Small reservoir water allocation strategy

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Scope: questions/ challenges the tool addresses

Water is a limited resource, with many users and uses. Water allocation strategies need to recognize this. The tool featured in this section uses estimates of water productivity and social values to inform decisions on the allocation of scarce water resources. The tool shows how the notion of water productivity can help in the evaluation of the socio-economic contributions of small multiple-use reservoirs. Some uses of small reservoirs are shown in Table 1.

Table 1 - Multiple uses of small reservoirs [1]

Use	**Nature of use**	**Contribution**
Drinking	Additive	Health (livelihood)
Livestock	Additive	Cash, health (nutrition), power and plant nutrients
Crops	Additive	Cash and health (nutrition)
Fisheries	Multiplicative	Cash and health (nutrition)
Grass	Additive	Cash and shelter
Bricks	Additive	Cash and shelter

Target group

Water resource managers, policy makers, and communities of users of small reservoirs.

Requirements for tool application

The tool requires skilled personnel who can calculate total water productivity derived from all uses of a reservoir, taking account of economic, social and physical values. The tool also requires community participation in identifying uses for reservoir water, and placing values on each one.

Description and application of the tool

In this tool, small reservoir water is allocated to alternative uses, based on estimates of water productivity for each. Water allocation strategies aim to increase the overall productivity of

[1] In additive uses, a unit of water that is consumed is not available for other uses. In multiplicative uses, water "consumed" for one purpose remains available for other purposes.

usable water resources. In doing so, these strategies follow two paths first set out by Molden et al (2001). The first path is to use a larger proportion of the developed primary water supply for beneficial purpopses, that is, to increase real water savings. The second path is to produce more output per unit of depleted water, that is, to increase water productivity.

Methods for developong a small reservoir water allocation strategy include the following:

- Total available water: A six-month dry season reservoir yield (April to September) is determined using a modification of a method developed by Mitchell (1987).
- Social values: Social values and community priorities for water use are elicited through surveys and interactions with key informants.
- Water productivity: Average annual water productivity in different uses is determined using standard procedures as described below.

Livestock water productivity

Livestock water productivity is estimated for cattle, goats, sheep and donkeys. The value of livestock products and services is estimated from annual average livestock sales, dry and wet season milk production, equivalent nitrogen content in dry matter manure (with litter) and traction/draught power for transport and ploughing. Livestock water productivity is calculated as a ratio of the value of livestock products and services to the amount of water consumed per annum for each type of livestock (FAO, 1986) and expressed as monetary water productivity (US$/m^3). Lumping livestock products and services is recommended in order to minimize the complexities typical of informal and mixed farming systems. Livestock data obtained through traffic counts is used in estimating water productivity at the level of the reservoir. Descriptive statistics for livestock can also be deduced from dip-tank livestock records and questionnaires.

Water productivity in brick manufacture

Estimating water productivity in brick manufacture involves measuring the mass of at least ten finished bricks and estimating the average mass of each brick at each reservoir. The quantity of water used in making 1000 bricks, and prices for bricks, are obtained through interviews with brickmakers. Water productivity is expressed either in terms of physical water productivity (kg/m^3) or monetary water productivity (US$/m^3). For bricks, monetary water productivity is more useful than physical water productivity.

Crop water productivity

Crop water productivity is estimated for commonly grown crops, for example, tomatoes, vegetables, green maize cobs, dry beans and wheat. Data for calculating crop water productivity are obtained through interviews and physical measurements. Data needs include the amount of water applied to a crop, the crop yield, and the farm-gate price of the crop. For vegetables, the average weight of one vegetable bundle may be determined. This can be multiplied by the number of bundles harvested in a given period to estimate total yield. Physical water productivity is estimated as total yield divided by the amount of water applied, estimated from the volume of water applied per bed, the number of beds, and the frequency of watering. (Lovell, 2000). Both physical (kg/m^3) and monetary water productivities (US$/m^3)

are calculated. Note that this approach estimates productivity of applied water only. Rainwater is not considered.

Fish water productivity

Estimating fish water productivity involves obtaining data on average fish catch per day in the wet and dry seasons, respectively. These data are verified against trial fish catches. The average weight and number of fish for each bundle are recorded, and the average price of fish bundles is obtained through interviews. Water depleted from fisheries is determined from the total volume of water that evaporates from the reservoir during wet and dry seasons (Lemoalle, 2006). Either physical (kg/m^3) or monetary water productivity (US$/$m^3$) may be estimated.

Domestic use water productivity

The monetary water productivity for domestic use of raw reservoir water is found by halving the cost of treated water per cubic metre as supplied and charged by the potable water provider in a given area (e.g., ZINWA at Avoca Business Centre in the Limpopo Basin). Productivity is expressed in US$/$m^3$. It is not necessary to cover the multiple benefits of domestic water use beyond the cost of supply.

