International Journal of Water Resources and Arid Environments 6(1): 41-49, 2017
ISSN 2079-7079

Water Accounting Concepts for Enhancing Water Productivity in the Irrigated Agriculture at Field and Basin Levels

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Abstract: The water accounting methodology provides a terminology to assess water use and productivity at the irrigated agriculture and basin levels in Egypt. At farm level, results show that net inflow, during the three growing seasons, in the crops sequences' including intercropping faba bean with sugar beet- tomatoes with maize- clover is30400m^{3}ha^{-1}, which are lower than that of the corresponding figures (37650m^3 ha^{-1}) in the solid crops sequence including wheat–rice-wheat. However, total depletion in the intercropping crops sequences higher 21820m^{3}ha^{-1} than that of corresponding figures (16200 m^3 ha^{-1}) in the solid crops sequences. Average of the gross and net depletion fractions (DF) are 0.78 and 0.70% higher in the intercropping crops sequence compared with solid one. Net inflow of rice was 15200 m^3 ha^{-1}greater following tomatoes intercropped with maize and faba bean intercropped with sugar beet than wheat in the solid crops sequence. Total outflow was lower in the intercropping crops sequence than sole crops sequence (7750 vs.13230 m^{3}ha^{-1}). The intercropping system has the highest productivity, about US$17183 ha^{-1} compared with US$3433 ha^{-1} for a sole one. At basin level, most of the water available for use is depleted beneficially indicating good performance because the depleted fraction of net and gross inflows for the basin is 0.74 and 0.7, the process fraction of depleted water is 0.92 and 0.93, the process fraction of available water is 0.83 and 0.81, the beneficial utilization of basin water resources was 90% and 87%, respectively in year 1989-1990 and 2012-2013. The gross value of production of the Nile system in 1989- 90 and 2012-2013 was reported at US$6.5 and US$35.3 billion. The water productivity per unit of water depleted by irrigation, per unit of water available to irrigation and per unit in flow increased four times from 1989-90 to 2012-13 although water scarcity, expand irrigated areas, growing growth population and a comprehensive sustainability development in Egypt during this period. Therefore, water accounting concepts and performance indicators are characterize to use at field and basin levels. For evaluation and performance assessment, they provides a good glance, gives some key information for planning that is useful in developing a coherent economic strategies for water savings and increasing water productivity, improves integrated water resources management is widely accepted as a means to achieve sustainable and equitable increases in productive use of water resources and provides tools to help us achieve better integration of irrigated agriculture within the broader context of water use in basins.

Key words: Water accounting • Performance indicators • Water productivity • Crop sequences • Intercropping

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INTRODUCTION

The term water productivity is used only to indicate the amount or value of product over volume or value of water depleted. The value of the product could be expressed in different terms (grain, biomass, money). Another approach considers differences in the nutritional values of different crops, or that the same quantity of one crop feeds more people than the same quantity of another crop. There is no specified definition of productivity and the value considered could depend on the focus as well as the availability of data. However, water productivity defined as kilogram per drop of water is a useful concept when comparing the productivity of water in different parts of the same system or river basin as well as when comparing the productivity of water in agriculture with

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other possible uses of water. Water productivity associated with evapotranspiration (WP_{ET}) show considerable variation, e.g. wheat varied from 0.6to 1.9 kgm^{-3}, maize from 1.2 to 2.3 kgm^{-3}, rice from 0.5to 1.1 kgm^{-3}, forage sorghum from 7 to 8 $kgm^{-3}$and potato tubers from 6.2 to 11.6 kgm^{-3}. Data on field level water productivity per unit of water applied (WP_{irrig}) are lower than WP_{ET} and vary over an even wider range. For example, grain WP_{irrig} for rice varied from 0.05 to 0.6 kg m^{-3}, for sorghum from 0.05 to 0.3kg m^{-3} and for maize from 0.2 to0.8 kg m^{-3}. The variability occurs because data were collected in different environments and under different crop management conditions and these affected the yield and the amount of water supplied [1]. Water accounting is a procedure for analyzing the uses, depletion and productivity of water in the field and water basin context. It is a supporting methodology useful in assessing effects of field level agricultural interventions in the context of water basins, allocation of water among users in a water basin and the performance of irrigated agriculture [2] and [3]. The success of water accounting is such that it has become an integral part of environmental water accounts in many countries, such as Egypt [3], Australia [4] and by the United Nations through the System of Environmental-Economic Accounting for Water (SEEA-Water).

