Impacts of reservoirs: participatory definition of indicators for health and environment

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Scope: questions/ challenges the tool addresses

Assessing health impacts of small reservoirs over time can be facilitated with the use of indicators. These could be defined by experts, as is described in some of the other tools, but if they are to be monitored by the communities, a different approach is needed. In this tool an approach for participatory development of indicators is described, based largely on experiences in Morocco between 2005 and 2007 (Laamrani et al. 2007a, 2007b). The research team together with the community jointly developed and evaluated impact indicators to assess changes in ecosystems associated with the development in 1990 of a small dam in Asgherkiss (Ait Lhaj & Laamrani 2007). By using mutually agreed definitions, the joint development and use of these indicators facilitated communication among the key stakeholders. This approach to the development and use of impact indicators may be helpful when planning new small reservoirs, in Morocco and in other countries in Africa and elsewhere.

Target group of the tool

Health professionals, researchers, and planners, designers, builders, managers and users (at the community level rather than specific households) of small multi-purpose reservoirs who wish to monitor changes in health benefits and risks related to these water storage structures.

Requirements for tool application

Disciplinary experts with a capacity for participatory approaches, and an open attitude in the community.

Tool: description and application

A participatory approach can help to develop site-specific indicators for the study area (see also the tool on participatory health impact assessment, described separately). Note that such participatory approaches, when applied in a different location, are likely to have generated a totally different set of indicators.

The approach described here is based on the study in Asgherkiss in Morocco, including intermediate steps in indicator development. The various tables shown below illustrate the

process of how a compact set of indicators was developed from categories, criteria, and systematic analysis. More details can be found in Report 3 prepared by Ait Lhaj and Laamrani (2007). At the end of the section, some 'expert indicators', and alternative ways of formulating indicators, are provided to help further stimulate ideas.

An impact is defined as "measurable or qualitative change that is caused by one or more factors related to the presence or use of the small reservoir and observed in the wider watershed or the people and animals living there" (definition by the Asgherskiss team as mentioned in Ait Lhaj and Laamrani 2007). According to this definition, impact is all about change. Measurement of change implies a comparison between "before" and "after" situations or, alternatively, "with" and "without" situations. It is not uncommon to find, however, that baseline data describing the "before" or "without project" situations are largely unavailable. Sometimes, subjective recall by community members is the only source of information. In the case of regional comparisons, the selection of control sites is often far from ideal. When data on which to base comparisons are difficult to find or are simply unavailable, the research team may need to be more creative, possibly making comparisons with international or national standards, or regional averages.

In the case study, the joint development of impact indicators used the following steps:

Identification of levels of impact

Participatory tools and meetings can be used to exchange findings and make an analysis of the many kinds of small reservoir impacts. These can then be grouped under themes, such as the ones presented in Table 1 and extended with criteria on how to measure the impact (Table 2).

Table 1. Identification of thematic groupings and their effects (adapted from Ait Lhaj & Laamrani 2007)

Thematic group	**Effects**
Water	Resource, mobilization, management, use
Health	Disease, risk, hygiene
Environment	Soil, fauna, flora, water properties
Agricultural production system	Crops, irrigation, livestock, fisheries, cultural practices
Socio-economics	Income, immigration, gender, infrastructure, labor, property, ownership

For appropriate measurement of impact, robust indicators should be used. Researchers should select indicators in terms of how well they meet relevant criteria. These criteria can be refined and made location-specific in meetings and discussions with the community, helping the sense of ownership. In the Moroccan context, the criteria are as follows (see Table 2 for values):

- Feasibility: the impact indicator has to be easy to use, visual, comprehensible, readily interpreted, context-specific, localized, available, inexpensive (in terms of cost for data collection)
- Reliability: the impact indicator has to be sturdy and exact, truly reflecting the variations of what is to be synthesized
- Reproducibility: the impact indicator has general value

- Frequency: the impact indicator has to be understandable and useful for all stakeholders (using simple protocols that are applicable every year)
- Quality of the impact indicator: precision of definition, its value, the various parameters and the flexibility in interpretation
- Coverage: where the impact indicator is valid
- Appropriateness: the impact indicator can be used for management and is valid across disciplines and sectors. (Later in the process it was proposed that appropriateness would be determined by other criteria, e.g. as such: [feasibility – frequency] + reproducibility + coverage + quality of the measurement).
- Multi-disciplinarity: more an attribute of an impact, showing links between various elements of the ecosystem.

