Increasing the Productivity of Water at Basin Scale in the Olifants River Basin, South Africa

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Abstract

As many other South African basins, the Olifants River basin is becoming more and more water stressed. One crucial goal of the recent water legislation is to achieve an equitable sharing of scarce water between users by introducing basin management and new water rights. But it is unlikely that available water resources in the basin will meet water allocations to new users, in particular emerging and small-scale farmers who have had and still have poor access to adequate water. The key issue to address is whether there are ways to increase water availability to these small farmers. The main hypothesis presented in this paper is that there are opportunities to re-allocate water from already acknowledged users to small-scale agriculture by increasing productivity of water. Using water accounting techniques and performance analysis, it is proposed to evaluate where and how much water can be saved and then investigate the technical and institutional paths towards water re-allocations in a sustainable way.

Introduction

Increasing the efficient use of water resources seems to be a high priority challenge for South Africa, in other to avoid future conflicts and economic growth limitations. It is considered that the country will face "absolute water scarcity" by the year 2025 (IWMI, 2000). Demand is projected to be higher than supply in the future to such an extent that the limit of water availability will be reached (Conley). Reform in the water sector is ambitious as it plans to achieve simultaneously, social equity, ecological sustainability and economic prosperity. These goals will not be achieved unless substantial amount of water is saved at the basin level.

The Water Act (1998) aims to develop a national water resources strategy that will provide a framework for protection, use, development, conservation, management, and control of water resources. The new water rights system will aim to give licenses to only more efficient users and therefore feasibility of the reallocation of water needs to be addressed and especially for former disadvantaged farmers. Economic prosperity, which can only be achieved through efficient use of water, has severe implications for equity

The Olifants river basin

Basin description

The Olifants river basin covers an area of 54 600 km^3. The population in the basin is about 3.4 million. Landuse in the basin includes irrigated agriculture, livestock, mining, and urban. The main irrigated crop is maize (Stimie et al., 2000). Irrigated

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agriculture was the largest water user in the late eighties, consuming about 500 million m^3 of water per year. Although this figure has declined over the years, irrigation is still the major water user in the basin.

Mean annual rainfall in the basin is 631 mm, and high evaporation occurs in the warm areas. The basin has 2,500 dams of which 90% are smaller than 20 000 m^3. There are 30 large dams (dams larger than 2 million m^3) and a total storage of 1,100 million m^3. The estimated usage in the basin in 1987 was 1,060 million m^3 /a, including evaporation. The available mean annual runoff is 1,235 million m^3 per year. The ecological needs are about 200 million m^3 per year. There are about 200 mines in the basin which use about 90 million m^3 /a.

A relatively small amount of water is also exported from the basin, e.g. downstream from Arabie dam to Pietersburg for domestic use.

The basin can be divided into 5 homogeneous regions: the highveld region constituting the Upper Olifants; the irrigated region in the Upper Middle Olifants; the Lower Middle Olifants where the former homelands are; the Steelpoort subcatchment; and the lowveld region, between confluence's of the Steelpoort and Letaba Rivers with the Olifants River (Figure 1). The water use at 1987 levels in the five regions according to the 1991 Olifants River basin study is given in Table 1.

Table 1: Approximate water use in 1987 in the 5 regions of the Olifants River basin in million m^3 per year

	Regions in Basin					
Type of use	**Upper**	**Upper Middle**	**Lower Middle**	**Steelpoort (Mountain)**	**Lowveld**	**Total**
Irrigation	63	220	60	82	91	516
Domestic & Industrial	42	15	8	6	21	92
Stock watering	11	6	5	4	-	26
Forests	10	5	-	8	35	58
Mines	12	1	4	5	38	60
TOTAL	**138**	**247**	**77**	**105**	**185**	**752**

The Olifants River flows through the Kruger National Park before entering in Mozambique. In some years there is no flow at all into the park during the dry season. Future projection of development in the catchment leads to think that these water shortages will occur most often. A recent technical assessment of the Olifants basin (BKS, 2000) shows that the water resources in the 60 % of the catchment will be fully utilized in 2010.

