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IWMI
Working
Paper
189

Small Reservoirs in Africa: A Review and Synthesis to Strengthen Future Investment

Davison Saruchera and Jonathan Lautze

International Water Management Institute
Pendeke DEVELOPMENT FLOW
CGIAR RESEARCH PROGRAM ON Water, Land and Ecosystems

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A Review and Synthesis to Strengthen Future Investment

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Pendeke Development Flow — Pendeke Development Flow, South Africa

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Contents

Executive Summary

Background Small reservoirs are a critical mechanism to strengthen resilience and enhance rural livelihoods in Africa. They provide a range of benefits, including increased access to water in local communities, improved household food security, diversified livelihood options, female empowerment and enhanced entrepreneurial activities. As a result, governments, development agencies and the private sector have invested significant resources in constructing new or rehabilitating existing small reservoirs. However, a range of factors, including insufficient maintenance, rapid siltation and ineffective institutions, can weaken the performance of small reservoirs.

Reconciling mixed evidence to generate a balanced picture - Despite existing data on various benefits and costs of small reservoirs in Africa, no comprehensive assessment of their impacts has been undertaken. Case studies yield important insights, but cannot be used individually to confidently generalize. This paper responds to the lack of comprehensive examination of the impacts of small reservoirs by undertaking a stock-take of available evidence to understand the frequency of reporting of various impacts, benefits and costs. A survey of available evidence provides the basis for more conclusive guidance on how to improve the performance of small reservoirs in Africa.

Objectives and methods - This paper synthesizes available literature on the benefits, performance and challenges of small reservoirs, and provides recommendations that can inform future investment. The study compiled and classified more than 80 documents concerning about 4,000 small reservoirs in Africa, according to a set of basic, descriptive and explanatory parameters. Basic parameters describe a reservoir's name, location and investment status. Descriptive parameters capture the impacts of a reservoir (what happened) and explanatory parameters capture the determinants of the impact (why it happened). In addition, the study included field-based research on the conditions around a set of 10 small reservoirs in southern Zambia, which enabled more nuanced analysis and discussion of key findings. Field-based data were collected through conducting interviews on a set of key parameters including benefits, costs, degree of functionality, institutions and maintenance.

Results from document analysis – Results from the desktop study show a range of benefits derived from small reservoirs. These benefits include improved reliability of access to domestic water and expanded irrigation water supply, as well as increased livestock watering and greater entrepreneurial activities. Further, positive impacts realized include improved household food security, increased household income, reduced out-migration and the empowerment of women. Identified costs were relatively fewer than benefits. Costs were limited to conflicts in communities on water and land use, membership fees for users, and negative health impacts arising from water-related diseases. The performance of small reservoirs is generally rated as mixed to poor. Operational lifespans of less than 10 years, and high water loss rates in small reservoirs illustrate this poor performance. Reasons for the poor performance include weak institutions, sedimentation, poor siting and inadequate maintenance.

Results from fieldwork - The case study based on fieldwork in southern Zambia confirmed both the benefits and challenges of small reservoirs that emerged from the document analysis. Further, fieldwork identified that the short-term planning horizon for investments in small reservoirs, often driven by emergency response, contributes to a rapid decline in the functionality of small reservoir infrastructure, the primary factor for such an outcome being sedimentation. However, the advocacy-oriented nature of investments in small reservoirs may create a positive narrative that eclipses their generally poor performance. More significantly, fieldwork provided evidence that suggests that reinvesting in old infrastructure might be more cost-effective than building a new reservoir, particularly since the structural quality of new small dams seems to be declining.

Key messages - The results point to five key messages. First, small reservoirs produce a range of benefits that provide practical value to rural communities. Second, the performance of small reservoirs – measured through economic analysis, reservoir longevity or other means – is generally not spectacular. Third, the primary factor explaining the temporal decrease in reservoir lifespan is sedimentation – explained by a host of factors, including institutions. Fourth, rehabilitation appears to be a better investment than new dam construction. Fifth, the quality of small dam infrastructure may be declining.

Conclusions - Ultimately, findings from this study suggest that rehabilitating existing reservoirs may be more efficient than building new infrastructure to gain the benefits of small reservoirs. At the same time, findings also point to broader lessons on the need to change the approach to small reservoir development and management. In other words, to consider adopting a long-term, more holistic approach (or model) to the construction and maintenance of small reservoirs that match the challenges associated with sustainably tapping the benefits of the water that they store. The following three points are worth mentioning in this regard:

- It is time to adapt the design of advocacy-based, disaster-responsive investments in small reservoirs, by drawing more evidence-based, practically informed approaches. In practice, this may mean insistence on the achievement of certain benchmarks by local institutions, such as provision for the collection and management of recurring costs of controlling sedimentation.
- The long-term approach needed for investments in sustainable small reservoirs will require formal institutions, presumably national small reservoir programs, to ensure sustainability by managing and maintaining infrastructure.
- Regular monitoring of reservoirs after investment is critical to the success of a long-term approach to investments in small reservoirs.

Introduction

Small reservoirs are critical to food security and resilience in Africa, providing essential services in rural areas. Erratic rainfall and associated variability in water resources availability are major constraints to improving food security and alleviating poverty in sub-Saharan Africa (SSA). Small reservoirs are a primary mechanism to cope with this variability and have been recognized as being important for multiple water uses, rural livelihoods and economies in the Limpopo (Senzanje et al. 2008) and Volta (Namara et al. 2010; Acheampong et al. 2014; Katic et al. 2014) basins. Reflecting the demand for their benefits, there are more than 1,000 small reservoirs in each of the Limpopo and Volta basins (Kibret et al. In submission). The benefits of small reservoirs are recognized elsewhere in Africa, such as in Tunisia (Khlifi et al. 2010; Boufaroua et al. 2013) and Ethiopia (Lasage et al. 2015; Berhane et al. 2016).

Limited evidence suggests that investments in small reservoirs in Africa have met with mixed success. Some small reservoir projects have been determined to be successful (Khlifi et al. 2010; Boufaroua et al. 2013; Lasage et al. 2015). Khlifi et al. (2010) highlighted the increase in crop and livestock production due to small reservoir operations. Boufaroua et al. (2013) stated that land and water conservation in Tunisia was successfully achieved through the construction of small reservoirs. Lasage et al. (2015) described sand dams as reliable sources of safe drinking water in Ethiopia. However, other investments in small reservoirs have been described as unsuccessful (Sally 2002; Birner et al. 2010; Berhane et al. 2016). Sally (2002) highlighted how the lack of maintenance and unclear accountability contributes to poor reservoir performance. Birner et al. (2010) cited institutional factors, notably user groups, accountability and inadequate financing as reasons for lack of success. Berhane et al. (2016) found that the lack of operation and maintenance, siltation and poor management derail the success of small reservoirs.

Support for small reservoirs continues. Despite questions on whether investments in small reservoirs are economically sustainable, provide substantial and equitable benefit to the poor in rural communities, and produce positive environmental impacts, public institutions and stakeholders continue to request support for investment in the creation or rehabilitation of reservoirs in SSA. This has resulted in numerous small reservoir programs in Africa in recent years. For example, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) supported a small reservoirs project in the Limpopo and Volta basins between 2004 and 2007 (http://www.smallreservoirs.org/ - accessed in 2017). Also, the Bill & Melinda Gates Foundation supported an agricultural water management solutions project (AgWater Solutions Project) between 2009 and 2012 that included a focus on small reservoirs (Evans et al. 2012a, 2012b, 2012c). Further, the African Development Bank (AfDB) supported the development of guidelines that govern and promote investments in multipurpose small dams in Zambia (AfDB 2012); the United States Agency for International Development (USAID) has supported the expansion of small water infrastructure to improve food security in Mali (USAID 2019). African governments, with assistance from international development agencies, have also made efforts to develop water infrastructure for community use. For example, the Government of Tigray Regional State, Ethiopia, invested in small reservoirs in 1995 to eradicate poverty (Gebregziabher et al. 2009); and the Government of Malawi also rolled out a program in the mid-1990s to revitalize colonial era small reservoirs in order to improve rural livelihoods (Nkhoma 2011).

There is a need for evidence that guides investments in small reservoirs. Some work has been done to generate guidance for future investments in small reservoirs. The Small Reservoirs Project (http://www.smallreservoirs.org/ - accessed on February 25, 2019) produced a toolkit outlining ways to achieve effective investments in small reservoirs. Sally et al. (2011) examined two case studies in Burkina Faso, and highlighted the need for more reliable data and awareness of power relationships to strengthen performance. Nkhoma (2011) examined small dams in Malawi and concluded that strengthening performance can be through better understanding of local contexts. Evans et al. (2012b) reviewed small reservoirs in Zambia and offered a set of governance and management suggestions for improving return on investment. Venot et al. (2012) reviewed small reservoir experiences in four countries and highlighted the need for more integrated approaches to their planning and management. Despite this important work, a comprehensive and up-to-date review of experience on investments in small reservoirs that is oriented toward the provision of implementation guidance is not available.

Objectives of this paper - This paper seeks to synthesize research on the impact of small reservoirs to identify conditions and factors that enhance the sustainable benefits from investments in them. In particular, the paper seeks to respond to the following questions:

1. What financial and institutional factors determine the level of infrastructure sustainability (particularly economic)?
2. What biophysical factors are most important for environmental sustainability of small reservoirs?
3. What are the trade-offs of investments in small reservoirs under different conditions and contexts, e.g., in relation to health (e.g., malaria risks)?
4. What factors affect the infrastructure longevity of small reservoirs?
5. What is the potential for (re)investment in small reservoirs under various conditions?

To respond to these questions, the paper provides a review of literature on small reservoirs in Africa. The paper applies a framework to capture – or reveal the absence of information on – the critical development areas highlighted by the five questions above. Moreover, this paper seeks to contribute to the development of an approach that strengthens investments in small reservoirs in Africa to enhance sustainability.

Complementing desktop work with a case study - The desktop review of literature on small reservoirs generated a number of insights about the benefits and challenges, complemented by a case study of investments in small reservoirs in the Southern Province of Zambia. The objective of the case study was to assess a sample of investments in small reservoirs according to the costs and benefits they produced, and to understand the factors that explain variations in performance. Particular focus was on two key knowledge gaps: (i) longevity of small reservoir infrastructure, and (ii) benefits of investing in new infrastructure versus reinvesting in the rehabilitation of old degraded infrastructure.

Approach and Methods

Defining Small Reservoirs

Small reservoirs have been variously defined using surface area, height of the dam wall, storage capacity and the availability of water (WCD 2000; van de Giesen et al. 2010; Evans et al. 2012a, 2012c; Ayantunde et al. 2016; Balana et al. 2016). WCD (2000) described a small reservoir as being, at most, 100 hectares (ha) in surface area, with a storage capacity below 30 million cubic meters (Mm^3) behind a dam wall that is less than 15 meters (m) in height. Van de Giesen et al. (2010) defined a small reservoir using the same surface area and dam height. By contrast, Evans et al. (2012c) indicated that a small reservoir's dam is less than 7.5 m high, with a storage capacity of 1 Mm^3 and a maximum irrigation area of 50 ha. Balana et al. (2016) agreed with the storage capacity specified by Evans et al. (2012c), but proposed a maximum dam height of 15 m. Ayantunde et al. (2016) described dams with a wall height of less than 10 m as a small reservoir; storage capacity is not considered a defining factor.

In this paper, we seek to foster inclusion of small reservoirs under various definitions, by adopting a relaxed standard that enables capture of information under the different interpretations elaborated above. The standard applied for this report is as follows: maximum dam height is 15 m, surface area is less than 100 ha, and reservoir storage capacity is less than 1 Mm^3, with perennial water storage.

Methods for Desktop Review

This review of investments in small reservoirs focused on Africa. Literature searches in the library of the International Water Management Institute (IWMI) and online searches provided information on location, water use, impacts, performance and institutional issues around small reservoirs. The literature searches used the following key words: small reservoirs, Africa, infrastructure, performance, investments, climate change, sustainability, institutions, health, environment, livelihoods, and gender. Overall, the literature search produced a list of 80 documents. Most of these documents included information on a set of reservoirs.

The documents were classified into basic, descriptive and explanatory parameters (Table 1). Basic parameters include the type of source from which data were extracted, reservoir(s) name and location, and whether a reservoir (and/or associated program) was a new investment or reinvestment.[1] Descriptive parameters aim to capture "what happened" while explanatory parameters aim to capture "why it happened."

Descriptive parameters Descriptive parameters enable the capture of impacts that result from the creation or presence of small reservoirs. The social, economic and environmental changes in the local landscape resulting from a reservoir(s), categorized as *impacts*, may be positive or negative. Examples of positive impacts are improved incomes and food security, while an example of a negative impact is conflict among water users. Performance measures included different metrics, from crop productivity to income. To capture this spectrum of metrics, a parameter on *performance benchmarks* was considered. In *performance*, we assess the degree to which a reservoir satisfies project-identified performance indicators. *Health* refers to the water-related health impacts resulting from the creation of a small reservoir.

Explanatory parameters Explanatory parameters attempt to capture the factors behind the evidenced impacts of reservoirs, which include financing, institutions, maintenance and suitability. *Financing* includes the funding sources, and structures of funding for the construction or rehabilitation of the reservoir. This may include a government contribution and donor contribution, or donor financing with a list of government obligations. *Institutions* refer to the community and national policy context of the management arrangements around the reservoir. *Maintenance* refers to measures in place to sustain the reservoir infrastructure. *Suitability* refers to the biophysical factors affecting the environmental sustainability of a reservoir. To identify factors not otherwise reflected that may be important to outcomes of reservoirs, we also sought to capture any mention of such factors that were noted as *keys to success*.