Table 2. Definition of used criteria and valuing system for the evaluation of impact indicators (Ait Lhaj & Laamrani 2007)

Criterion and definition	**Value**				
Feasibility: Easy, economic, technical	1. Not feasible	2. Somewhat feasible	3. Feasible	4. Highly feasible	
Reliability: Verifiable, sensible	1. Unreliable	2. Somewhat reliable	3. Reliable	4. Highly reliable	
Reproducibility: Stable, not site-specific	1. Not Reproducible	2. Reproducible to some extent	3. Reproducible	4. Highly reproducible	
Frequency: Dynamics	Number of measures				
Quality of the measurement	0. Not measurable	1. Qualitative	2. Quantitative		
Coverage: Space covered, basin, upstream, region, site	1. Rural community	2. Upstream	3. Users	4. Ecosystem	5. Downstream
Appropriateness Capacity, degree, quality of information on impact of small reservoir	1. Irrelevant	2. Somewhat relevant	3. Relevant	4. Highly relevant	

Development of impact indicators

An indicator is the measured aspect of an objective element or group of elements related to a specific context. Small reservoir indicators should indicate the state of the system before and/or after the impacts of any changes are realized. Indicators may be either quantitative or qualitative; either way they should be descriptive. Data collected through participatory approaches are by definition qualitative and subjective, but for impact assessment that is not necessarily undesirable. In general, indicators sum up complex information and foster dialogue among stakeholders (scientific, managerial, political, and users). Comparisons can be made with status of indicators measured 'before' or 'without' reservoirs; or with international

standards or averages. However, indicators always represent a model of reality and never reality itself so it has to be accompanied by qualitative information and commentary.

In Morocco, impact indicators were chosen to help identify and quantify the components of the ecosystem and characterize their spatial and temporal variation. They enabled a quantitative and qualitative evaluation to be made of the status of the ecosystem and its health.

At Asgherkiss all identified indicators of ecosystem and human health have shown changes since the construction of the small reservoir. Indicators have been grouped to arrive at a common indicator that demonstrates the major impact. The indicators (Table 1) are listed in a matrix by thematic group with the values for each of the criteria (Table 2) as columns. For each indicator the values for each of the criteria are then established in a participatory way, e.g. in a meeting, and added to arrive at a total score.

Final selection of key indicators

This phase consists of an evaluation of the matrices, using the total score to determine which indicators are most efficient. This systematic analysis takes into account the relation between the various elements and their relative importance. Selected impact indicators have to be measurable so they can be valued and compared to standards. In practice this means that the indicators will be constructed on a case to case basis by looking at the impacts of the small reservoir. Table 3 presents the key indicators by thematic area that were finally retained by the team at Asgherkiss Dam in Southern Morocco, as an example. More details on these indicators can be found in the Appendix, as an illustration of the rationale behind the participatory selection process.

Table 3. Selected key impact indicators as developed for Asgherkiss small reservoir in southern Morocco (Ait Lhaj & Laamrani 2007)

Theme	**Impact**	**Key impact indicator**
Water	Water resources	Volume of stored water
	Water quality	Microbiological analysis by water storage type
	Water use	Amount of water consumed
		Coverage of water needs by use from the reservoir
		Number of storage structures
	Institutions	Importance of water-related conflicts
		Technical constraints (e.g. pressure differences, water loss, state of dam)
Environment	Status of natural resources	Type and number of bird species
		Number of new plant species
		Number of mosquito species
	Quality of natural resources	Groundwater level measurements
	Recreational and social value	Recreation infrastructure present
Agriculture	Production	Irrigated area
	Technical aspects	Use of new inputs
	Diversification	New crops
	Animal production	Type of livestock management
		Livestock units
	Agricultural income	Number of working days