Water productivity for thatching grass

Samples of thatching grass are harvested from a reservoir buffer area and packaged into standard bundles by residents involved in grass harvesting. The bundles are weighed on a hanging balance, their mass recorded, and the area from which sample bundles were harvested is measured. Grass density is estimated from the mass of the harvested bundles, and the area from which they were harvested. Estimates of grass density are then applied to the total area of the grassed buffer zone to estimate the total number of bundles that could be harvested. Total mass of the bundles are calculated by proportional multiplication with the mass of a standard bundle. For monetary water productivity, sales prices of standard bundles are obtained through interviews. Volume of water depleted by grass is estimated by multiplying grass evapotranspiration, which can be obtained using CropWat 4.0 model for Windows 4.3 (Clarke et al., 2000) by the area of the grassed buffer. A cropping pattern of alfalfa grass is normally assumed when determining grass evapotranspiration. Grass water productivity may be calculated in physical or monetary terms.

Recreation Water Productivity

Water productivity for recreation is estimated from the number of person-hours spent by individuals whilst swimming, boating or otherwise enjoying the reservoir. This is determined through interviews. Person-hours are multiplied by the minimum average wage for casual labourers in rural areas, assuming that time spent in recreation has an opportunity cost. Water productivity is then expressed in monetary units per unit volume of available reservoir water. The assumption is that reservoir recreation is a function of the available water volume and is maximized at full reservoir capacity. Recreation is a non-consumptive use.

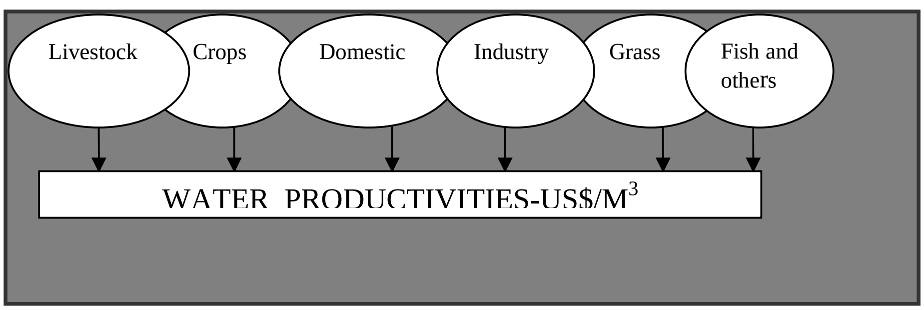
Application of the Water Allocative Strategy

Once water productivities are calculated, water is allocated to uses with the highest productivities. This maximizes incomes from the available dry season reservoir yield. Four scenarios are considered selecting a water allocation strategy.

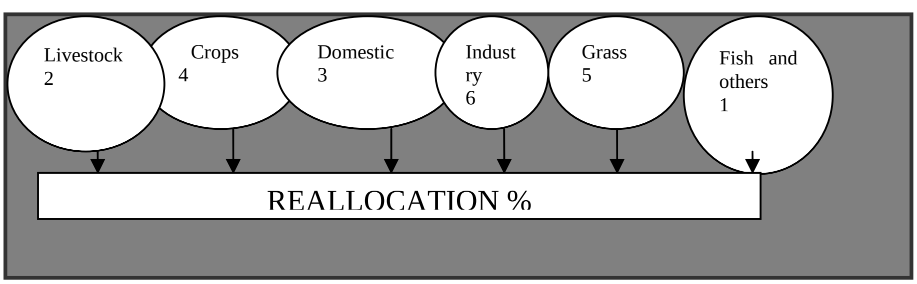
- Zero scenario: This assumes no intervention. Present water uses and allocations are analysed for their water productivities.
- First scenario: Water is reallocated across subsectors (uses or products) towards those with the highest water productivities.
- Second scenario: Water is reallocated across sectors, towards those with the highest water productivities. The environmental allocation is reduced to only 11 % of the yield. Nguyen-Khoa et al (2005) and Renwick (2001a) consider this to be the minimum "dead" water reserve required for enhancement of aquatic organisms and fish.
- Third scenario: Water from the second scenario is reallocated across sub-sectors of the first scenario.

Summary: The procedure for using the Water Allocative Strategy Tool [2]