[1] In cases where only the year of construction is given for a reservoir, we assumed there was no reinvestment.

TABLE 1. Classification framework for the list of documents produced by the literature search.

Category	Parameter	Explanation
Basic	Document citation	*Self-explanatory*
	Type of source	Journal, research report, policy paper
	Reservoir location	Country, basin and coordinates
	Reservoir name(s)	*Self-explanatory*
	Year of completion	*Self-explanatory*
	New investment or reinvestment?	*Self-explanatory*
Descriptive	Positive impacts and benefits	Positive outcomes the reservoir contributes to
	Negative impacts	Negative effects of the reservoir on the local community
	Performance benchmarks	Criteria or measures against which reservoir performance is assessed
	Performance	Evaluation of each reservoir's performance: Good, average, poor (stratification also conducted to reveal verdicts is based on qualitative versus quantitative assessment)
	Health	Disease risk and impact associated with the reservoir
Explanatory	Financing	Source and structure of reservoir funding
	Institutions	Community and national regulations used to operate reservoir
	Maintenance	Arrangements in place to maintain reservoir infrastructure
	Suitability	Biophysical location of reservoir
	Keys to success	Factors identified as critical to reservoir success

Following the classification of documents based on the above framework, a review and presentation of information was undertaken on the following 14 points. For each point, except for the first three, a link to the five key questions, elaborated in the introduction, is shown in parentheses. Please note that effective performance is viewed as being important for sustainability.

1. Geographic distribution of small reservoirs of focus in Africa.
2. Temporal dimension of sources and identification of whether they focus on new investments or reinvestments.
3. Focus of small reservoir documents.
4. Number of documents focused on new investments versus reinvestments *(potential for reinvestment)*.
5. Positive impacts or benefits of small reservoirs as well as frequency of reference to such benefits *(trade-offs)*.
6. Costs or negative impacts of small reservoirs as well as frequency of reference to such costs or negative impacts *(trade-offs)*.
7. Impacts on health that have been documented as well as frequency with which these impacts have been documented *(trade-offs)*.
8. Factors identified to contribute to the longevity or sustainability of small reservoirs *(longevity)*.
9. Benchmarks used to assess the performance of small reservoirs *(trade-offs)*.

10. Assessment of the performance of small reservoirs, divided into assessments based on qualitative versus quantitative criteria *(infrastructure sustainability)*.
11. Factors that render a site suitable for effective small reservoir performance *(infrastructure sustainability)*.
12. Financing source and structure are used to support reservoir creation or rehabilitation *(institutions and financing)*.
13. Types of institutions that have governed the operation and maintenance of small reservoirs *(institutions and financing)*.
14. Factors identified as keys and barriers to success *(reservoir longevity)*.

Attempts were made to address the following two questions in the context of each point: (i) What does the weight of evidence tell us? and (ii) What major gaps exist in the knowledge presented? The depth of data generally did not lend itself to the application of statistical analyses. Therefore, both analytical thrusts used qualitative and simple quantitative methods.

Methods for the Case Study

Key organizations that are active in investments in small reservoirs in southern Africa were approached, and assistance was obtained from CARE International (Zambia) and the Department of Geography and Environmental Studies at the University of Zambia (UNZA). CARE International implemented a program to rehabilitate small reservoirs from 2006 to 2010. UNZA currently oversees a program aimed at creating a database of small reservoirs in Zambia, through a project conducted by the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL).

Data collection through interviews - Interviews conducted with key informants available at 10 reservoirs helped to gather data on the benefits and costs of the reservoir, reservoir longevity and performance trends, institutional arrangements, maintenance and conflicts. The questionnaire used for these interviews is given in the Annex. Basic information was also recorded, and this included coordinates, reservoir name, year of construction and, when relevant, year of rehabilitation, funding agency, and number of villages using the water in the reservoir. To the extent possible, we used data in UNZA's database to verify information obtained from water users. Direct observations assessed water quality – turbidity – and vegetation cover around the reservoir shoreline.

Schedule - The site visits took place during the period September 27-29, 2017. Visits to the first four sites, all in the Monze District, took place on September 27, 2017. On September 28, 2017, another four sites were visited - two in Choma District and one each in Kalomo and Zimba districts. The remaining two sites, both in Kazungula District, were visited on September 29, 2017. At each site, interviews were conducted with at least two users of the small reservoir.

Aims of data collection and examination - Qualitative methods were necessary as the depth of the data did not warrant statistical analysis. Key thrusts driving data collection and examination included the following:

- Benefits realized by water users.
- Costs resulting from the reservoirs.
- Duration of reservoir use, current level of functionality (i.e., siltation) and performance trends.

- New versus rehabilitated reservoir and nature of any rehabilitation.
- Institutional arrangements controlling access to the reservoir and encouraging maintenance.
- Level of dependence on the reservoir.
- Gender dynamics.

Sites in Southern Province, Zambia - Reservoir sites were selected to include several new investments and reinvestments. Sites were identified with the assistance of CARE Zambia and UNZA. Ultimately, 10 sites were selected so that there was a balance between the reservoirs operated by CARE Zambia and those which were of interest to UNZA. Seven reservoirs stored water in approximately 9 months of the year (~January-September). Three reservoirs had water available all year round.

Results

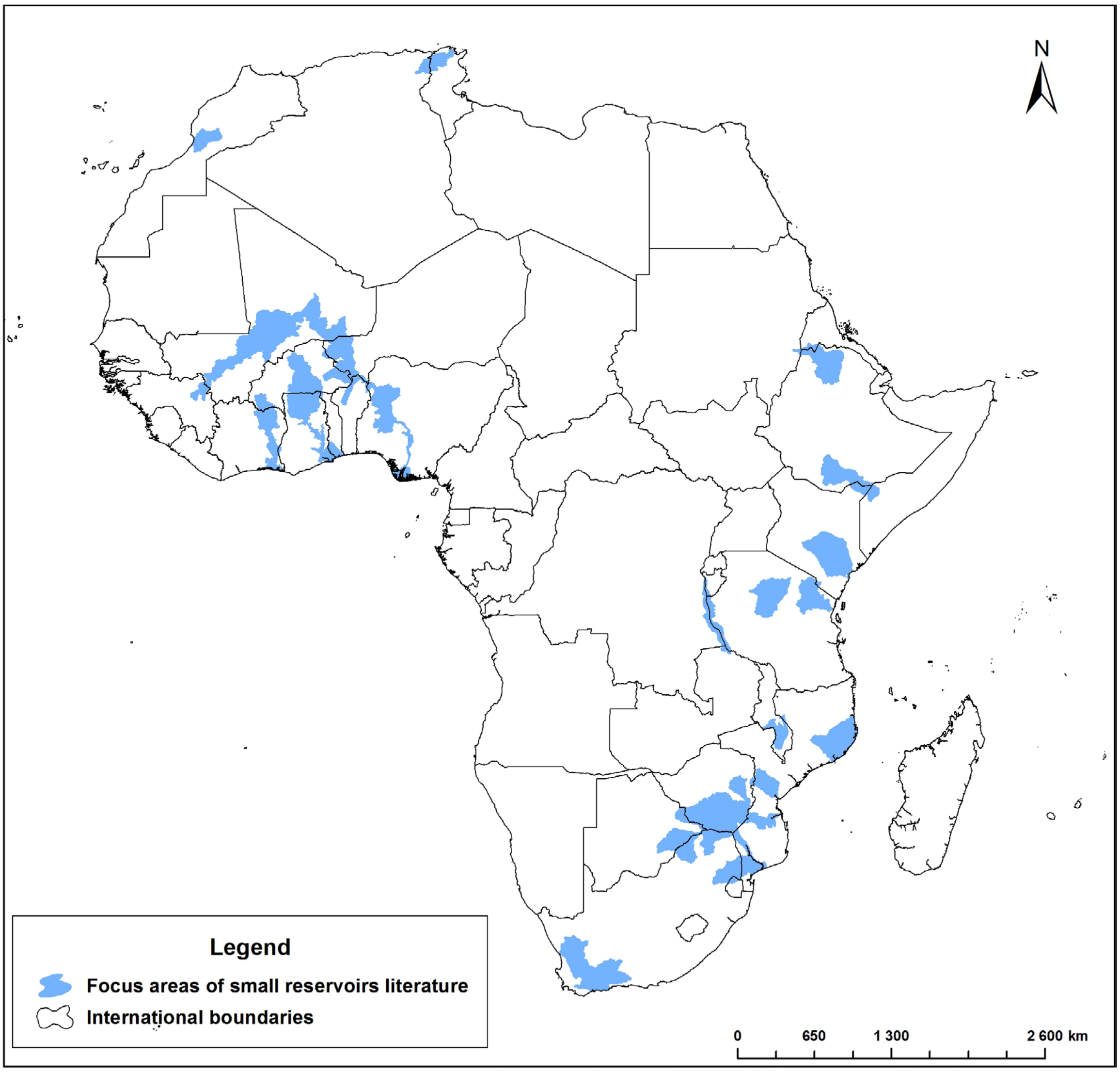
Desktop Review

Geographic distribution of small reservoir literature **-** The bulk of analytical work on small reservoirs focuses within the Volta and Limpopo basins. More than one-third of the literature collected focuses on the southwestern part of Burkina Faso and the Upper East Region of Ghana, in the Volta Basin. The focus of over 15% of the literature was within the Limpopo Basin, mostly in the Mzingwane sub-catchment in southern Zimbabwe. Some notable work undertaken in the Tigray Region of Ethiopia constitutes 15% of the literature collected. Several studies have been conducted in Kenya, Mali, Tanzania, Tunisia and Zambia, and the literature covers individual studies from Botswana, Malawi, Morocco, Mozambique, South Africa and Uganda. About 5% of the literature focused broadly on the SSA region as a whole. Figure 1 provides an indication of the spatial distribution of the focus of literature on small reservoirs.[2]

Chronology of literature on small reservoirs - The majority of the studies were published within the last 20 years. About 80% (i.e., 64 documents) of the literature collected is from 2001 to 2010, while only six documents are from the period 1991-2000 and only one document is from the period 1981-1990. Scholarship is mostly from academic papers, research reports and working papers. Papers from peer-reviewed journals make up over half (55%) of the literature collected. Research reports and working papers from research institutions make up just over 12% of the literature collected. Grey literature including project reports, conference papers, best practice manuals, graduate student theses, book chapters and policy briefs constitute about a third of the literature collected.

[2] Documents focused at a country or continental level are not depicted in the map.

FIGURE 1. Geographic focus of the small reservoir literature.



Source: Created by Luxon Nhamo/IWMI.

Focus of the literature on small reservoirs **-** The primary focus of the more than 80 papers included in this review are characterized in 11 broad categories (Table 2). Sedimentation receives the most attention with 11 citations, followed by reservoir performance and productivity, and livelihood impacts and project evaluation, with 10 citations each. Irrigation, and institutions governing the operation of reservoirs, both receive eight citations each. Similarly, hydrological processes and best practice guidelines both receive seven citations each. Water use and information and communication technology (ICT) also receive five citations each, while health impacts receive the least focus with four citations. Approximately seven other documents placed central focus on other topics such as water quality, gender, conservation and climate change; grouped under the heading of 'Other'.

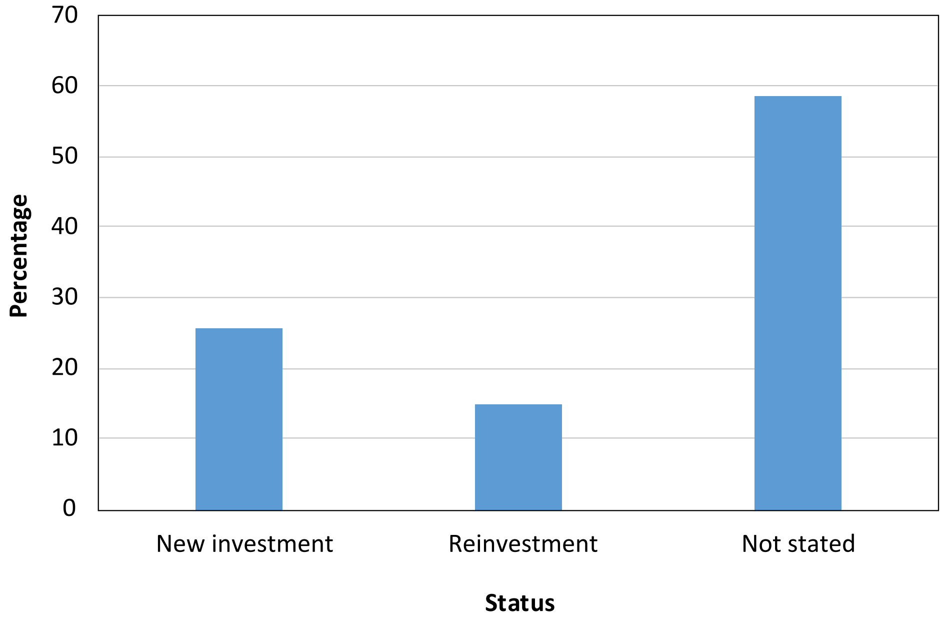
TABLE 2. Broad focus areas of the literature collected.