Theme	Impact	Key impact indicator
Socio-economics	Financial flows	Contribution of newly introduced activities
		Contribution of each activity in income generation
	Work	Time required for water collection
	Organization of the population	Number of organizations
	Way of living	Types of houses
		Consumed products
Health and hygiene	Reduction of diarrhea and parasitic diseases	Home water treatment
		Bacteriological and physical-chemical water quality in water sources
		Bacteriological and physical-chemical quality of water stored at home

Many impacts identified in the course of the process were hard to measure. Hence the final score was used to reconcile the identification of powerful tools for impact assessment and the expectations of the community that was looking for a plan of action to increase benefits and reduce risks associated with the small reservoir.

Expert indicators

A completely different approach to indicators is to depart from references and experts, without interaction with other stakeholders. Indicators chosen in this fashion will be less site-specific and hence better suited to cross-comparisons. On the other hand, such indicators may be less relevant for development and not necessarily related to the impacts of small reservoirs in all circumstances. In some cases, e.g. in a large study where not all sites can be visited, or when a first phase is done as a desk study, the use of expert indicators may be the best choice. Usually a long list of required information is developed, then revised after the first round of data collection. A selection of data can then be collected monthly at selected reservoirs and quarterly at control sites (Scheffer & Hackenitz 2003). Data are derived from a variety of secondary and primary sources through appropriate methodologies, such as measuring and observation, sampling, focus group discussions, local contact with key informants and officials, national monitoring programs, maps and remote sensing imagery. Detailed data can be collected on a monthly basis for 12 consecutive months for a selection of indicators of climate, water quality, health and land cover. The list below is an expert brainstorm suggestion of data most relevant for health issues (sometimes with an indication of the methodology), followed by a few examples of indicators. Naturally the final selection of data and indicators has to be based combined with those from other tools and on local circumstances.

Climatic indicators

- Rainfall
- Evaporation
- Temperature
- Humidity

Water quality indicators

- Electric Conductivity - EC (probe)
- Turbidity, chlorophyll (probe, e.g. “aquafluor” from Turner)
- Water temperature (thermometer)

Health data

- *Anopheles* larvae
- Vector snails
- Bacteria: *E.coli*, thermotolerant coliforms, fecal *Streptococcus*
- Parasites: *Giardia, Cryptosporidium*
- Disease incidence: e.g. malaria, schistosomiasis, diarrhea, trachoma, Chagas disease, leishmaniasis.
- Top five disease prevalence by age group
- Body weight at birth or at age of five years
- Preventive measures at household level (observation)
- Health facilities and staff

Community data

- Housing type: wall, roof, eaves
- Sanitation coverage and use
- Domestic water handling
- Water storage facilities (observation, interviews, secondary data)
- Household economy: major income, expenditure posts, transport and health costs
- Daily activity scheme: washing, laundry, occupational, school by gender / age classes
- Distance from the dam, watering points, firewood collection, grazing areas
- Cooking facilities (observation)
- Estimated and projected population (statistics)
- Population growth rate % (statistics)
- Average household size

Reservoir and other water infrastructure

- Flow velocity (visual estimation or simple measurement)
- Aquatic vegetation coverage of reservoir and surrounding area: submerged, floating, erect, types (visual observation)
- Algal blooms coverage (visual observation)
- Water use points

Agriculture

- Presence of irrigation facilities
- Plot size, scheme size, management arrangements
- Livestock numbers by type
- Other domestic animals

Examples of health indicators for monitoring

Schistosomiasis

- The percentage of children with *Schistosoma* eggs in their stools or urine, as an indication for the actual transmission of schistosomiasis to the human population.
- The number of intermediate host snails per square meter, as an indication for the transmission potential for *Schistosomiasis.*

- The percentage of infected snails, as an indication for the actual transmission of schistosomiasis by the snail population.

Cryptosporidium

- The percentage of children with *Cryptosporidium* oocysts in their stools, as an indication for fecal contamination of the drinking water source by humans or cattle.

Trachoma

- The percentage of children with eye infections, as an indication for personal hygiene.
- The percentage of children with acute trachoma, as an indication for transmission of trachoma and low environmental hygiene.
- The percentage of adults with advanced or past trachoma, as an indication for past transmission of trachoma, and possibly an improvement in hygiene.