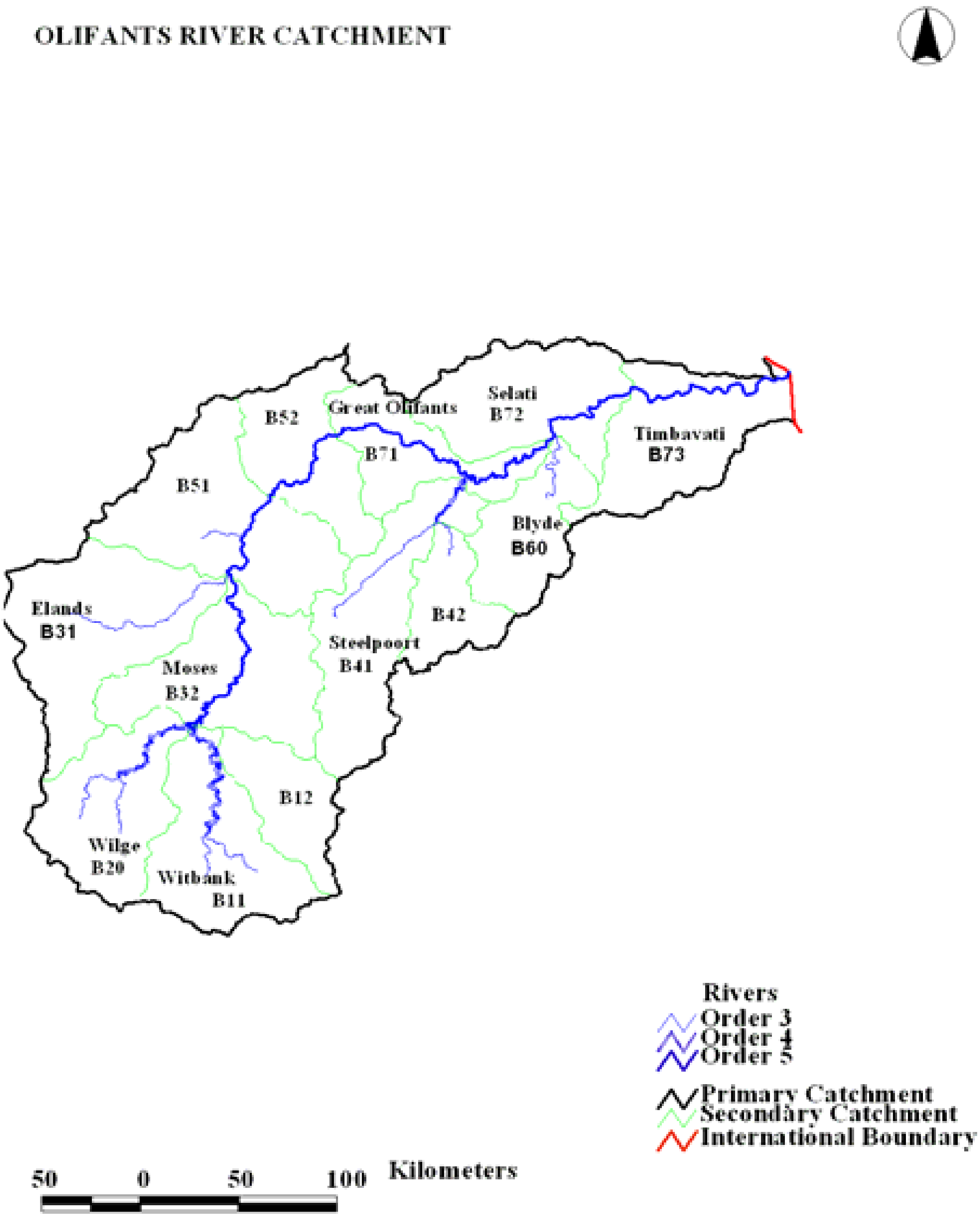

Figure 1. The Olifants river basin.

Water Scarcity

A simple comparison of storage and usage in the basin leads to the conclusion that the basin is not water short. However, seasonal and spatial shortages often occur. For example, the Steelpoort and Blyde Rivers that contribute 42% of the mean annual run off of the Olifants River only join the Olifants River at the lower end of the basin. In the upper Olifants area water has to be imported for the coal fired power stations. Because of its polluting potential, this water may only be released according to a permit after use. Power stations require about 208 million m^3 annually.