Broader focus	# Sources	Sources
Sedimentation	11	Sichingabula 1997; Aynekulu et al. 2006; Haregeweyn et al. 2006; Tamene et al. 2006; Adwubi et al. 2009; Hentati et al. 2010; Ndomba 2011; Chihombori et al. 2013; Tumbare 2013; Schmengler and Vlek 2015; Alahiane et al. 2016
Reservoir performance and productivity	10	Abernethy 1994; Faulkner et al. 2008; Mdemu et al. 2009; Mufute et al. 2008; Senzanje et al. 2008; Khlifi et al. 2010; Venot et al. 2012; Teka et al. 2013; Acheampong et al. 2014; Katic et al. 2014
Livelihood impacts and project evaluation	10	IFAD 1998, 2005; Tibaldeschi and Boulenger 2002; GoM 2004; Sawunyama et al. 2005; Burns and Suji 2007; Lasage et al. 2008; Venot and Hirvonen 2013; Nkhoma 2011; Gwazani et al. 2012
Irrigation	8	Stephens 1984; Mugabe et al. 2003; Makurira et al. 2007; Wisser et al. 2010; Eguavoen et al. 2012; Evans et al. 2012a, 2012b, 2012c
Institutions governing the operation of reservoirs	8	Sullivan et al. 2009; Birner et al. 2010; Rusinga et al. 2011; Sally et al. 2011; Venot et al. 2011; Venot and Krishnan 2011; Otto and Venot 2012; Venot 2014
Hydrological processes	7	Meigh 1995; van de Giesen et al. 2005; Basima et al. 2006; Leemhuis et al. 2009; Mantel et al. 2010; Berhane et al. 2013; Lasage et al. 2015
Best practice guidelines for design and operation	7	Fowler 1989; HR Wallingford 2004a, 2004b; Nissen-Petersen 2006; Stephens 2010; AfDB 2012; Andreini et al. 2005
Water use	5	Rusere 2005; Senzanje et al. 2008; Balana 2015; Fowe et al. 2015; Ayantunde et al. 2016
Use of ICT in reservoir management	5	Liebe et al. 2005; Sawunyama et al. 2006; Annor et al. 2009; Mulengera et al. 2012; Munamati et al. 2007
Health impacts	4	Tayeh 1998; Ghebreyesus et al. 1999; Ersado 2005; Boelee et al. 2009a
Other (e.g., water quality, gender, climate change)	7	van de Giesen et al. 2010; Mbinji 2010; Namara et al. 2010; Boufaroua et al. 2013; Balana et al. 2016; Berhane et al. 2016; Liebe et al. 2007

New investment versus reinvestment - More than half of the sources do not mention whether a project is a new investment or reinvestment (Figure 2). Nonetheless, 41% of the literature specifies investment status, of which 26% of the projects are new investments and the remaining 15% are reinvestments. It is not clear whether such a distribution reflects realities on the ground of greater focus on new investment or whether the literature places greater focus on new investments.

Project funding - Only 24 documents mention the source of project funds clearly. In the 24 cases, the government appears only twice as exclusive funder of a project. In the other 22 cases, donors funded the projects with the government playing some part (13 cases) or exclusively by donors (nine cases). Several international organizations are mentioned more than once – the International Fund for Agricultural Development (IFAD) (five times), AfDB (four times), and Action Aid and Red Cross (twice each). Other international bodies that received a single mention are the Danish International Development Agency (DANIDA), Finnish International Development Agency (FINNIDA), Plan International, USAID, the World Bank and World Vision, and the governments of China, Germany and France. Some local nongovernmental organizations (NGOs) that contribute to project funding include the Relief Society of Tigray (Ethiopia), Sahelian Solutions Foundation (Kenya) and SAIPRO (Tanzania). Descriptions of the exact structure of the funding are given in

FIGURE 2. Investment status of projects.



six documents that are project reports. In all six cases, donors provided the bulk of the funding (>80%), with the government providing the remainder. For example, governments provided 12% in the Small Dams Rehabilitation Programme, Burkina Faso (Tibaldeschi and Boulenger 2002), and 10% in the Bankable Investments' Small Dams Project in Mozambique (GoM 2004). It is not clear whether these government contributions were monetary or otherwise. In the two cases where the government exclusively funded projects (e.g., the Hill Lakes Project in Tunisia and the Mhakwe Dam Project in Zimbabwe), the project costs are not stated.

Institutions - There is a prevalence of participatory institutions in the management of small reservoirs. While only 22 documents state the type of local institutions involved in the running of reservoir operations, 21 of the 22 documents disclose that elected user associations (e.g., water user associations, dam committees or local water committees) and farming groups (where the reservoirs are used for irrigation purposes) such as farmer cooperatives are in charge. Only in a single case is a reservoir governed exclusively by a traditional authority. Members of user associations pay user fees or water levies to contribute to the running of the reservoir administration, or some specified amount towards capital cost of the projects. For example, in Chimanimani, Zimbabwe, members pay ~USD 3 a month (Rusinga et al. 2011), and in Bahir Dar, Ethiopia, they pay ~USD 1-2 as a joining fee and ~USD 4-7 as a capital contribution fee (Eguavoen et al. 2012).

Benefits and positive impacts **-** Benefits or positive impacts of small reservoirs can be grouped into 15 categories (Table 3). The most notable are increased availability of irrigation water (25 citations), livestock watering (18 citations), domestic water supply and improved sanitation (16 citations), and entrepreneurial and local employment opportunities (16 citations). These direct benefits contributed to other positive impacts such as improved household income (16 citations) and improved food security (15 citations). Other significant benefits include ecosystem services (10 citations), local economic development and poverty alleviation (seven citations), and recreation and aesthetics (four citations). The empowerment of women, improved drought resilience and aquifer recharge are cited four times each, while reduced youth migration, improved farming systems and promotion of conservation activities all appear less significant.

TABLE 3. Benefits or positive impacts of small reservoirs.

Benefit or positive impact	# References	Sources
Irrigation water supply	25	Meigh 1995; IFAD 1998, 2005; Tayeh 1998; GoM 2004; Rusere 2005; Burns and Suji 2007; Faulkner et al. 2008; Mdemu et al. 2009; Lasage et al. 2008; van de Giesen et al. 2010; Namara et al. 2010; Rusinga et al. 2011; Evans et al. 2012a, 2012c; Eguavoen et al. 2012; Gwazani et al. 2012; Venot et al. 2012; Katic et al. 2014; Venot 2014; Schmengler and Vlek 2015; Ayantunde et al. 2016; Balana et al. 2016; Berhane et al. 2016; Liebe et al. 2005
Livestock watering	18	Meigh 1995; Tayeh 1998; GoM 2004; Rusere 2005; Sawunyama et al. 2005; Burns and Suji 2007; Mdemu et al. 2009; Senzanje et al. 2008; Khlifi et al. 2010; Eguavoen et al. 2012; Evans et al. 2012a, 2012c; Venot et al. 2012; Venot 2014; Schmengler and Vlek 2015; Ayantunde et al. 2016; Berhane et al. 2016
Domestic water supply and improved sanitation	16	Tayeh 1998; GoM 2004; Rusere 2005; Sawunyama et al. 2005; Burns and Suji 2007; Lasage et al. 2008; Senzanje et al. 2008; Boelee et al. 2009a; Evans et al. 2012a, 2012c; Venot et al. 2012; Lasage et al. 2015; Venot 2014; Schmengler and Vlek 2015; Ayantunde et al. 2016; Balana et al. 2016
Entrepreneurial and local employment opportunities	16	IFAD 1998, 2005; Rusere 2005; Basima et al. 2006; Burns and Suji 2007; Lasage et al. 2008; Senzanje et al. 2008; van de Giesen et al. 2010; Khlifi et al. 2010; Venot and Hirvonen 2013; Evans et al. 2012a, 2012c; Gwazani et al. 2012; Venot et al. 2012; Acheampong et al. 2014; Ayantunde et al. 2016
Improved household income	16	IFAD 1998, 2005; GoM 2004; Ersado 2005; Burns and Suji 2007; Lasage et al. 2008; Boelee et al. 2009a; Khlifi et al. 2010; Mbinji 2010; Sally et al. 2011; Eguavoen et al. 2012; Gwazani et al. 2012; Venot et al. 2012; Katic et al. 2014; Venot 2014; Berhane et al. 2016; Liebe et al. 2007
Improved food security	15	GoM 2004; IFAD 2005; Ersado 2005; Sawunyama et al. 2005; Burns and Suji 2007; Makurira et al. 2007; Lasage et al. 2008; Annor et al. 2009; Boelee et al. 2009a; Mbinji 2010; Wisser et al. 2010; Eguavoen et al. 2012; Boufaroua et al. 2013; Katic et al. 2014; Liebe et al. 2007
Ecosystem services: fishing, aquaculture, reed harvest	10	IFAD 2005; Rusere 2005; Burns and Suji 2007; Mdemu et al. 2009; Senzanje et al. 2008; Annor et al. 2009; Rusinga et al. 2011; Evans et al. 2012c; Venot 2014; Ayantunde et al. 2016; Balana et al. 2016
Local economic development and poverty alleviation	7	GoM 2004; Burns and Suji 2007; AfDB 2012; Eguavoen et al. 2012; Venot et al. 2012; Boufaroua et al. 2013; Balana et al. 2016
Recreation and aesthetics	4	Senzanje et al. 2008; Venot et al. 2012; Boufaroua et al. 2013; Venot 2014
Empowerment of women	4	Tibaldeschi and Boulenger 2002; Venot et al. 2012; Eguavoen et al. 2012; Venot 2014
Enhanced drought resilience	4	Liebe et al. 2005; Venot and Hirvonen 2013; Venot et al. 2012; Lasage et al. 2015
Aquifer recharge	4	Sawunyama et al. 2005; Boelee et al. 2009a; Boufaroua et al. 2013; Berhane et al. 2016
Reduced youth migration	3	IFAD 2005; Boelee et al. 2009a; Venot 2014
Improved farming systems	3	IFAD 2005; Ersado 2005; Katic et al. 2014; Berhane et al. 2016
Promotion of conservation activities	3	Tibaldeschi and Boulenger 2002; Venot et al. 2012; Boufaroua et al. 2013

The benefits of small reservoirs have contributed substantially to community and household welfare. The availability of irrigation water supply in Burkina Faso, for example, enabled families to acquire 50% of income from irrigation plots (Sally 2002). In Jendouba, Tunisia, household income rose by 55% due to improved farming systems and increased productivity from the use of irrigation water (Khlifi et al. 2010). Entrepreneurial activities such as brick-making also account for significant household income in Chivi, Zimbabwe (Burns and Suji 2007). Furthermore, the existence of small reservoirs has led to conservation measures such as contour farming, reforestation and strategies employed to mitigate siltation (Tibaldeschi and Boulenger 2002).

Negative impacts - There is relatively little reference to negative impacts of small reservoirs in the literature (Table 4). The most frequently referenced adverse impact is conflicts among users and between beneficiaries and non-beneficiaries of reservoir projects (seven citations). The second most frequently referenced negative impact is the membership fees of user associations (three citations). Finally, the reduction of downstream flow is cited only twice as a negative impact.

TABLE 4. Negative impacts of small reservoirs.

Negative impacts	# References	Sources
Water and land use conflicts	7	IFAD 2005; Burns and Suji 2007; van de Giesen et al. 2010; Venot and Hirvonen 2013; Rusinga et al. 2011; Sally et al. 2011; Eguavoen et al. 2012; Venot et al. 2012
Membership fees of user associations	3	Faulkner et al. 2008; Rusinga et al. 2011; Eguavoen et al. 2012
Reduction of downstream flow	2	Lasage et al. 2008, 2015

Conflicts are common in small reservoir communities. Conflict between traditional authorities and user associations was reported in Chimanimani, Zimbabwe (Rusinga et al. 2011), while conflicts between reservoir beneficiaries and non-beneficiaries were also reported in the Upper East region, Ghana (IFAD 2005). Further, conflicts may develop among the water users, as seen in Comoé and Nakamba, Burkina Faso, where local power relations skewed access to water (Sally et al. 2011). Reduction of downstream flow from the damming of the river, a notable negative impact, is evidenced in Boroma, Ethiopia, where flow was reduced by as much as 19% (Lasage et al. 2015).

Health impacts - The health impacts of small reservoirs are both positive and negative. On the positive side, improvement in household nutrition (five citations) is the most notable, coupled with improved hygiene (two citations). Burns and Suji (2007) recorded improved nutrition in Chivi, Zimbabwe, for example, and both nutrition and hygiene improved considerably in several regions of Burkina Faso (Boelee et al. 2009a). On the negative side, the increased risk of waterborne disease (six citations) is the only impact reported. Diseases such as malaria and schistosomiasis are a real risk – both being cited four times each in literature. Incidences of malaria increased in settlements near reservoirs in Tigray, Ethiopia (Ghebreyesus et al. 1999), and the prevalence of schistosomiasis increases in the Upper East region of Ghana (IFAD 1998).

Performance benchmarks - Systematic assessment of reservoir performance is not extensive. Assessment of reservoir performance can be divided into eight parameters that can each be assessed by quantitative indicators. These parameters are water storage efficiency, physical condition of infrastructure, water supply/use, agricultural productivity, institutional effectiveness, socioeconomic development, economic returns and health impacts (Table 5). However, the population of the indicators in this study often relied on qualitative user perceptions and rapid appraisals on dam sites.

TABLE 5. Performance benchmarks.

