into planning and impact assessment tools for watershed planners, as an integrated part of the planning toolbox.

4.2 Small reservoirs on a local scale

On a local scale, the hydrological impact of small reservoirs is relatively small as they only capture parts of the total runoff in the head of a watershed. In terms of food security, economic development, and income diversification, small reservoirs have a significant impact on rural communities. This becomes obvious especially when comparing coping strategies in villages with and without reservoirs in years where the harvest from rainfed agriculture, and thus staple food production, was poor. Where irrigation systems are accessible, parts of the produce can be used for subsistence, or
income from marketable crops can support food purchases. In villages without access to irrigation schemes, such situations often lead to malnutrition and starvation.

For proper functioning of small reservoirs, both water storage and use should be efficient. The storage efficiency is affected by two main processes, namely evaporation and percolation losses. The percolated water feeds into the groundwater, and therefore could also be seen as a transfer into a different storage medium. While constituting a water loss to the reservoir, the percolated water can be used elsewhere as groundwater. Water losses through evaporation, in contrast, constitute a real water loss to the local system, as the water vapor is transported away with the wind. In the Tanga watershed, evaporative water losses are being studied with an innovative floating weather station, and percolation losses are being determined through chemical reservoir and groundwater water analysis.

Siltation is another process that can affect the storage efficiency. Its degree varies regionally, depending on topography, soil and vegetation characteristics, and farming practices in the catchment. While siltation certainly poses a problem, it should be mentioned that all water related structures are built for a certain lifespan. The existence of reservoirs that supply water for several decades, even without any rehabilitation, indicates that their beneficial life span is significant. Nevertheless, desiltation of reservoirs after decades of use could extend their lifespan significantly.

The water use efficiency is another major factor for the overall efficiency of a reservoir. A simple measure for the use efficiency is that of relative water supply (Levine, 1999). It is defined as the ratio of water supplied to the crop to actual crop water requirements. Faulkner (in preparation) reported that water use efficiencies differ largely among irrigation schemes, but where never a limiting factor to the extent of use.

For a better, more efficient use of existing reservoirs, educational measures could play an important role. Stakeholders can learn to improve their water use efficiency in irrigation role play games. These should also include instructions in the proper use of agrochemicals as fertilizers and pesticides, as well as the importance of irrigation system and reservoir maintenance through the user collective. For such maintenance purposes, the structural simplicity of reservoirs and small scale irrigation schemes is an appealing advantage. Small defects in the channel system, spillway or dam erosion are easily identified by the users, and maintenance can be organized and financed through local water user associations. Leaking dam walls or clogged outlet valves, in contrast, can pose a greater challenge, and may require technical backing by a local institution.

5. Conclusions

Supplying the rural population with water is a distributed problem, and large numbers of small reservoirs can be seen as a distributed solution to it. They are multi-purpose water supplies that help to improve smallholder livelihoods and food security. Small reservoirs are a suitable means to help supply the required quantities at village level. Yet, the impact of ensembles of these reservoirs on regional water systems is still rarely studied.

The Small Reservoirs Project is addressing these shortcomings and seeks to provide tools for planning and evaluating ensembles of small, multi-purpose reservoirs for the
improvement of smallholder livelihoods and food security. Remote-sensing techniques and extensive field measurements are investigated to better understand the hydrological impact of regional reservoir storage volumes and the effects of their further development. Economical, social, biological, and health effects are an integrated part of the study. The results are synthesized in a Reservoir Ensemble Toolbox, which is developed and disseminated in conjunction with local institutions. The toolbox addresses planning, development, and management of small reservoir ensembles at a basin/watershed level to limits conflicts over water, markets, and other resources and to minimize undesirable environmental interactions among the reservoirs. At a local/community level the toolbox seeks to promote the use of small multi-purpose reservoirs that are well sited and designed, and operated and maintained in sustainable fashion. They need to be economically viable while assuring to improve the livelihoods of the local residents.

Acknowledgement: The Small Reservoirs Project is a CGIAR Challenge Project on Water for Food (CP 46). Comparative and supplementary research is conducted in the Limpopo Basin, Zimbabwe, and the São Francisco Basin, Brazil. Further information can be found at http://www.smallreservoirs.org

Literature

Faulkner, J.W., Steenhuis, T., van de Giesen, N., and M. Andreini, (submitted): Water use, productivity, and profitability of small scale irrigation schemes in Ghana’s Upper East Region, draft for submittal for publication. Submitted for publication to Irrigation and Drainage Systems.