Water demand and equity

From a river basin study carried out in 1991 by DWAF some of the issues that emerged were availability of water in relation to demand, and the impact of land use on water resources. These two issues are still of concern, and the National Water Act (NWA, 1998) has provided direction to address them, possibly through the establishment of Water Management Areas. The NWA, albeit being ambitious, promises equitable sharing of water resources and leans towards addressing inequities of the past. But this notion of equity, clearly expressed in the law, is difficult to address (Levine, 1989). Large areas of this basin lie in the former homelands where the population is still extremely poor (Merrey, 2000). These areas stand to benefit if water resources are shared more equitably. As stated earlier, allocating water only to the most efficient uses has severe implications on equity

Irrigation and small-scale farming

In the Olifants basin irrigated agriculture covers approximately 100,000 ha and is the main user of water (around 50 %), that is about 510million m 3 /year. (Stimie, 2000). This figure is expected to increase to about 593 million m^3/annum in 2010, an increase of about 9% in the irrigation sector (BKS, 2000). The irrigation sector consists of large scale and small-scale irrigation. The large-scale sector is very well established, and it is possible to estimate water use by this sector. By contrast the small-scale sector, also referred to as the emerging farmers, is not as well organized. There is a general paucity of data regarding both the area under small-scale use and the total water consumption by this sector. But, despite this lack of information, there is a potential for future irrigation by the emerging farmers (BKS, 2000).

Regarding the irrigated schemes, experts (UNIN, 2000) conclude a high level of heterogeneity among farmers. This heterogeneity acts as a brake upon increasing the recognized low efficiency of irrigation. Efficiencies of less than 50 % are common (DWAF/ARC). More recent analyses (e.g. van Koppen, 2000) have highlighted competition between small and large-scale farmers. For example at the Boschkloof scheme where some of the farmers are interested in expanding the irrigated areas, and have temporary plots of 10 ha instead of the 1 ha plots they currently own. Such an expansion would entail increased water use, an allocation that may not be available.

In a recent paper Svendsen and Merrey (2000) pointed out that an important strategic objective of the National Department of Agriculture is to provide pathways for mobility from the small holder sector to the commercial sector. But an important condition for such successful transition is that there exist opportunities for expansion of operations, with appropriate access to increasing quantities of land, water, capital, purchased inputs, information, and markets.

The institutional arrangements in this basin are detailed in Stimie et al. (2000). They explain that the Department of Water Affairs and Forestry has initiated a process to establish bodies in the form of Water User Associations under Catchment Management Agencies to regulate water use. This process seems functionally applicable to commercial irrigation, industry, mining, and forested areas. However, it may bypass the large number of small holders currently making use of resources in the basin (Svendsen and Merrey, 2000).

The Knowledge Gap

The other problem while addressing equity issues is that outside of former government schemes, there is limited knowledge of the area irrigated by emerging farmers in the basin (Stimie *et al*, 2000). In a recent hydromapping exercise for the Steelpoort Basin, a sub-basin of the Olifants, Stimie *et al*. (2000) found that previous government studies only refer to irrigation in what was in 1991 the Republic of South Africa. Irrigation in former self-governing territory of Lebowa, for example, was not mentioned in the reports. In addition, there are other several small-scale irrigation projects, vegetable gardens, and many other unidentified small-scale irrigation plots. It therefore remains difficult to estimate the water use of community irrigation in the basin. Merrey (2000) explains that the current extent of small holder irrigation in several provinces of South Africa is not known with certainty. As a result a reliable database of individual scheme and community characteristics is not available.

Hypothesis

The National Water Act, NWA, (1998) clearly defines the government's responsibility for both equitable allocation of water for beneficial use and redistribution of water (NWA, 1998). Among solutions put forward by the Department of Water Affairs and Forestry in its water conservation strategy (DWAF, 2000), re-allocation of water to more efficient users is cited. While water *conservation* concentrates its efforts on optimizing efficiency without questioning the uses themselves, *reallocation* implies shifting water from those uses and sectors that show a low value added per unit of water consumed to those of primary social need or with higher water productivity. (Libiszewski, 1995).

If productivity of water in all sectors in the Olifants basin is improved, it will be possible to make water available for uses that are currently without, or those with inadequate allocation through reallocation of water from already established legal users. Expansion, for example of smallholder irrigation, may not require extra water. Only reallocation from one sector to another will be required.