Parameter	Performance indicators	# References	Sources
Water storage efficiency	*Rate of sedimentation*	9	Sichingabula 1997; Tamene et al. 2006; Adwubi et al. 2009; Hentati et al. 2010; Ndomba 2011; Chihombori et al. 2013; Schmengler and Vlek 2015; Alahiane et al. 2016; Aynekulu et al. 2006
	Dam and system losses	5	Mugabe et al. 2003; HR Wallingford 2004a; Makurira et al. 2007; Lasage et al. 2015; Teka et al. 2013
Physical state of infrastructure	*Status/function of dam infrastructure*	6	Mufute et al. 2008; Mbinji 2010; Evans et al. 2012c; Venot et al. 2012; Acheampong et al. 2014; Venot 2014
Water supply/use	*Water availability versus water requirements*	3	Makurira et al. 2007; Teka et al. 2013; Boelee et al. 2009b
Agricultural productivity	*Water productivity*	6	Abernethy 1994; Faulkner et al. 2008; Mdemu et al. 2009; Senzanje et al. 2008; Venot et al. 2012; Venot 2014
	Extent of irrigated area	3	IFAD 2005; Venot et al. 2012; Venot 2014
	Number of irrigators	3	IFAD 2005; Venot et al. 2012; Venot 2014
	Farm profitability	3	Abernethy 1994; Faulkner et al. 2008; Boelee et al. 2009b
Institutional effectiveness	*Effectiveness of reservoir management*	4	IFAD 2005; Senzanje et al. 2008; Evans et al. 2012c; Acheampong et al. 2014;
	Equity of institutional arrangements	4	IFAD 2005; Evans et al. 2012c; Acheampong et al. 2014; Boelee et al. 2009b
	Equitable access to resource	3	Mbinji 2010; Venot et al. 2012; Acheampong et al. 2014
Socioeconomic development	*Number of benefits realized*	4	IFAD 2005; Mbinji 2010; Evans et al. 2012c; Venot et al. 2012
	Nutrition/diet	3	IFAD 2005; Lasage et al. 2008; Boelee et al. 2009b
	Mean household income	3	Abernethy 1994; IFAD 2005; Boelee et al. 2009b
Economic returns	*Cost-benefit analysis: net present value and economic rate of return*	3	Abernethy 1994; Evans et al. 2012a; Katic et al. 2014
Health impacts	*Disease prevalence*	2	Abernethy 1994; Boelee et al. 2009b

Two indicators measure water storage efficiency. The most cited is the *rate of sedimentation* (nine citations), which determines the lifespan of a dam. The higher the sedimentation rate, the lower the performance of the reservoir. The second indicator is *dam and system losses* (five citations) resulting from seepage, leakage and evaporation. The second parameter - physical state of infrastructure - measures the degree to which a reservoir is functional. It is measured by the *status/function of dam infrastructure* (six citations), essentially whether or not a dam is operational. Water supply is measured by the *water availability versus water requirements* (three citations), which essentially measures the extent of a reservoir's capacity in meeting water demand.

Since many reservoirs serve an irrigation purpose, considerable attention has been spent on measuring the productivity of agriculture as a determinant of reservoir performance. Five indicators were apparent. *Water productivity* (six citations) measures crop yields per volume of water used, while *extent of irrigated area* (three citations), as compared to the total command area, assesses land utilization. The *number of irrigators* (three citations) refers to the uptake of irrigated farming as an indicator of reservoir efficacy. *Farm profitability* (three citations) is measured using gross product value per hectare, net present value per hectare, irrigation service fee per hectare, or cost of operation and maintenance per hectare.

Institutional effectiveness is measured by *effectiveness of reservoir management* (four citations), as seen by the fee collection rate and conflict resolution capacity, for example. Another measure is the *equity of institutional arrangements*, which is an assessment of the access of members to the authority that governs reservoir operations, whether it is a traditional authority or an elected user association (four citations). Socioeconomic assessments are largely qualitative measures where, using a baseline, the project achievements are evaluated after a certain period of reservoir operations. Such measures include the *number of benefits realized* (four citations), changes in *nutrition/diet* (three citations) and changes in the *mean household income* (three citations). One study (Katic et al. 2014) offered only economic assessments of performance, for which a *cost-benefit analysis* measured through the net present value and economic rate of return is most common. Health impacts, a measure of waterborne *disease prevalence*, were cited twice.

Performance **-** Although the literature proposes multiple performance indicators, they are rarely applied to assess the performance of the projects they report on. Only about a quarter of the documents (i.e., 21 documents) reviewed attempts to measure performance. Of these 21 documents, just over half (11 documents) point to less-than-favorable performance due to lower-than-expected irrigation production and greater-than-expected levels of sedimentation; to a lesser extent, adverse health impacts and the poor condition of dam infrastructure were also noted to explain poor performance. Less than half of the studies (8 documents) report satisfactory to positive performance generally based on socioeconomic and livelihood impacts. Performance can indeed be meagre, as shown in the Mutangi case, where productive water use was only 3% of total storage volume, with over 90% of storage lost through evaporation and leakages (Mugabe et al. 2003). With respect to sedimentation, predictions suggest that some reservoirs will silt up before half their expected life span in northern Ethiopia (Tamene et al. 2006). In the Tigray region, dams with an envisioned lifespan of 30 years were set to run their cycle in just 4.4 to 5.7 years (Aynekulu et al. 2006).

It is not immediately clear that the investment status of the reservoirs directly influences performance (Table 6). Only five of the poorly performing reservoir programs have information on their investment status - three are reinvestments and two are new investments. Of the seven studies that state investment status and where performance was deemed satisfactory to high, four are new investments and three are reinvestments.

TABLE 6. Performance stratified by investment status**.**

	Documents that assess performance and indicate investment status	New investment	Reinvestment
Satisfactory-to-high performance	7 – IFAD 1998, 2005; Lasage et al. 2008; Senzanje et al. 2008; Mbinji 2010; Schmengler and Vlek 2015; Katic et al. 2014	4 - Lasage et al. 2008; Senzanje et al. 2008; Schmengler and Vlek 2015; Katic et al. 2014	3 - IFAD 1998, 2005; Mbinji 2010
Poorly performing	5 – Mugabe et al. 2003; Makurira et al. 2007; Faulkner et al. 2008; Mdemu et al. 2009; Chihombori et al. 2013	2 - Faulkner et al. 2008; Chihombori et al. 2013	3 - Mugabe et al. 2003; Makurira et al. 2007; Mdemu et al. 2009

Factors affecting reservoir longevity:

(a) The role of sedimentation - Sedimentation constitutes a persistent problem in small reservoirs. Studies show that 50% of reservoirs studied in Ethiopia were on course to lose their economic life before even half of their design period (Haregeweyn et al. 2006). HR Wallingford (2004a) found out that 15% of small reservoirs in Zimbabwe and Tanzania, whose life was expected to be 20 years, were going to be silted in about half that time. The global average of annual storage loss due to siltation is 0.5 to 1% of total reservoir storage capacity, but it seems African reservoirs are silting up considerably faster than average. Major reasons given for this massive sedimentation include land use practices (cultivation and grazing), insufficient flow, excessive seepage, poor surface cover and slope relief (Tamene et al. 2006; Mufute et al. 2008). Tumbare (2013) argued that a storage ratio (net storage capacity to annual average inflow) of 10% is required to minimize the rate of sedimentation.

(b) Suitability of a dam site - Less than a quarter of the literature (i.e., 14 documents) reference the suitability of a reservoir site, and these bring forth four factors that determine the location of a small reservoir. The most cited (seven citations) is the catchment size, which determines the runoff yield the reservoir will achieve. Caution is advised on building a small reservoir in a large catchment or vice versa. The slope and character of landscape, as determinants of erosion, reservoir depth and dam size, are cited three times. The rock and soil types (three citations each) determine the seepage and reservoir foundation stability.

(c) The significance of a dam's design - Only four elements of dam design emerge more than once in the literature (Table 7). The most cited is *spillway material* (four citations), which should be concrete in order to avoid erosion, especially in sand dams. *Surface area* (two citations) determines the rate of evaporation. A wide and shallow reservoir loses more water to evaporation compared to a deep and narrow reservoir. Other factors that can be incorporated in the design is the *mitigation of disease risk* (two citations), which can be accomplished through infiltration galleries (for guinea worm), and the provision for *environmental flows* by creating a bottom outlet on the dam.

TABLE 7. Design factors.

Factor	Explanation	# References	Sources
Spillway material	Stones or concrete to avoid erosion	4	Stephens 1984; Fowler 1989; HR Wallingford 2004a; Birner et al. 2010
Surface area	Deep and narrow is better than wide and shallow	2	Teka et al. 2013; Fowler 1989
Mitigation of disease risk	Provision to mitigate possible adverse health impacts	2	Tayeh 1998; Lasage et al. 2008
Environmental flows	Provide outlet for ecological flow	2	Stephens 2010; Tumbare 2013

(d) The role of maintenance - While the literature emphasizes the critical role of maintenance in prolonging reservoir lifespan, rarely do documents elaborate beyond simply mentioning maintenance as best practice. Only three documents refer to the importance of letting the water users collectively organize reservoir maintenance. The bigger challenge has been the levying and collection of sufficient user fees to fund maintenance (Lasage et al. 2008; Katic et al. 2014). Worth noting, however, is the recommendation from IFAD (2005) that routine maintenance can be delegated to water users but major maintenance should be the responsibility of the local government that can secure the required expertise.

***Keys to success* -** Predictably, the most common key to successful reservoir performance is strong institutions (Table 8). *Responsive institutions*, the water management rules and regulations around a reservoir, received 12 citations, followed by *catchment protection and siltation management* (9 citations). *Capacity building* and *coordination* received six citations each. The importance of information for technical decision making (five citations) is the same as the recognition of multiple water uses. *Participation of stakeholders* in planning and assessment has been cited as important, as well as accurate *siting* and carrying out *feasibility studies* before investments, all with four citations each. Less significant are *efficient water use*, with three citations, and *simple design*, *health education*, *cost-benefit analysis* and *effective planning* are all cited only twice each.

TABLE 8. Keys to the success of a reservoir.

Factor	Explanation	# References	Sources
Responsive institutions	Acceptance of multiple institutions and recognition of local informal institutions	12	Faulkner et al. 2008; Birner et al. 2010; Namara et al. 2010; Gwazani et al. 2012; Otto and Venot 2012; Sally et al. 2011; Evans et al. 2012a, 2012b, 2012c; Venot et al. 2012; Acheampong et al. 2014; Sullivan et al. 2009
Catchment protection and siltation management	Strategies to limit sedimentation, e.g., build in-stream thresholds, bottom outlets and sediment by-pass reforestation, erosion control, grazing control	9	Fowler 1989; Sichingabula 1997; Haregeweyn et al. 2006; Adwubi et al. 2009; Hentati et al. 2010; Mbinji 2010; Evans et al. 2012b; Chihombori et al. 2013; Alahiane et al. 2016
Capacity building	Train and empower water user associations, and also government officers	6	IFAD 2005; Mufute et al. 2008; Birner et al. 2010; Sally et al. 2011; Evans et al. 2012a, 2012c
Coordination	Strong organization of stakeholders and clarity of roles	6	Ghebreyesus et al. 1999; Lasage et al. 2008; Mufute et al. 2008; Birner et al. 2010; Evans et al. 2012c; Sullivan et al. 2009
Information	Storage and use of technical information for monitoring	5	HR Wallingford 2004a; Liebe et al. 2005; Haregeweyn et al. 2006; Sawunyama et al. 2006; Andreini et al. 2009
Recognition of multiple water uses	In the design of dams and crafting of institutions	5	Otto and Venot 2012; Evans et al. 2012b; Venot et al. 2012; Acheampong et al. 2014; Ayantunde et al. 2016
Participation of stakeholders	Avoid externally driven assessment or top-down planning	4	Venot and Hirvonen 2013; Venot et al. 2012; Ayantunde et al. 2016; Boelee et al. 2009b
Siting	Relief (of slope), aridity of area, etc., must inform choice of site	4	Mantel et al. 2010; Evans et al. 2012a; Boufaroua et al. 2013; Tumbare 2013

(Continued)

TABLE 8. Keys to the success of a reservoir. (Continued)

Factor	Explanation	# References	Sources
Feasibility studies	To include water requirements, health risks, and positive and negative impacts	4	Sichingabula 1997; HR Wallingford 2004b; Evans et al. 2012a, 2012c
Efficient water use	For irrigation and other water uses	3	Makurira et al. 2007; Mbinji 2010; Liebe et al. 2005
Simple design	That is easily accessible and caters for multiple uses	2	Nissen-Petersen 2006; Lasage et al. 2008
Health education	To minimize health impacts	2	Tayeh 1998; Boelee et al. 2009a
Cost-benefit analysis	Carried out before investing	2	Ersado 2005; Evans et al. 2012a
Effective Planning	Should follow adaptive learning and be demand driven	2	Nkhoma 2011; Evans et al. 2012b

Examples highlighting the importance of institutions and coordination are abundant. In Upper East Ghana, the satisfactory performance of reservoirs was attributed to the recognition of local institutional realities and the acceptance of multiple water uses by the community (Acheampong et al. 2014). In Kenya, effective community organization led to the positive impacts that were realized by water users (Lasage et al. 2008). The importance of effective coordination is substantiated by Nkhoma (2011), who found that a lack of political interest in promoting small reservoirs, coupled with very weak actor coordination, contributed to the very poor performance of small reservoirs in Malawi. It was also identified that feasibility studies and stronger coordination could have improved performance in Zambia (Evans et al. 2012c).