0. Identify various water uses, allocations and water productivities: *zero scenario*

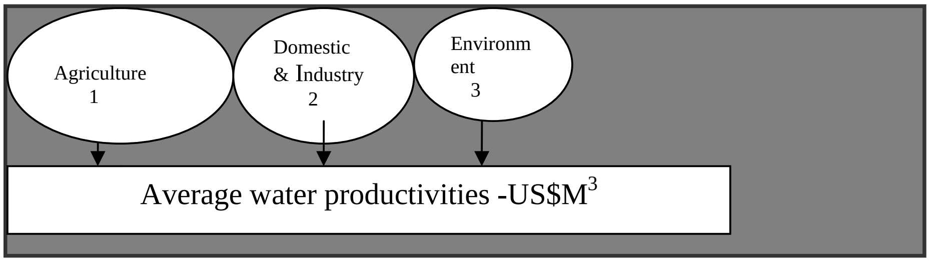


1. Reallocate water across uses based on water productivities of sub-sectors: *first scenario*

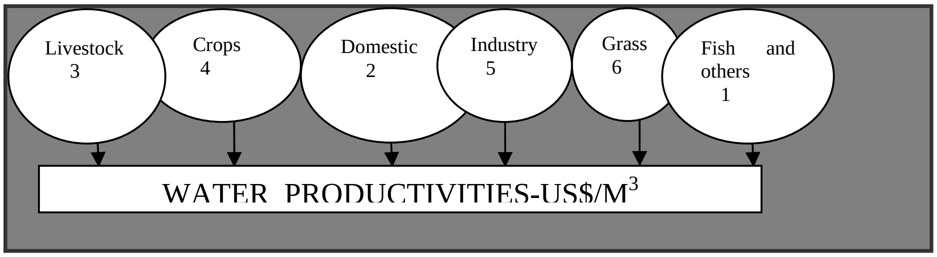


2. Reallocate water across sectors, giving more water to sectors with higher water productivities: *second scenario*

[2] Size of circles and numbers inside circles represent the size of water productivities. Large circles or small numbers indicate higher water productivity.

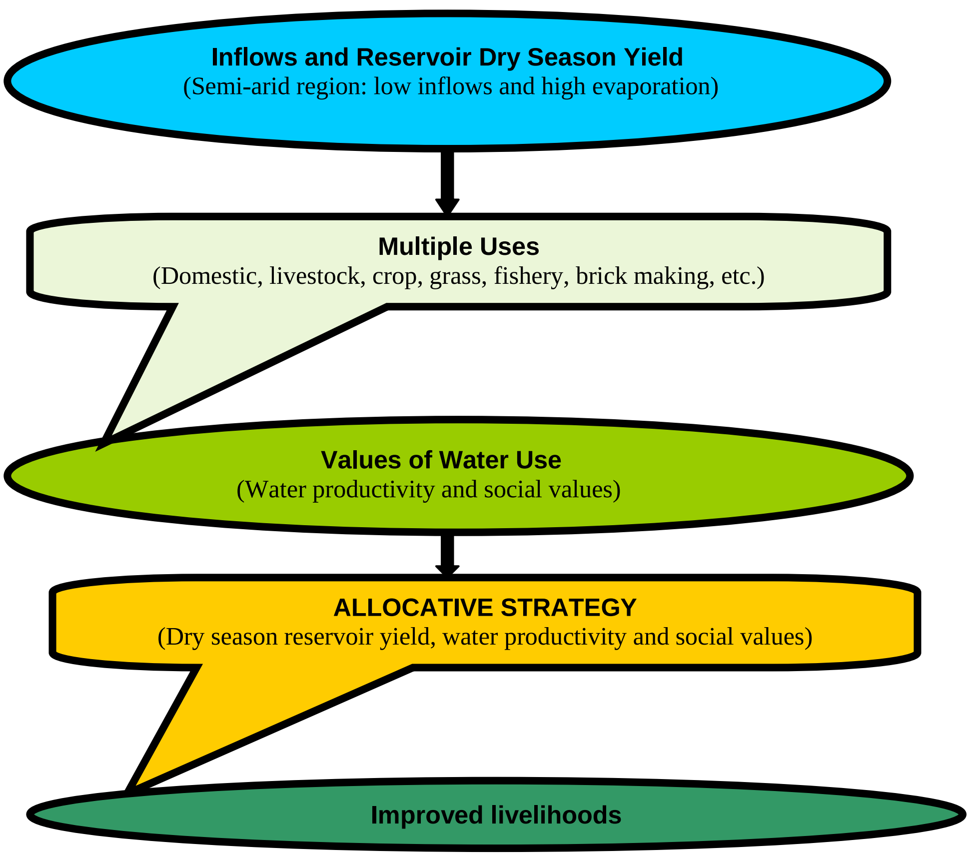


3. Distribute sectorally re-allocated water to sub-sectors-third scenario



In all four scenarios, water is allocated in such a way that maximum benefits can be attained with sustainable use of the dry season reservoir yield. The strategy can be used where water resources are scarce, especially in semi-arid areas. A summary of the process used in formulating strategy is shown in the flow chart below.

Figure 1 - Formulation of a water allocation strategy



Lessons learnt and recommendations

The small reservoir water allocation strategy as described above was applied to to the Siwaze sub-catchment of the Limpopo Basin, it was found that:

- Vegetables, green maize, and grass had higher physical water productivity compared to other products
- Livestock, vegetables and bricks, in that order, had the highest monetary water productivity
- On an aggregate basis under the zero scenario, the top three returns were from fishing followed by domestic uses and crops
- In the second scenario, the top two returns (in terms of monetary water productivity) were from livestock followed by industrial use
- Under the third scenario, the best returns to water are obtained by allocating water to agriculture then domestic and industrial uses
- Under sectoral re-allocation, livestock followed by industry offer the top two returns.

Livelihoods could be improved and poverty reduced in rural communities if a water allocation strategy were to be introduced that recognizes individual-use water productivities and social values. In the Siwaze example, reallocation of water based on water productivities and social values at sectoral and sub-sectoral levels led to an increase in incomes of up to 350%. Strategy formulation, however, must incorporate input from various stakeholders. It is necessary to consult with a wide spectrum of stakeholders in order to get the most representative values and priorities. It is recommended that this tool be tested over a wider range of situations and over a longer time period.

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