Water use

- The number of water contacts in 15 hours at a particular water use point, as an indication for variations in the intensity of water use over the day and between seasons.
- The number of liters of water used per person per day in the studied households, as an indication for the water intake for domestic purposes per capita per day over the seasons.

Diarrhea

- The number of diarrhea episodes per person in the most exposed age group reported by the health facilities per year, as an indication for the consumption of water or food that is contaminated with fecal matter.

Lessons learned

While a list of data and indicators compiled by experts is generally longer and more generic, the use of participatory methods in defining key indicators has many advantages. Generally the indicators thus derived are more site-specific, practical, and more relevant for the assessment of (future) impacts of small reservoirs on ecosystem and on human health.

In the Moroccan case, scoring each identified indicator on its feasibility, reliability, reproducibility, frequency, quality of measurement, coverage, multi-disciplinarity and appropriateness proved useful in selecting a final list of key indicators. However, in other locations or under other circumstances, different criteria might be appropriate.

Recommendations

In other areas where small reservoirs were developed, it will be interesting to see which key indicators can be identified to better determine the correlation between selected indicators and their predictive value on impacts. It would already be of great help if these indicators could be evaluated with other local, national or even international stakeholders; or if the same process were used in other areas and well documented

Limitations of the tool

Any list of indicators be it compiled by experts or in dialogue with the community or other stakeholders, is never complete. No matter how beautifully it characterizes the performance of a reservoir, over time circumstances will change and the list will have to be changed.

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Selected websites on related impact indicators

WHO and UNICEF Joint Monitoring Programme (JMP) for water supply and sanitation. http://www.wssinfo.org/

United Nations/World Water Assessment Programme

http://www.unesco.org/water/wwap

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Appendix: Final selection of key indicators in Morocco

In Morocco, all identified indicators of ecosystem and human health had shown changes since the construction of the small reservoir at Asgherkiss Dam in Southern Morocco. In a facilitated meeting, indicators from Table 1 have been grouped and listed, by thematic group, as rows in a matrix with the criteria of Table 2 as columns. This score table is not included here but can be found in the project reports by Ait Lhaj and Laamrani (2007). The group of participants then scored values each of the criteria, which were added to arrive at a total score. The ones with the highest scores were retained as key indicators in Table 3. Selected impact indicators have to be measurable so they can be valued and compared to standards. The key indicators for Asgherkiss in Morocco (from Table 3) are described in a bit more detail below to provide insight into the participatory process that provided the justification for selecting precisely these indicators.

Under the water theme, four groups of impacts and their proper indicators were distinguished: *water resources*, *water quality*, *water use* and *institutions*. The 26 identified indicators were all considered reproducible and measurable, and most as feasible, reliable and appropriate as well. Eventually, 'volume of stored water' was selected as a good indicator for water resources as it can be measured twice a year, though it only covers the downstream area of the small reservoir. Under *water quality*, the four identified indicators had the same characteristics, though 'microbiological analysis by water storage type' was found to be the most appropriate indicator to provide information on water quality. For *water use*, the indicators 'amount of water consumed', 'coverage of water needs by use from the reservoir' and 'number of storage structures' are most efficient. Under *institutions*, the 'importance of water-related conflicts' and 'technical constraints' are the two indicators identified as the most interesting.

In the environmental domain, the following groups of impacts were defined: *status of natural resources*, *quality of natural resources* and *recreational and social value of the water sources*, with a total of 17 indicators initially. In the first group, 'number of mosquito species', 'type and number of bird species' and 'number of new plant species' were considered the most suitable indicators to evaluate the impact of the small reservoir on various elements of the ecosystem. It should be noted here that the indicator on birds was also evaluated in relation to the potential risk of bird flu transmission in southern Morocco. Under *quality of natural resources*, two indicators were found most interesting: 'groundwater level measurements' and 'microbiological water analysis by type of source'. In addition, chemical analysis of water and soil can give an important indication of the quality of natural resources, especially when potentially polluting activities take place, such as agriculture, small industry or craft. Moreover, 'frequency of floods' and 'water erosion' are also important and very closely linked to the implementation of the dam. But these indicators are not very feasible so they are less useful unless an indirect, easy and reliable way of measuring these can be found. Hence only 'groundwater level measurements' was retained as key indicator. For *recreational and social value*, the inventory of recreation infrastructure seems the most important indicator that provides most information on the impact of the small reservoir on recreation. The 'value of the landscape' is also a good indicator, but more study is needed to determine how to approach this.