Case Study

Examining a sample of small reservoir case studies - Performance of 10 reservoirs in the Southern Province of Zambia (Figure 3) were examined. Overall, while the reservoirs played a consistently critical role in sustaining rural communities, their performance was generally not strong (Table 9). This finding crosscuts reservoirs constructed in different years - new and rehabilitated reservoirs. Poor performance was typically due to severe siltation, which compromised storage capacity and therefore the ability to derive benefits from the reservoirs. Only two of the 10 reservoirs appeared unaffected by siltation.

Benefits of reservoirs - Water in reservoirs is mainly used for livestock watering. This is the case for all the reservoirs (Figure 4). While agriculture is practiced, priority is generally given to livestock. Year-round cultivation is reported in only six reservoirs – Bodela, Mboole and Mulabalaba. Brick-making is a notable income-generating venture, practiced in six reservoirs. The potential to use reservoirs for fish production was typically constrained by the reality that most reservoirs are dry for approximately 3 months each year.

Negative impacts of reservoirs - There appeared to be limited adverse effects to the community from the reservoirs. No major waterborne diseases have been recorded, while malaria cases were mentioned only around two reservoirs. Nonetheless, the turbidity of water in the heavily silted dams appeared to increase rates of diarrhea and other diseases in cattle, which constrains their development.

FIGURE 3. Map showing the location of reservoirs.

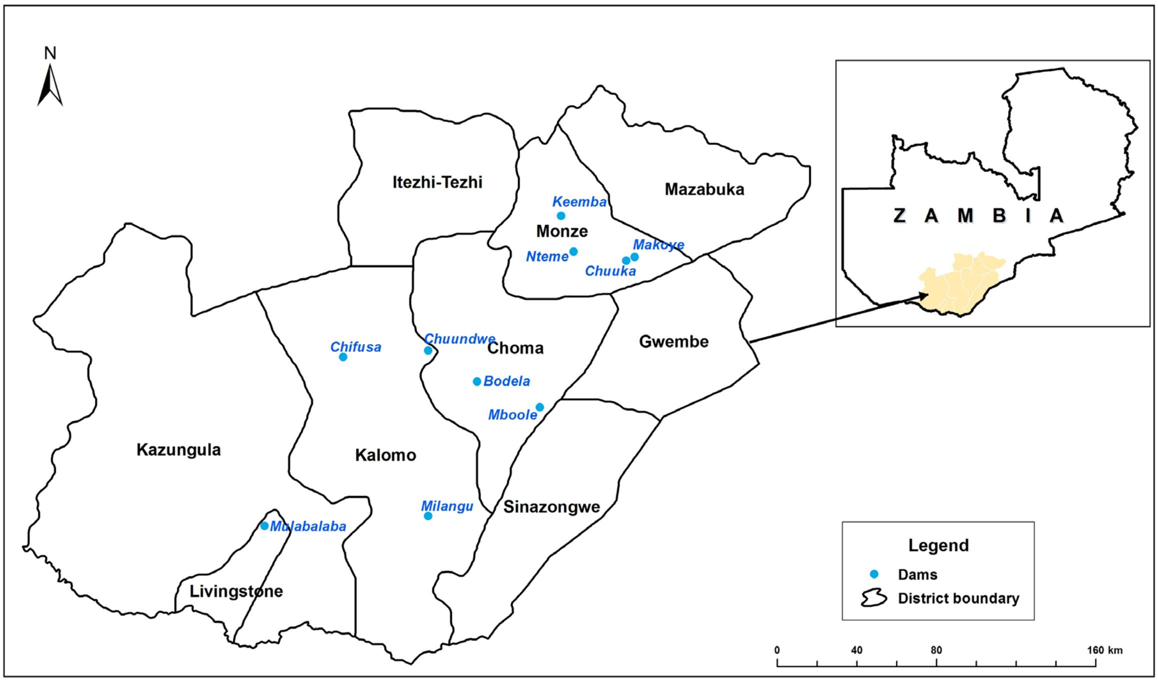


FIGURE 4. Benefits of reservoirs.

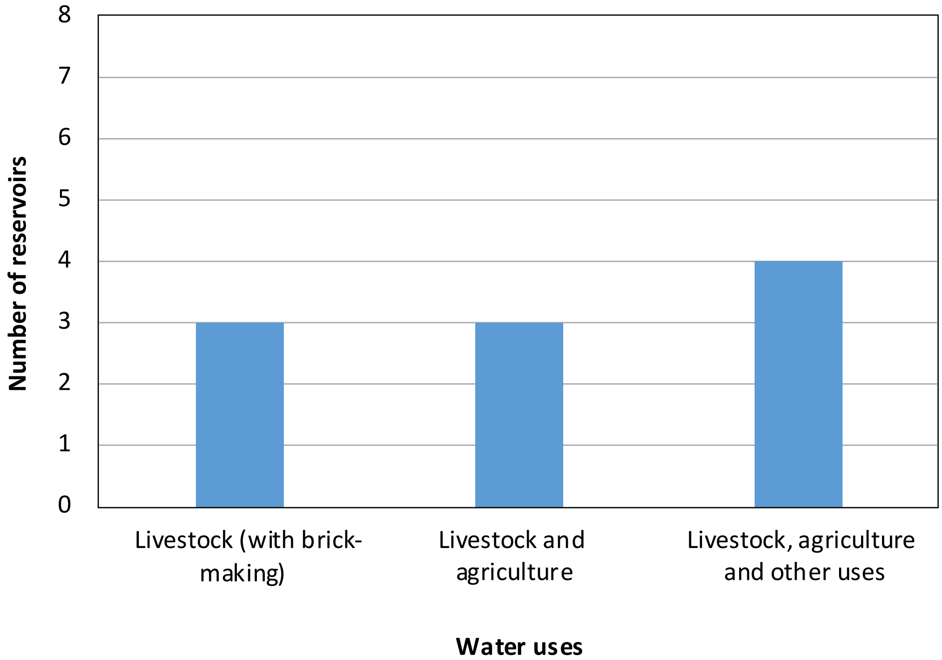


TABLE 9. Reservoir characteristics.

Name	Year	# Villages	Benefits	Negative impacts	Degree of functionality	Institutions and maintenance
Nteme	1948 (New)	6	Livestock Brick-making	Mosquitoes (minor)	Considerably compromised by siltation	Non-viable committee Disputes settled by a headman No maintenance
Keemba	1964 (New) 1992 (Minor rehabilitation)	>20	Livestock Brick-making	Cows get diarrhea from turbid water	Severely silted	Non-viable committee No maintenance
Chuuka	1964 (New)	>20	Livestock Brick-making	Cows get diarrhea from turbid water	Severely silted; valve to release sediments broke in 1974	Committee is partially functional; prioritizes livestock over brick-making. No maintenance
Makoye	1940 (New) 1984 and 1988 (Rehabilitated)	6	Livestock Brick-making Gardens Fish Dip tank	--	Some silting issues; still fairly functional	Partially viable committee that tries to enforce rules, but traditional authority more in charge
Bodela/ Siyafakwenda	1960s (New) 2000 (rehabilitated) 2015 (rehabilitated) 2017 (rehabilitated)	2	Agriculture/ gardens Livestock	--	Some siltation	Active committee; undertake maintenance and enforce access rules for different uses
Mboole	2002 (New)	5	Domestic Cattle Agriculture Some fishing	--	Very functional, unclear if siltation poses any issue Dam is underutilized	Headman managed cattle access
Chifusa	1948 (New) 2009 (Rehabilitated)	>20	Livestock Agriculture Brick-making	--	Somewhat reduced storage due to silt	Viable committee prioritizes livestock over agriculture. Organizes minor maintenance

(Continued)

TABLE 9. Reservoir characteristics (Continued)

Name	Year	# Villages	Benefits	Negative impacts	Degree of functionality	Institutions and maintenance
Chuundwe	1999 (Constructed) 2011 (Rehabilitated)	12	Livestock Agriculture	--	Substantial silt	A committee is in charge, elected every 3 years. Monitors water use and state of infrastructure. Final authority is the headmen
Milangu	1990 (New) 2009 (Rehabilitated)	6	Livestock Agriculture		Substantially silted and degraded. Water seeps through embankment	Non-viable committee
Mulabalaba	2004 (New) 2009 (Rehabilitated)	~10	Livestock Agriculture Brick-making Fish	Possible malaria	Functioning well; perhaps minor siltation issues	Dam Committee and Agriculture Cooperative are active; they enforce access rules and maintain the dam

Reservoir longevity - Six reservoirs are more than 50 years old. Of these, two have not been rehabilitated but retain some level of functionality. Seven of the ten reservoirs have been rehabilitated at some stage. Although factors beyond the status of the initial structure may drive an organization to undertake a rehabilitation, it would appear that dams built earlier survive longer than those built more recently (Table 10). Dams built in the 1960s or before endured 28 to 61 years until rehabilitation. Dams built in the 1990s or after lasted 5 to 19 years until rehabilitation.

TABLE 10. Longevity of “old” versus “new” dams.

	Dam	Construction year	Rehabilitation year	Years between construction and rehabilitation
“Old” dams	Keemba	1964	1992 (minor)	28
	Makoye	1940	1984 and 1988	44
	Bodela / Siyafakwenda	1960s	2000, 2015, 2017	~35
	Chifusa	1948	2009	61
“New” dams	Chuundwe	1999	2011	12
	Milangu	1990	2009	19
	Mulabalaba	2004	2009	5

Diminishing returns - Eight of the ten reservoirs produced diminishing returns due to lost storage capacity resulting from siltation. It is only at Mboole (constructed in 2002) and Mulabalaba (renovated recently) that villagers failed to mention siltation as a problem. On the other hand, Chuuka, Milangu and Nteme have lost over half their storage capacity due to siltation. In addition, at other reservoirs, such as Chifusa and Makoye, inadequate water storage has suspended agriculture.

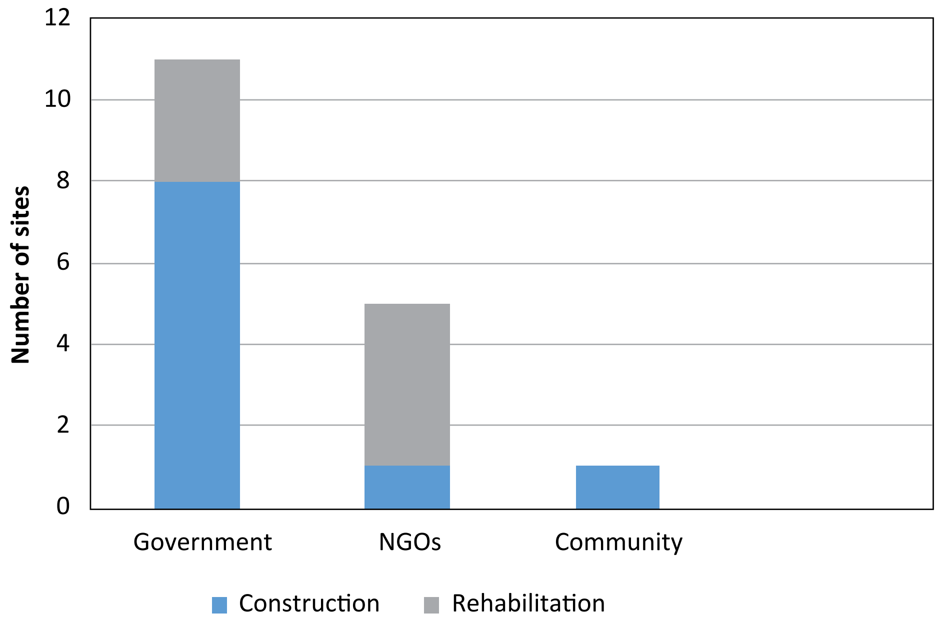
What exactly is rehabilitation? - The nature of rehabilitation varied across sites but was often a relatively minor, several-month activity (Table 11). It mainly involved repairing of spillways, raising embankments, and planting grass around the reservoir. This typically involves manual labor, sponsored by NGOs or government programs, where members of the community receive food and a small allowance for each day of work. Only in one case was there some desilting using heavy machinery. Costs of rehabilitation could not be immediately verified. Given the similar benefits realized from rehabilitation and existing reservoirs compared to the higher construction costs of new reservoirs, it would appear that rehabilitation brings greater return on investment.

TABLE 11. Reservoir rehabilitation.

Dam	Description of rehabilitation	Time involved in rehabilitation
Keemba	Repair of spillway	1 month
Bodela	Repair of embankment and spillway, planting grass	2 months
Chifusa	Repair of spillway, raising of embankment, planting grass	2 months
Chuundwe	Raising of spillway, planting grass	3 months
Makoye	Dredging, repair of spillway, planting grass	6 months
Milangu	Repair of embankment, planting grass	1 year
Mulabalaba	Raising of embankment, repair of spillway	2 years

Who finances investments in small reservoirs? - Financing for investments in reservoirs, especially in new sites, generally comes from the government (Figure 5). The government built eight of the ten reservoirs. In one case, the community constructed the reservoir, and an NGO financed another. However, NGOs are more involved in rehabilitation than new construction. In three cases, the government rehabilitated the reservoirs for which they provided funding. In four cases, an NGO financed rehabilitation.

FIGURE 5. Sources of financing for small reservoirs.