Objectives

In exploring the feasibility of reallocation a wide range of issues including technical, socio-political, social, economic and land tenure have to be addressed. Limiting ourselves to technical considerations only, this paper presents the IWMI water accounting methodology, and how it can be used to identify where water can be saved in the Olifants River basin through evaluation of actual productivity of water for irrigation and other uses.

Methodology

Water accounting

The International Water Management Institute (IWMI) recently developed a water accounting methodology (Molden, 1997). The approach is to construct a water balance for an identified basin in order to track water depletion within the basin. The components for water accounting at the basin level are described below.

Gross Inflow

Gross inflow is defined as the sum of precipitation and surface sources from outside basin.

Storage Change

Storage change is the sum of reservoir storage change and groundwater storage change. It is assumed to be zero for a long period.

Net inflow

Net inflow is the sum of gross inflow and storage change in the basin.

Available Water

Available water represents the amount of water available for use at the basin, service or use levels without unsustainable withdrawals from storage. For the Olifants basin, this would be the sum of precipitation, inflow from surface and subsurface sources, groundwater storage change provided without groundwater over exploitations, and water from transbasin diversions.

Outflow

The outflow is the discharge at the outlet of the basin. Outflow has two components, committed and uncommitted outflow. *Committed outflow* is the part of the outflow that is required for uses outside of the basin. *Uncommitted outflow* is water that is neither depleted nor committed outflow. It can be allocated to other uses downstream.

Depletion

Water depletion is defined as the use or removal of water from the basin that renders it unavailable for further use. Two types of depletion are considered: *process depletion* and *non-process depletion, where:*

- *Process depletion* is the amount of water depleted to produce an intended good. For examples evaporation of crops and uses for domestic and industrial purposes.
- *Non process depletion* is the amount of water depleted but not for a human designated purpose (for example transpiration from trees and shrubs, evaporation from fallow lands and reservoirs). It is classified into two categories: beneficial and non-beneficial. Reservoir evaporation is non-beneficial non-process depletion, but water transpired by vegetation considered important for environment could be classified as beneficial non-process depletion.

Non depletive use is the use of water that does not cause any depletion, for example fisheries.

Indicators

The following indicators were defined in the water accounting methodology.

(1) DF_{gross} = Depleted/Gross inflow

(2) $DF_{available}$ = Depleted/Available

(3) PF_{gross} = Process Depletion/Gross inflow

(4) $PF_{depleted}$ = Process Depletion/Depleted

(5) $PF_{available}$ = Process Depletion/Available

This method has been applied in basins in Egypt, Sri Lanka, and China, providing an overview of where water can be saved and where water productivity can be increased.

Preliminary water accounting for the entire Olifants Basin was done by Blank et al. (1999). Inflow into the basin consists of precipitation and surface water supplied from outside the basin. One of the main results of the preliminary study is that the large proportion of rainfall is attributed to the beneficial non-process depletion, or natural environment uses such as evapotranpiration of natural vegetation. Irrigation is the larger depletive user in the basin, especially the Upper Middle region (Blank et al., 1999). The basin scale analysis did not adequately reflect temporal and spatial variations in the basin. Further analyses in individual sub-basins and at different time and spatial scales are required in order to reflect this variability that is characteristic of the basin. For the analysis in this paper, the Steelpoort sub-basin is considered.

The expected results of the first stage (water accounting) will be to see the distribution of the water by resources (rain, surface water, groundwater) and by sectoral uses of these water resource. We will have then a good understanding of the major constraints and the main areas where water is wasted or sub-optimally used.

Steelpoort sub-basin

The Steelpoort basin covers 7 139 km^2 and represents 13 % of the total area of the Olifants basin. Its topography can be classified as undulating highveld country, between 1200 and 1800 m above sea level. Average temperature varies between 19 and 22°C in summer and between 13 and 19°C. in winter. But the climate is less dry with precipitation ranging between 630 and 1000 mm. The average rainfall is 750 mm. In the South African context the potential of the aquifer is rather good (from moderate to very high depending of the areas). The total storage capacity in terms of dams is 16.5 million m^3. In the South African context the basin is densely populated with 117 persons/km2.

It seems that there’s already locally a real competition between mining and irrigation in the basin even if the irrigated area has declined over the past 10 years (Stimie et al., 2000). This competition is very apparent during the winter months.