In the agricultural domain (26 indicators initially) under *production*, it was not so easy to determine the most relevant indicator as only 10 households with their plots close to the distribution system had access to irrigation water from the dam (Tafrat irrigation system). The presence of the dam has improved water availability throughout the year and so the irrigated area of Tafrat has increased. Still, production methods have largely remained traditional, based on organic manure. It is expected that this will not change rapidly in the future, because of the small size of the agricultural plots in this mountainous area. Hence only the 'use of new inputs' is likely to be a valuable indicator to monitor technical development, and in Asgherkiss this showed no change since dam construction. Under *diversification*, it can be concluded that the small reservoir has not led to the introduction of new crops or animal species. Contrary to this, under *animal production*, the 'type of livestock management' and 'Livestock Units' are two indicators that provide important information on the impact of the small reservoir. These are both appropriate, easy to measure and well related to the cultivation of (irrigated) fodder crops and sale of one or two calves per household annually. This can be considered a positive impact of the dam on animal production, increasing *agricultural income*. The 'number of working days' was considered the most efficient indicator to provide information on changes in agricultural income, as it is more feasible and reliable than other indicators. Actually, the community assessment of working days showed that it was also related to the increase in irrigated area downstream of the small reservoir, and the increase in irrigation frequency upstream of the reservoir, which was possible because of reduced pressure on available water sources.

The socio-economic impacts of small reservoirs held 24 indicators that can be grouped into four groups: *financial flow*, *work, organization* and *way of living* of the population in question. *Financial flows* indicators reflect the earning and expenditure of cash. Evaluation of the various indicators has shown that the most significant and efficient are 'contribution of each activity, especially the newly introduced ones, in income generation' (2 indicators combined), 'expenditure by market' and 'frequency of market visits'. These indicators are inexpensive and require little time to measure. They provide information on the state of financial flows after construction of the small reservoir. Under *work*, the indicators tell us the amount of time and effort devoted to various activities by sub-groups of the community, i.e. men, women and children. The presence of a small reservoir can lead to changes in the production system by creating new activities and tasks, while old ones may disappear. Also, it will have an impact on hygiene and nutrition, represented by more time dedicated to domestic tasks and child care. Important indicators are hence the 'daily working schedule' with particular attention to the 'time required for water collection' (retained as key indicator), 'newly introduced activities' and 'labor division by gender'. The group indicators under *organization of the population* shows the degree of (formal) social relations between people as well as the institutional mechanisms in place for problem solving. The 'number of organizations' is the most suitable indicator because it can easily provide reliable and appropriate information that refers indirectly to the other indicators. Under *way of living* the effect of the small reservoir on people's habits is assessed, especially nutrition and housing. The most appropriate indicator is 'consumed products' because that is most likely to have changed.

In the health domain, reduction of diarrhea and parasitic diseases was considered as the one most important outcome. Out of no less than 36 indicators, 'home water treatment', 'bacteriological and physical-chemical water quality' at the water source and at home all had the highest total score. These indicators are very reliable and applicable to all water samples, be it from upstream, downstream or both. In addition to being most appropriate, these indicators are (quantitatively) measurable and their values can be compared to national and international standards. Secondary indicators 'maintenance of water source', 'water protection at household' and 'hand washing before meals' are as effective as the first three, but are only qualitatively measurable. Other indicators such as 'type of water sources used', 'other activities near water source', 'amount of soap used/week' and 'presence of traces of human or animal feces near water points' are appropriate, easy to use and both feasible and reliable, but sometimes they are limited because of the required frequency and coverage. Other indicators had either problems of measurement or could be assessed only in well-targeted clinical studies.