Number of villages using reservoirs - Demand varied considerably across reservoirs. Some reservoirs serve only two villages while others serve as many as 27. Reservoirs used by a greater number of villages appear to be used mainly for livestock watering. Reservoirs used for multiple purposes, including agriculture, were often used by 10 villages or less.

Institutional arrangements appear weak - Dam committees, usually established during construction or rehabilitation, often appear to lose momentum following completion of the investment project. Only three reservoirs possess active committees, and all these had both livestock and significant irrigation water use. As such, dam maintenance and enforcement of rules – mainly on prioritization of water use, reservoir bank access, dispute resolution and membership contributions – are generally poor. In nine of the ten sites, traditional authorities enforce rules, but enforcement is largely limited to dispute resolution. Only in one site was the committee able to organize maintenance.

Vegetation to reduce siltation - Reservoir conservation mostly consists of planting grass around the reservoir perimeter. This is common in rehabilitated sites, where five reservoirs have grass planted around them. Older sites do not. An NGO provided the grass. The type of grass could not be conclusively determined.

Gender issues did not emerge - Key informants – which included women and men – did not identify gender imbalances, and suggested access to land and water, and ownership of cows, were not constrained by an individual's gender. Dam committees include both men and women.

Discussion

Headline Findings

This paper reviewed over 80 documents concerning more than 4,000 small reservoirs in East, Southern and West Africa, and this was complemented with visits to 10 sites in southern Zambia. It synthesizes past experience and provides guidance for an approach to strengthen future investments in small reservoirs. Despite the availability of wide-ranging literature focused on small reservoirs in Africa, a stock-take of available evidence was not available. The findings from the evidence on investments in small reservoirs presented in this paper are among the most conclusive in existence.

The study produced five major findings. First, small reservoirs produce a range of benefits that exceed the costs, providing considerable value to rural communities. Second, the performance of small reservoirs – measured through economic analysis, reservoir longevity or other means – is generally not spectacular. Third, the primary factor explaining the decrease in reservoir viability over time is sedimentation. Sedimentation is the result of a host of factors, of which institutions is prominent. Fourth, generally, rehabilitation of existing reservoirs may be a better investment than the construction of new dams. Fifth, the quality of construction of small reservoirs may be declining.

Small reservoirs produce a range of benefits - Benefits of small reservoirs include, inter alia: domestic water supply, irrigation water supply, livestock watering and support to varied entrepreneurial activities. These benefits contribute to a set of broader outcomes, including household food security, income generation and drought resilience in the short term, and local economic development, reduced out-migration and the economic empowerment of women in the long term. Negative impacts are limited to the occasional increase in disease, sporadic conflict between water users and labor requirement for manual repair of infrastructure. Ultimately, it appears that small reservoirs hold potential for achieving transformational benefits in rural communities with relatively limited risk of adverse impacts.

Small reservoirs may not reflect good investments using conventional measures **-** Performance of small reservoirs is *variable to low* when measured against economic and water resource indicators or longevity. Water productivity and relative water supply in small reservoirs are generally low, storage water losses (evaporation and seepage) are generally high, and the state of infrastructure is often poor. Central to poor performance of small reservoirs are: (i) sedimentation that reduces the life span of the dams, and (ii) weak institutions that govern reservoir maintenance.

Reconciling evidence of extensive benefits with poor performance - Valid questions can be raised in relation to how narratives of extensive benefits can be squared with evidence of low levels of performance. It may be that the evidence of benefits documented – which seem consistent with the value often attached to reservoirs by communities – comes mainly from the advocacy and NGO community. Whereas critical scrutiny of performance may be driven by another set of actors, notably the academic community. Whatever the case, the bottom line is that poor performance of small reservoirs is common and small reservoirs often fail to provide sustained benefits.

The role of sedimentation and the need for a shift toward a long-term approach to achieve sustainability - Sedimentation remains the central determinant of reservoir longevity, yet the institutions governing reservoirs at a local (e.g., committees) or regional (e.g., government program) level may not recognize the importance of sediment control. 'Responsive institutions' were cited as being key to the sustainability of small reservoirs. Nevertheless, the strength and viability of user associations tend to be *variable to weak*; and traditional authorities, where accountability is not entirely clear, often remain in control. To manage small reservoirs and control siltation effectively, local institutions may need to implement *proactive* measures to reduce sediment flows. Regional institutions should monitor water and sediment flows to enable the provision of guidance and support to reduce such flows.

Rehabilitation is a better investment - Evidence from southern Zambia suggests that it may be more beneficial to reinvest in existing small reservoir infrastructure than to build new infrastructure. Rehabilitated sites are likely to achieve greater return on investment due to their production of similar benefits at lower costs. While the nature of rehabilitation no doubt varies, the time and resources required appeared far less than that needed for the construction of new dams. Further, rehabilitation may be more demand-responsive. Indeed, while it is not entirely clear whether existing reservoirs have gradually created demand for their use or whether construction of the existing reservoirs responded to preexisting community demand that lacked a water supply, what seems clear is that older sites have demand that is often not fully satisfied. Rehabilitation to augment water availability at existing sites, therefore, often enables harnessing of potential benefits. Conversely, new sites may lack such immediate demand, resulting in potential not immediately utilized.

Additional Considerations

There may be danger of a build-neglect-rebuild cycle: NGOs and governments may lack incentives for construction that lasts long term - While rehabilitation achieves more benefits at a lower cost thereby comprising a stronger investment, such dynamic may also present a perverse incentive for both the government and NGOs to construct dams that do not last. Rehabilitation indeed offers an opportunity to produce and document high short-term benefits for low short-term costs, which will reflect well in impact assessment reports conducted in the aftermath of project completion. However, any incentive to construct infrastructure that lasts long term would not appear to exist, as there is rarely long-term monitoring and reporting by investors. There may even be an incentive to construct dams that do not last long term since degraded sites may present opportunities to rehabilitate, which reflect good investments. Contractual processes around bidding and implementing small reservoir projects are lucrative, and incentives may not always reside where they should (Venot et al. 2012).

Benefits of a systems approach: Dams used for agriculture and other uses appear better maintained - A final note, generated only from the field portion of the research, is that reservoirs mainly used for livestock watering do not attract the same maintenance levels as those that support both livestock watering and agriculture. Part of the explanation for this may relate to the reality that reservoirs used solely for livestock are generally polluted with cow dung and not particularly pleasant. Another part may relate to the reality that agriculture brings people closer to the reservoir perimeter, provides a filter that may reduce siltation, and fosters development of agricultural cooperatives that contribute to a sense of community ownership. Therefore, a systems approach that integrates livestock and irrigation may harness the potential for better-maintained, multi-purpose reservoirs that last longer.

Conclusions

Small reservoirs are a critical coping mechanism in water-stressed rural areas in Africa, providing immense livelihood benefits that include improved food and water security, entrepreneurial activities and climate resilience. Challenges associated with the implementation of investments in small reservoirs include appropriate site selection, weak institutions, insufficient maintenance and sedimentation. The findings from this study suggest that the benefits of small reservoirs may be tapped more efficiently by rehabilitating old sites rather than building new infrastructure. However, the findings also point to broader lessons on the need to change the way of doing business, i.e., to adopt a long-term, more holistic approach (or model) to the construction and maintenance of small reservoirs that matches the degree of the challenge associated with sustainably tapping the benefits of the water that they store.

Returning to the questions posed in the description of objectives, some points have emerged as less important than predicted (Table 12). Key trade-offs between positive and negative impacts, for example, did not come through as a major issue. Rather, the major issue is sustaining positive impacts generated. Doing so, in turn, may require strong, motivated and capacitated local institutions reinforced by national programs. Further, it may require a longer-term perspective to development than is typically implemented.

TABLE 12. Key questions and responses.

Questions	Responses
What financial and institutional factors determine the level of infrastructure sustainability (particularly economic)?	Source of finance does not appear to have a direct effect on sustainability. Indirectly, NGO-financed infrastructure focused on rehabilitation nonetheless correlates with reduced sustainability.
What biophysical factors are most important for the environmental sustainability of small reservoirs?	Upstream watershed management to reduce sedimentation is key.
What are the trade-offs of investments in small reservoirs under different conditions and contexts, e.g., in relation to health (i.e., malaria risks)?	Negative impacts did not come through strongly. Trade-offs may be viewed as minimal. The larger issue is fostering effective management and governance to promote infrastructure longevity.
What factors affect the infrastructure longevity of small reservoirs?	Community ownership, and strong local institutions based on participation and reinforced by national programs
What is the potential for (re)investment in small reservoirs under various conditions?	Potential for reinvestment should be high. However, there may be a perverse incentive encouraging the creation of reinvestment opportunities through poor quality construction. As such, adopting a longer-term view to development and management, while ultimately better, may reduce reinvestment opportunities. The potential for new investments is nonetheless high as long as long-term time horizons are realized through prolonged (e.g., > 20 years) reservoir functionality.

Three final points: First, it may be time to adapt the design of advocacy-based, disaster-responsive investments in small reservoirs, by drawing more evidence- and practice-based approaches to investments in small reservoirs. This may provide for greater sustainability of benefits. Activities for sedimentation management and institutional development, in particular, could incorporate a focus on sustainability from the outset. Further, acknowledging the challenges associated with achieving sustainability in both these areas could foster appreciation for the importance attached to sustainability; including quantification of benefits forgone through failing to achieve sustainability.

Second, related to the long-term approach needed for investments in sustainable small reservoirs will require institutions that facilitate sustainability by managing and maintaining infrastructure. Commitment to such sustainability could be reflected in the formulation of specific arrangements for dam management and maintenance by institutions both at a local and regional level—as well as plans for how institutions at alternate levels may interact in a mutually reinforcing way to foster sustainability. The bottom line is that it may be time to move beyond general box-ticking on implementation of soft activities (e.g., capacity development) expected to foster sustainability to the creation of institutional arrangements, matched to the local context, to ensure benefits of small reservoirs are sustained.

Third, critical to the success of a long-term approach to investments in small reservoirs is regular monitoring of reservoirs after investment. Effective monitoring that gathers and uses relevant information for reservoir management, assesses institutional effectiveness (e.g., frequency of meetings and level of payment of levies), and measures storage capacity (e.g., sedimentation rate) can greatly enhance the potential for sustained realization of benefits. Important indicators for long-term monitoring include water storage efficiency, physical state of infrastructure, institutional effectiveness and health impacts. In the resource-constrained contexts that pervade Africa, application of an effective monitoring framework can allow management institutions to target their maintenance efforts to those sites most in need. Monitoring is, therefore, critical and should be undertaken in conjunction with bodies responsible for management and maintenance of small reservoirs.

The limitations of this paper are acknowledged. First, this paper is a synthesis or stock-take of available evidence on small reservoirs in Africa. It is not a rigorous cost-benefit analysis of the performance of small reservoirs in Africa, as the data derived from the secondary sources utilized do not support a rigorous economic analysis. However, the data does allow for the identification of broad trends and determination of relative weights of evidence. Second, the representativeness of small reservoirs in southern Zambia could not be conclusively determined. The authors assume that the sample of small reservoirs examined broadly reflects conditions in much of Africa, and findings derived from such reservoirs help to explain the broader, Africa-level results. Definitive confirmation of the consistency of such sites with those found throughout the rest of Africa was not possible.

Ultimately, small reservoirs provide essential benefits that can be more sustainably realized. A disproportionate focus on short-term impacts – as seems to be the norm – undoubtedly results in lost benefits in the long term. It is critical to foster a shift in perspective toward the long term, in order to harness the full benefits of small reservoirs and enable their performance to transition from currently evidenced levels to a level that renders more attractive investment opportunities.

References

Abernethy, C. L. 1994. *Report on a visit to Burkina Faso, 2-18 March 1994*. Colombo, Sri Lanka: International Irrigation Management Institute (IIMI). 37p. Available at http://publications.iwmi.org/pdf/H_15945.pdf (accessed on April 30, 2019).

Acheampong, E.N.; Ozor, N.; Sekyi-Annan, E. 2014. Development of small dams and their impact on livelihoods: Cases from northern Ghana. *African Journal of Agricultural Research* 9(24): 1867-1877.

Adwubi, A.; Amegashie, B.K.; Agyare, W.A.; Tamene, L.; Odai, S.N.; Quansah, C.; Vlek, P. 2009. Assessing sediment inputs to small reservoirs in Upper East Region, Ghana. *Lakes & Reservoirs: Research & Management* 14(4): 279-287. https://doi.org/10.1111/j.1440-1770.2009.00410.x

AfDB (African Development Bank), 2012. *Development of operational guidelines for investments in multi-purpose small dams*. Project proposal,

Alahiane, N.; Elmouden, A.; Aitlhaj, A.; Boutaleb, S. 2016. Small dam reservoir siltation in the Atlas Mountains of Central Morocco: Analysis of factors impacting sediment yield. *Environmental Earth Sciences* 75: 1035. https://doi.org/10.1007/s12665-016-5795-y

Andreini, M.; Andah, W.; Balazs, C.; Boelee, E.; Cecchi, P.; Huber-Lee, A.; Liebe, J.; Rodrigues, L.; Senzanje, A.; Steenhuis, T.; van de Giesen, N. 2005. *Small multi-purpose reservoir ensemble planning: Innovative methods*. Paper presented at the Challenge Program/Nile Basin Workshop, Entebbe, Uganda, November 27 - December 2, 2005. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF).

Andreini, M.; Schuetz, T.; Senzanje, A.; Rodriguez, L.; Andah, W.; Cecchi, P.; Boelee, E.; van de Giesen, N.; Kemp-Benedict, E.; Liebe, J.R. 2009. *Small multi-purpose reservoir ensemble planning*. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF). 55p. (CPWF Project Report 46).