Surface water

The Steelpoort River is one of the main tributaries of the Olifants River. The Olifants River basin study 1991 estimates the runoff in the basin at about 380 million m^3/a (Olifants study 1991).

There is one water transfer scheme in the Steelpoort basin. It transfers water for irrigation to the Blyde River basin, another sub-basin of the Olifants River basin. A 5.5-km long canal with a capacity of 283 l/s conveys water from the Spekboom River to a farm next to the Ohrigstad River. (Olifants basin study, 1991).

Groundwater

The Olifants basin study of 1991 estimates the mean annual recharge of the aquifers in the Steelpoort at 296 million m^3/a.

Water use in the Steelpoort sub-basin

The main water uses in the basin are irrigation, mining, industry, domestic, and environmental. The water requirements of these sectors are described briefly below.

Irrigation

The irrigation sector consists of large and small-scale irrigation. The characteristics of the two sectors especially regarding organization are similar to that of the Olifants basin described earlier.

<u>Large scale Irrigation</u>

Irrigated area in the Steelpoort basin has declined from approximately 12000 ha in 1988 to approximately 8206 ha in 1997. The DWAF study estimated the water use for the irrigation sector in the basin at 85 million m^3/a in 1997. It projected a growth of irrigated acreage to 13818 ha in 2000, with a total water use of 91.2 Mm^3/a that was not realized. The Water Affairs study 1999 assumes that the future irrigation water demand will remain more or less on the 1997 level and bases this assumption on the general opinion of irrigation farmers.

<u>Small-scale irrigation</u>

Due to the previous system of governance it seems to have been difficult to get a reliable estimate of the area under community irrigation. For example the Olifants basin study 1991 only refers to irrigation in what was in 1991 the Republic of South Africa. This includes the 924ha Tswelopele irrigation scheme and the other small-scale irrigation projects in this area. It may not be indisputable that there are many other unidentified small-scale irrigation schemes in the province.

Mines and quarries

A high concentration of mines is found in the Steelpoort basin. There are chrome, granite, magnesium, alluvial gold, coal, vanadium and platinum mines, as well as mines for construction materials like brick, stone and sand. In all there are about 50 mines in the basin. It has been estimated that the total mining water consumption is about 9.6 million.

Industrial and domestic use
The industrial and domestic (towns and settlements) uses are compounded because the data available does not separate the two. Combined domestic and industrial demand is estimated at 6 million m^3 for in the year 2000.

Forestry
The forested area in the was 8055ha in 1985 and water consumption was 6.9 million m^3/a. Based on projections, the current forested area in 2000 is about 13655ha, with a water consumption of 11.6 million m^3/a. This area is projected to increase to 16055ha in 2010 with a water consumption of about 13.7 million m^3/a.

Environment
No specific water reservations have been made for the environment in the Steelpoort basin up to now. At present there is a process going on that calculates the Reserve for several rivers. It is defined in the National Water Act of 1998 (NWA) as the portion of every significant water resource (watercourse, surface water, estuary or aquifer) to satisfy basic human needs and to protect aquatic ecosystems. The NWA requests that the Reserve must be maintained in all significant rivers in the country. Experience with other east flowing rivers in the Northern Province and Mpumalanga indicates that the Ecological Reserve amounts to between 15 and 25% of the natural mean annual runoff MAR (Water Affairs, 1999). For the Steelpoort this would come down to a volume roughly between 55 million m^3/a and 100 million m^3/a.

Aquaculture and stockwater
The water use by this sector is currently 4.6 million m^3.

Application of the method in the Steelpoort basin

The following figures are only given only as an example on what will be done. They must be refined and can't be cited as is.

Details of calculation and first analysis

Composition of inflow

Gross inflow into the Steelpoort basin comes only from precipitation. There are no transbasin diversions into this basin. An average mean annual rainfall of 750 mm was assumed over the basin area of 7,139 km^2. The net inflow is here equal to gross inflow. The storage change in the catchment over longer time periods storage is assumed to be zero. However, it would be necessary to study both seasonal and annual variations of storage, for there's a relatively good artificial storage capacity in the basin (20 millions cubic meters).