Annor, F.O.; van de Giesen, N.; Liebe, J.; van der Zaag, P.; Tilmant, N.; Odai, S.N. 2009. Delineation of small reservoirs using radar imagery in a semi-arid environment: A case study in the upper east region of Ghana. *Physics and Chemistry of the Earth, Parts A/B/C* 34(4-5): 309-315. https://doi.org/10.1016/j.pce.2008.08.005

Ayantunde, A.A.; Karambiri, M.; Yameogo, V.; Cofie, O.O. 2016. *Multiple uses of small reservoirs in crop-livestock agro-ecosystems of the Volta River Basin with an emphasis on livestock management*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 29p. (IWMI Working Paper 171). Available at http://www.iwmi.cgiar.org/Publications/Working_Papers/working/wor171.pdf (accessed on March 01, 2019).

Aynekulu, E.; Atakliti, S.; Ejersa, A. 2006. *Small-scale reservoir sedimentation rate analysis for a reliable estimation of irrigation schemes economic lifetime (A case study of Adigudom area, Tigray, Northern Ethiopia).*

Balana, B.B. 2015. Trade-offs or synergies?: Assessment of ecosystem services in multi-use small reservoirs in Burkina Faso. In: *International conference on tropical lakes in a changing environment: Water, land, biology, climate and humans (TropiLakes), Bahir Dar, Ethiopia, September 23-29, 2015*, (eds.) Nyssen, J.; Enyew, A.; Dessie, M. Book of Abstracts. Bahir Dar, Ethiopia: Bahir Dar University. Pp. 42-43.

Balana, B.; Appoh, R.; Addy, P.S.; Ashitei, G.; Odonkor, E.; Nimoh, F. 2016. *How women's access to small reservoirs can improve household livelihoods in northern Ghana*. WLE Briefing Series No. 09. Available at https://wle.cgiar.org/how-women%E2%80%99s-access-small-reservoirs-can-improve-household-livelihoods-northern-ghana (accessed on March 1, 2019).

Basima, L.B.; Senzanje, A.; Marshall, B.; Shick, K. 2006. Impacts of land and water use on plankton diversity and water quality in small man-made reservoirs in the Limpopo basin, Zimbabwe: A preliminary investigation. *Physics and Chemistry of the Earth, Parts A/B/C* 31(15-16): 821-831. https://doi.org/10.1016/j.pce.2006.08.026

Berhane, G.; Martens, K.; Al Farrah, N.; Walraevens, K. 2013. Water leakage investigation of micro-dam reservoirs in Mesozoic sedimentary sequences in Northern Ethiopia. *Journal of African Earth Sciences* 79: 98-110. https://doi.org/10.1016/j.jafrearsci.2012.10.004

Berhane, G.; Gebreyohannes, T.; Martens, K.; Walraevens, K. 2016. Overview of micro-dam reservoirs (MDR) in Tigray (northern Ethiopia): Challenges and benefits. *Journal of African Earth Sciences* 123: 210-222. https://doi.org/10.1016/j.jafrearsci.2016.07.022

Birner, R.; McCarthy, N.; Robertson, R.; Waale, D.; Schiffer, E. 2010. *Increasing access to irrigation: Lessons learned from investing in small reservoirs in Ghana*. Paper presented at the workshop on Agricultural Services, Decentralization, and Local Governance, June 3, 2010, Accra, Ghana.

Boelee, E.; Cecchi, P.; Kone, A. 2009a. *Health impacts of small reservoirs in Burkina Faso.* Colombo, Sri Lanka: International Water Management Institute (IWMI). 40p. (IWMI Working Paper 136). Available at http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR136.pdf (accessed on March 7, 2019).

Boelee, E.; Laamrani, H.; Lhaj, A.A. 2009b. Impacts of reservoirs: Participatory definition of indicators for health and environment. In: *Small reservoirs toolkit, theme 3: Ecosystems and health*, (eds.) Andreini, M.; Schuetz, T.; Harrington, L. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF); Colombo, Sri Lanka: International Water Management Institute (IWMI); Brasilia, DF, Brasil: Brazilian Agricultural Research Corporation (Embrapa Cerrados Center); Harare, Zimbabwe: University of Zimbabwe (UZ); Accra, Ghana: Ghana Water Research Institution (WRI); Delft, The Netherlands: Delft University of Technology (TUD); Stockholm, Sweden: Stockholm Environment Institute (SEI); Marseille, France: Institut de Recherche pour le Developpement (IRD); Bonn, Germany: Center for Development Research, University of Bonn; Ithaca, NY, USA: Cornell University. 13p.

Boufaroua, M.; Slimani, M.; Oweis, T.; Albergel, J. 2013. Hill lakes: Innovative approach for sustainable rural management in the semi-arid areas in Tunisia. *Global Nest Journal* 15(3): 366-373.

Burns, J.; Suji, O. 2007. *Impact assessment of the Zimbabwe Dams and Gardens project*. Medford, Massachusetts, USA: Feinstein International Center.

Chihombori, J.; Nyoni, K.; Gamira, D. 2013. Causes and rate of reservoir sedimentation due to changes in catchment management. A case of Marah Dam in Masvingo Province of Zimbabwe. *Greener Journal of Geology and Earth Sciences* 1(1): 7-12.

Eguavoen, I.; Derib, S.D.; Deneke, T.T.; McCartney, M.; Otto, B.A.; Billa, S.S. 2012. Digging, damming or diverting? Small-scale irrigation in the Blue Nile Basin, Ethiopia. *Water Alternatives* 5(3): 678-699.

Ersado, L. 2005. *Small-scale irrigation dams, agricultural production, and health: Theory and evidence from Ethiopia*. Policy Research Working Paper No. 3494. Washington, DC: World Bank.

Evans, A.E.V.; Giordano, M.; Clayton, T. (Eds.). 2012a. *Investing in agricultural water management to benefit smallholder farmers in Ghana. AgWater Solutions Project country synthesis report*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 29p. (IWMI Working Paper 147). Available at http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR147.pdf (accessed on February 25, 2019).

Evans, A.E.V.; Giordano, M.; Clayton, T. (Eds.). 2012b. *Investing in agricultural water management to benefit smallholder farmers in Zambia. AgWater Solutions Project country synthesis report*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 29p. (IWMI Working Paper 150). Available at http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR150.pdf (accessed on February 25, 2019).

Evans, A.E.V.; Giordano, M.; Clayton, T. (Eds.). 2012c. *Investing in agricultural water management to benefit smallholder farmers in Ethiopia. AgWater Solutions Project country synthesis report*. Colombo, Sri Lanka: International Water Management Institute (IWMI). 27p. (IWMI Working Paper 152). Available at http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR152.pdf (accessed on February 25, 2019).

Faulkner, J.W.; Steenhuis, T.; van de Giesen, N.; Andreini, M.; Liebe, J.R. 2008. Water use and productivity of two small reservoir irrigation schemes in Ghana's Upper East Region. *Irrigation and Drainage* 57(2): 151-163.

Fowe, T.; Karambiri, H.; Paturel, J.-E.; Poussin, J.-C.; Cecchi, P. 2015. Water balance of small reservoirs in the Volta Basin: A case study of Boura Reservoir in Burkina Faso. *Agricultural Water Management* 152: 99-109. https://doi.org/10.1016/j.agwat.2015.01.006

Fowler, J. 1989. Design and construction of small earth dams. *Appropriate Technology* 3(4): 4-7.

Gebregziabher, G.; Namara, R.E.; Holden, S. 2009. Poverty reduction with irrigation investment: An empirical case study from Tigray, Ethiopia. *Agricultural Water Management* 96(12): 1837-1843. https://doi.org/10.1016/j.agwat.2009.08.004

Ghebreyesus, T.A.; Haile, M.; Witten, K.H.; Getachew, A.; Yohannes, A.M.; Yohannes, M.; Teklehaimanot, H.D.; Lindsay, S.W.; Byass, P. 1999. Incidence of malaria among children living near dams in northern Ethiopia: Community based incidence survey. *British Medical Journal* 319(7211): 663-666. https://doi.org/10.1136/bmj.319.7211.663

GoM (Government of the Republic of Mozambique). 2004. *Government of Mozambique. Support to NEPAD/CAADP implementation*. Bankable Investment Project Vol III: Small Dams Rehabilitation/Construction Project. Available at http://www.fao.org/3/ae417e/ae417e00.htm (accessed on April 25, 2019).

Gwazani, R.; Gandiwa, E.; Gandiwa, P.; Mhaka, V.; Hungwe, T.; Muza, M. 2012. The socio-ecological impacts of small dams: A case study of Mushandike Sanctuary, Zimbabwe. *Journal of Sustainable Development in Africa* 14(6): 184-194.

Haregeweyn, N.; Poesen, J.; Nyssen, J.; De Wit, J.; Haile, M.; Govers, G.; Deckers, S. 2006. Reservoirs in Tigray (Northern Ethiopia): Characteristics and sediment deposition problems. *Land Degradation & Development* 17(2): 211-230. https://doi.org/10.1002/ldr.698

Hentati, A.; Kawamura, A.; Amaguchi, H.; Iseri, Y. 2010. Evaluation of sedimentation vulnerability at small hillside reservoirs in the semi-arid region of Tunisia using the Self-Organizing Map. *Geomorphology* 122(1-2): 56-64. https://doi.org/10.1016/j.geomorph.2010.05.013

HR Wallingford. 2004a. *Guidelines for predicting and minimising sedimentation in small dams*. Report OD 152. Oxfordshire, UK: HR Wallingford.

HR Wallingford. 2004b. *Sedimentation in small dams. Development of a catchment characterisation and sediment yield prediction procedure*. Report OD TN 120. Oxfordshire, UK: HR Wallingford.

IFAD (International Fund for Agricultural Development). 1998. Republic of Ghana: Land Conservation and Smallholder Rehabilitation Project – phase I - Interim evaluation. Evaluation Report.

IFAD. 2005. Republic of Ghana: Land Conservation and Smallholder Rehabilitation Project – phase II - Interim Evaluation project report.

Katic, P.; Lautze, J.; Namara, R.E. 2014. Impacts of small built infrastructure in inland valleys in Burkina Faso and Mali: Rationale for a systems approach that thinks beyond rice? *Physics and Chemistry of the Earth, Parts A/B/C* 76-78: 83-97. https://doi.org/10.1016/j.pce.2014.11.010

Khlifi, S.; Ameur, M.; Mtimet, N.; Ghazouani, N.; Belhadj, N. 2010. Impacts of small hill dams on agricultural development of hilly land in the Jendouba region of northwestern Tunisia. *Agricultural Water Management* 97(1): 50-56. https://doi.org/10.1016/j.agwat.2009.08.010

Kibret, S.; Lautze, J.; McCartney, M.; Nhamo, L.; Yan, G. In submission. Malaria around large dams in Africa: Effect of environmental and transmission endemicity factors. *Proceedings of the National Academy of Sciences of the United States of America.*

Lasage, R.; Aerts, J.C.J.H.; Mutiso, G.-C.M.; De Vries, A. 2008. Potential for community based adaptation to droughts: Sand dams in Kitui, Kenya. *Physics and Chemistry of the Earth, Parts A/B/C* 33(1-2): 67-73. https://doi.org/10.1016/j.pce.2007.04.009

Lasage, R.; Aerts, J.C.J.H.; Verburg, P.H.; Sileshi, A.S. 2015. The role of small scale sand dams in securing water supply under climate change in Ethiopia. *Mitigation and Adaptation Strategies for Global Change* 20(2): 317-339. https://doi.org/10.1007/s11027-013-9493-8

Leemhuis, C.; Jung, G.; Kasei, R.; Liebe, J. 2009. The Volta Basin water allocation system: Assessing the impact of small-scale reservoir development on the water resources of the Volta Basin, West Africa. *Advances in Geosciences* 21: 57-62. https://doi.org/10.5194/adgeo-21-57-2009

Liebe, J.; van de Giesen, N.; Andreini, M. 2005. Estimation of small reservoir storage capacities in a semi-arid environment: A case study in the Upper East Region of Ghana. *Physics and Chemistry of the Earth, Parts A/B/C* 30(6-7): 448-454. https://doi.org/10.1016/j.pce.2005.06.011

Liebe, J.; Andreini, M.; van de Giesen, N.; Steenhuis, T. 2007. The small reservoirs project: Research to improve water availability and economic development in rural semi-arid areas. In: *The hydropolitics of Africa: A contemporary challenge*, (eds.) Kitissou, M.; Ndulo, M.; Nagel, M.; Grieco, M. Newcastle, UK: Cambridge Scholars Publishing. Pp. 325-332.

Makurira, H.; Mul, M.L.; Vyagusa, N.F.; Uhlenbrook, S.; Savenije, H.H.G. 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, Parts A/B/C* 32(15-18): 1090-1097. https://doi.org/10.1016/j.pce.2007.07.020

Mantel, S.K.; Hughes, D.A.; Muller, N.W.J. 2010. Ecological impacts of small dams on South African rivers Part 1: Drivers of change – water quantity and quality. *Water SA* 36(3): 351-360.

Mbinji, J. 2010. *Climate change and performance of small reservoirs in the Upper East Region of Ghana*. A thesis submitted to the Faculty of Social Sciences, Lund University, Sweden.

Mdemu, M.V.; Rodgers, C.; Vlek, P.L.G.; Borgadi, J.J. 2009. Water productivity (WP) in reservoir irrigated schemes in the upper east region (UER) of Ghana. *Physics and Chemistry of the Earth, Parts A/B/C* 34(4-5): 324-328. https://doi.org/10.1016/j.pce.2008.08.006

Meigh, J. 1995. The impact of small farm reservoirs on urban water supplies in Botswana. *Natural Resources Forum* 19(1): 71-83. https://doi.org/10.1111/j.1477-8947.1995.tb00594.x

Mufute, N.L.; Senzanje, A.; Kaseke, E. 2008. The development of a risk of failure evaluation tool for small dams in Mzingwane Catchment, Zimbabwe. *Physics and Chemistry of the Earth, Parts A/B/C* 33(8-13): 926-933. https://doi.org/10.1016/j.pce.2008.06.029

Mugabe, F.T.; Hodnett, M.G.; Senzanje, A. 2003. Opportunities for increasing productive water use from dam water: A case study from semi-arid Zimbabwe. *Agricultural Water Management* 62(2): 149-163. https://doi.org/10.1016/S0378-3774(03)00077-5

Mulengera, P-M.B.; Manzungu, E.; Kileshye-Onema, J. 2012. ICT-based identification and characterisation of small reservoirs in the Limpopo River Basin in Zimbabwe. *Environment and Natural Resources Research* 2(3): 25-42. http://dx.doi.org/10.5539/enrr.v2n3p25

Munamati, M.; Senzanje, A.; Masona, C.; Basima, B.L. 2007. Small reservoirs water quality monitoring using plankton abundance and diversity. In: *Small reservoirs toolkit*. Pp. 1-6. Available at http://www.smallreservoirs.org/full/toolkit/tools.html (accessed April 25, 2019).

Namara, R.E.; Horowitz, L.; Kolavalli, S.; Kranjac-Berisavljevic, G.; Dawuni, B.N.; Barry, B.; Giordano, M. 2010. *Typology of irrigation systems in Ghana.* Colombo, Sri Lanka: International Water Management Institute (IWMI). 27p. (IWMI Working Paper 142). Available at http://www.iwmi.cgiar.org/Publications/Working_Papers/working/WOR142.pdf (accessed on March 8, 2019).

Ndomba, P.M. 2011. Developing sediment yield prediction equations for small catchments in Tanzania. In: *Advances in data, methods, models and their applications in geoscience*, (eds.). Chen, D. Croatia: InTech. Pp. 241-260.

Nissen-Petersen, E. 2006. *Water from small dams: A handbook for technicians, farmers and others on site investigations, designs, costs estimates, construction and maintenance of small earth dams*. Nairobi, Kenya: ASAL Consultants Limited for the Danish International Development Assistance.

Nkhoma, B.G. 2011. The politics, development and problems of small irrigation dams in Malawi: Experiences from Mzuzu ADD. *Water Alternatives* 4(3): 383-398.

Otto, B.; Venot, J-P. 2012. *The circumstances of corruption in planning small reservoirs in sub-Saharan Africa*. Water integrity brief. Berlin, Germany: Water Integrity Network Association; Colombo, Sri Lanka: International Water Management Institute (IWMI).

Rusere, S. 2005. *An assessment of the multiple uses of small dams, water usage and productivity in the Limpopo Basin*. Doctoral dissertation. Harare, Zimbabwe: University of Zimbabwe.

Rusinga, O.; Murwendo, T.; Zinhiva, H. 2011. Political implications of building small dams in communal areas of Zimbabwe: The case of Mhakwe dam in Chimanimani district. *Journal of Sustainable Development in Africa* 14(4): 147-157.

Sally, H. 2002. *Performance and self-management of small-scale reservoir-based irrigation schemes in Burkina Faso*. [Performance et auto-gestion des petits périmètres irrigués autour des barrages au Burkina Faso]. Paper presented at the 18th ICID Congress on Irrigation and Drainage, July 21-28, 2002, Montreal, Canada.

Sally, H.; Lévite, H.; Cour, J. 2011. Local water management of small reservoirs: Lessons from two case studies in Burkina Faso. *Water Alternatives* 4(3): 365-382.

Sawunyama, T.; Basima Busane, L.; Chinoda, C.; Twikirize, D.; Love, D.; Senzanje, A.; Mhizha, A. 2005. *An integrated evaluation of a small reservoir and its contribution to improved rural livelihoods: Sibasa Dam, Limpopo Basin, Zimbabwe*. Paper presented at the 6th WaterNet/WARFSA/GWP-SA Symposium, November 1-3, 2005, Swaziland.

Sawunyama, T.; Senzanje, A.; Mhizha, A. 2006. Estimation of small reservoir storage capacities in Limpopo River Basin using geographical information systems (GIS) and remotely sensed surface areas: Case of Mzingwane catchment. *Physics and Chemistry of the Earth, Parts A/B/C* 31(15-16): 935-943. https://doi.org/10.1016/j.pce.2006.08.008Get rights and content

Schmengler, A.C.; Vlek, P.L.G. 2015. Assessment of accumulation rates in small reservoirs by core analysis, ^{137}Cs measurements and bathymetric mapping in Burkina Faso. *Earth Surface Processes and Landforms* 40(14): 1951-1963. https://doi.org/10.1002/esp.3772

Senzanje, A.; Boelee, E.; Rusere, S. 2008. Multiple use of water and water productivity of communal small dams in the Limpopo Basin, Zimbabwe. *Irrigation and Drainage Systems* 22(3-4): 225-237. https://doi.org/10.1007/s10795-008-9053-7

Sichingabula, H.M. 1997. Problems of sedimentation in small dams in Zambia. In: *Human Impact on Erosion and Sedimentation: Proceedings of the Rabat Symposium, April, 1997*. IAHS Publication No. 245. Pp. 251-259.

Stephens, T. 1984. Water and power supplies for small-scale irrigation in Mashonaland East. In: *African regional symposium on small holder irrigation, September 5-7, 1984, University of Zimbabwe, Harare, Zimbabwe*, (ed.) Blackie, M.J. Pp. 87-94.

Stephens, T. 2010. *Manual on small earth dams: A guide to siting, design and construction*. FAO Irrigation and Drainage Paper 64. Rome: Food and Agriculture Organization of the United Nations (FAO). 124p.

Sullivan, A.; Meinzen-Dick, R.; Opoku-Ankomah, Y.; Ampomah, M.B.; Dembele, Y.; Goldin, J.; Pereira, M.I. 2009. Institutions and governance of small reservoir water resources. In: *Small reservoirs toolkit, theme 5: institutions*, (eds.) Andreini, M.; Schuetz, T.; Harrington, L. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF); Colombo, Sri Lanka: International Water Management Institute (IWMI); Brasilia, DF, Brasil: Brazilian Agricultural Research Corporation (Embrapa Cerrados Center); Harare, Zimbabwe: University of Zimbabwe (UZ); Accra, Ghana: Ghana Water Research Institution (WRI); Delft, The Netherlands: Delft University of Technology (TUD); Stockholm, Sweden: Stockholm Environment Institute (SEI); Marseille, France: Institut de Recherche pour le Developpement (IRD); Bonn, Germany: Center for Development Research, University of Bonn; Ithaca, NY, USA: Cornell University. 13p.

Tamene, L.; Park, S.J.; Dikau, R.; Vlek, P.L.G. 2006. Analysis of factors determining sediment yield variability in the highlands of northern Ethiopia. *Geomorphology* 76(1-2): 76-91. https://doi.org/10.1016/j.geomorph.2005.10.007

Tayeh, A. 1998. The effect of size of surface drinking water sources on dracunculiasis prevalence in the Northern Region of Ghana. *International Journal of Environmental Health Research* 8(4): 285-292. https://doi.org/10.1080/09603129873390

Teka, D.; van Wesemael, B.; Vanacker, V.; Poesen, J.; Hallet, V.; Taye, G.; Deckers, J.; Haregeweyn, N. 2013. Evaluating the performance of reservoirs in semi-arid catchments of Tigray: Tradeoff between water harvesting and soil and water conservation. *CATENA* 110: 146-154. https://doi.org/10.1016/j.catena.2013.06.001

Tibaldeschi, G.; Boulenger, X. 2002. *Small dams rehabilitation programme: Burkina Faso*. Appraisal report. African Development Fund.

Tumbare, M.J. 2013. Sedimentation of small and medium sized dams: Discussion issues. *Journal of Engineering, Design and Technology* 11(2): 112-128. https://doi.org/10.1108/JEDT-08-2011-0055

USAID (United States Agency for International Development). 2019. Agriculture and food security. Available at https://www.usaid.gov/mali/agriculture-and-food-security (accessed on April 25, 2019).

van de Giesen, N.; Liebe, J.; Andreini, M.; Steenhuis, T. 2005. Use of small reservoirs in West Africa as remotely-sensed cumulative runoff gauges. In: *Proceedings of the Second International CAHMDA-II International Workshop on The Terrestrial Water Cycle: Modeling and Data Assimilation across Catchment Scales, October 25-27, 2004, Princeton University, New Jersey, USA*, (eds.), Teuling, A.J.; Leijnse, H.; Troch, P.A.; Sheffield, J.; Wood, E.F. Pp. 28-31.

van de Giesen, N.; Liebe, J.; Jung, G. 2010. Adapting to climate change in the Volta Basin, West Africa. *Current Science* 98(8): 1033-1037.

Venot, J.P. 2014. Rethinking commons management in sub-Saharan West Africa: Public authority and participation in the agricultural water sector. *Water International* 39(4): 534-548. https://doi.org/10.1080/02508060.2014.911647

Venot, J.P.; Hirvonen, M. 2013. Enduring controversy: Small reservoirs in sub-Saharan Africa. *Society & Natural Resources* 26(8): 883-897. https://doi.org/10.1080/08941920.2012.723306

Venot, J.P.; de Fraiture, C.; Nti Acheampong, E. 2012. *Revisiting dominant notions: A review of costs, performance and institutions of small reservoirs in sub-Saharan Africa.* Colombo, Sri Lanka: International Water Management Institute (IWMI). 39p. (IWMI Research Report 144). Available at http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB144/RR144.pdf (accessed on March 8, 2019).

Venot, J.P.; Andreini, M.; Pinkstaff, C.B. 2011. Planning and corrupting water resources development: The case of small reservoirs in Ghana. *Water Alternatives* 4(3): 399-423.

Venot, J.P.; Krishnan, J. 2011. Discursive framing: Debates over small reservoirs in the rural South. *Water Alternatives* 4(3): 316-324.

WCD (World Commission on Dams). 2000. *Dams and development: A new framework for decision-making*. London and Sterling, VA: Earthscan Publications Ltd. Available at https://www.internationalrivers.org/sites/default/files/attached-files/world_commission_on_dams_final_report.pdf (accessed on March 8, 2019).

Wisser, D.; Frolking, S.; Douglas, E.M.; Fekete, B.M.; Schumann, A.H.; Vörösmarty, C.J. 2010. The significance of local water resources captured in small reservoirs for crop production – A global-scale analysis. *Journal of Hydrology* 384(3-4): 264-275. https://doi.org/10.1016/j.jhydrol.2009.07.032

Annex. Questionnaire.

A. Investment

1. Describe the program under which reservoir(s) were constructed. Specifically outline:
   - Year and location
   - Number of reservoir/s
   - How many were constructed and how many were rehabilitated?
   - Objective of the initiative
   - Financial arrangements
   - Community involvement
   - Intermediaries involved and their role
   - How many years since the reservoirs were constructed?
   - How many are still functional?
2. What particular design aspects did you consider to improve reservoir sustainability?
3. What biophysical factors determined the suitability of locating a reservoir site?
4. Did you conduct a feasibility study and predict a certain rate of return on investment? Can you specify? What was the predicted lifespan of the reservoir?
5. Are efforts made to measure demand in different potential sites for investments in small reservoirs, in order to ensure that investments are demand-responsive? If so, how is this undertaken?

B. Management

6. What institutions exist for the management of the reservoir at different levels (dam, local and national)? Explain in detail the role of each actor.
7. What maintenance arrangements are in place? Specify the roles of funders, community and the government.
8. Do you have a monitoring and evaluation system? Please explain how it is implemented.
9. Describe the local community's management capacity.

C. Performance

10. Have your investments met your expectations (performance, impacts, lifespan, etc.)?
11. What are the benchmarks or indicators that you use to assess performance or success? Explain in detail the methodology for each criteria.
12. In what areas did your project succeed, and what were the major factors that influenced the success?
13. In what areas did your project fail, and what were the major barriers?
14. Describe the rate of failure in new reservoirs compared with those that are rehabilitated.
15. Do you calculate sedimentation? What methods do you use?
16. From your experience, what would you say are the key factors that are critical to success of the reservoir.

D. Impacts

17. Describe the extent of benefits realized by the beneficiaries of your project.
    - What are the benefits?
    - How many people benefitted?
18. What is the economic return on new versus rehabilitated reservoirs?
19. Which of the following were impacted by your project?
    - Irrigation
    - Livestock
    - Domestic water supply
    - Household welfare
    - Health
    - Environment
    - Other

E. Social and gender dimensions

20. From your experience, what were the institutional arrangements for:
    - Water use
    - Maintenance arrangements
    - User fees
    - Conflict resolution
21. What is the proportion of men and women using the reservoir?
22. Describe women's water use.
23. What is the level of accessibility for women? (physical, institutional and technological?)
24. If not, what are the driving factors for the difference in access across genders? Please describe in detail.

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