Uncommitted outflow

As a first approximation, surface outflow is obtained by substracting depletive uses directly extracted from the river (that is irrigation, domestic/industrial, mining) from Mean Annual Runoff under natural conditions. The latter is given by BKS. It could be also useful to study the evolution in the time of the outflow from the basin in order to see the potential influence of agriculture and other sectors on water demand.

Committed outflow
Stimie (2000) considers that the environment needs (ecological reserve) could be estimated between 55 and 100 million m3/a. The higher estimation is used here.

Depletive use
To evaluate depletive use of water we used figures from different sources (Blank et al., 2000, Stimie et al., 2000, and BKS, 2000). In the case of conflicting figures, the higher values were used in the analysis. Non-irrigated crop evapotranpiration was given using a proportion of the figure given by Blank for the whole basin. It is clear that the use of remote sensing will be of interest at this stage.

Non-process depletion
Evapotranspiration from natural vegetation is estimated as a proportion of that of the entire Olifants basin. Blank et al. (1999) estimated the evapotranspiration of the Olifants basin to be 14,000 x 10^6 m^3. This component needs further verification, possibly by use of remote sensing techniques. Evaporation from dams was estimated considering that the capacity of storage is only 2 % of the whole basin because there are no important dams in this sub-basin.

Results

The tentative results of the water accounting methodology are shown in Table 2.

Table 2. Steelpoort sub-basin water accounting.

	Total (million m^3)	**Components**
Gross inflow	5,354	
Precipitation		5,354
Surface sources from outside basin		0
Subsurface sources from outside basin		0
Storage change	0	
Surface		0
Groundwater		0
Net inflow	5,354	
Uncommited Outflow	222	
Surface outflow from river		222
Surface outflow from drains		0
Subsurface outflow		0
Committed Outflow	101	
Environment		100
Diversion out of the basin		1
Outflow	323	
Available water	5,253	
Depletive uses		
Process depletion	290	
Irrigated crop evapotranspiration		85.2
Non-irrigated crop evapotranspiration		182
Mining		9.6
Domestic (urban/industrial)		6
Domestic (non urban)		2.6
Livestock watering		4.6
Non-Process depletion		
Beneficial depletion	8	
Forest evapotranspiration		8
Non-Beneficial depletion	4,741	
Evapotranspiration from natural vegetation		1,820
Evapotranspiration from bare ground		2,918
Free water surface evaporation		3
Total depletion	5,031	

Table 3. Water accounting indicators

Depleted Fraction	
of Gross inflow	0.94
of Available Water	0.95
Process Fraction	
of Gross inflow	0.05
of Depleted Water	0.06
of Available Water	0.06

The depleted fraction (DF_{gross}) of gross inflow is 0.94 and depleted fraction of available water is 0.95, indications that water resources in the basin are almost fully utilized. For the whole Olifants basin the first analysis (Blank et al., 2000) the depleted fraction was 1, an indication that water in the basin is fully utilized.

Process depletion accounts for a small proportion of water resources in the basin. Of this amount, agricultural use accounts for more than 90% of the total use. The mining and domestic sectors account for less than 10 % of the water use.

Due to lack of data pertaining to irrigated area and water use in the smallholder sector, this analysis could not separate the process fraction for this sector.

Concluding remarks

Of all the water entering the basin, only 5 percent is depleted by process uses (municipal, industrial, and agricultural). Of this process depletion, 90% is by agriculture. From a management perspective, this would be the most logical starting point for water savings in the basin. However, as the remaining 95% of inflow into the basin is consumed by non-process uses much of which has little or no benefit, such as evaporation from bare ground, the focus for saving water in the basin needs to be shifted to these low productive uses. For example, if only two percent of the total non-process depletion is captured or saved, it translates into nearly 100 million m^3, a figure that is greater than the current irrigation consumption for the basin. The issue to be addressed therefore is whether or not this water can be harnessed for agricultural and other beneficial purposes.

The results presented here are a reflection of mean conditions in a basin that has both spatial and temporal variation. Water accounting analyses of both wet and dry conditions are necessary in order to reflect reality. Only then can more realistic assessments of water savings in the basin be made. It would be possible to clearly identify where water savings can be made, for example those sectors that consume the bulk of the process water. It would also then be possible to identify where inequities in water allocation exist and subsequently address possible reallocations from high to low depletive uses.

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