The first water accounting exercises focused on the physical resource, trying to describe the status of water resource use and consequences of water resources related actions [2]. Procedures of water accounting were quickly enriched by linking water use to relevant productivity indicators [5] in order to provide water managers with strategic information on water allocation in the region. This information can be used to design strategies of water saving, to examine the potential for water reallocation, to identify water using activities that require more detailed analysis.

When water is becoming a limiting factor for agriculture, a systems performance indicator rather than a crop performance indicator is needed to determine the optimum crop rotation, water allocation among those crops and ultimate net return of the cropping system should be [3]. Raising water productivity at field level could be achieved through improved practices at field level relate to changes in, soil, water and crop management. They include: selecting appropriate crops structure pattern, crop intercropping and high yielding - short duration cultivars; planting methods (e.g. on raised beds); minimum tillage; timely irrigation to synchronize water application with the most sensitive growing periods; nutrient management; modern irrigation systems; and improved drainage for water table control.

Changing the focus from the field level to river basin level changes the relative importance of the various water management processes. At the larger scale, the effect of agriculture on other water users, the environment and human health becomes at least as important as production issues. Options for improving water productivity at the agro-ecological or river-basin level are found in: better land use planning; better use of medium term weather forecasts; improved irrigation scheduling to account for rainfall variability; and conjunctive management of various sources of water, including water of poorer quality where appropriate. Therefore, integrating germplasm improvement and resource management is very significant in the enhancement of water productivity at the field scale and above.

The highest economic water productivity in agriculture may be not matching with the political desire for national food security. In most cases, the economic water productivity in growing staple crops is less than that for growing vegetables or flowers for export markets. Crop substitution involves switching high water consuming crops for less water consuming crops or for crops with higher economic productivity.

Indicators of Water Productivity: Water productivity is a very strong measure that can be applied at different scales to match with the needs of different stakeholders. This is achieved by defining the inputs of water and outputs in units appropriate to the users' indicator needs.

Water Productivity (WP) can either be related to the physical mass of production or the economic value of produce per unit volume of water. Water productivity can be measured for gross or net inflow, depleted water, process depleted water, or available water. Water productivity has a broader basis than water use efficiency [3] , [5] and [6], which relates production of mass to process depletion (evapotranspiration or transpiration for irrigated agriculture). Here it is defined in terms of net inflow, depleted water and process depletion [6].

$$WP_{\text{inflow}} = \frac{\text{Productivity}}{\text{Net Inflow}}$$

$$WP_{\text{depletion}} = \frac{\text{Productivity}}{\text{Depletion}}$$

$$WP_{\text{process}} = \frac{\text{Productivity}}{\text{Process depletion}}$$

Depleted Fraction (DF) is that part of the inflow that is depleted by both process and non-process uses. Depleted fraction can be defined in terms of net, gross and available water.

Table 1: Field level water accounts in North Delta: intercropping crop sequences

	Sugar beet/ Faba bean	Maize/ Tomatoes	Clover (four cuttings)	Three Seasons
Inflow				
Irrigation (m^3 ha^{-1})	7520	13170	8210	28900
Effective rainfall (m^3 ha^{-1})	500	0.0	500	1000
Subsurface (m^3 ha^{-1})	0.0	0.0	0.0	
Lateral seepage flows (m^3 ha^{-1})	0.0	0.0	0.0	
Gross inflow (m^3 ha^{-1})	8020	13170	8710	29900
Storage change (m^3 ha^{-1})	160	170	170	500
Net inflow (m^3 ha^{-1})	8180	13340	8880	30400
Depletion				
ET (process and no process) (m^3 ha^{-1})	6010	10950	4860	
Total depletion (m^3 ha^{-1})	6010	10950	4860	21820
Outflow				
Surface runoff (m^3 ha^{-1})	0.0	0.0	0.0	
Deep percolation (m^3 ha^{-1})	1510	2220	4020	
Total outflow	1510	2220	4020	7750
Performance indicators				
Depleted fraction (gross)	0.95	0.83	0.56	0.78
Depleted fraction (net)	0.73	0.82	0.54	0.70
Production (kg ha^{-1})	64774	52992	15000	
Production per net flow (kg m^{-3})	7.9	3.9	16.9	
Production total depletion (kg m^{-3})	10.8	4.8	30.9	
Total Production in USD	3788	11355	2040	17183

Table 2: Field level water accounts in North Delta: solid crop sequences

	Wheat	Rice	Wheat	Three Seasons
Inflow				
Irrigation (m^3 ha^{-1})	5710	15200	5710	36140
Effective rainfall (m^3 ha^{-1})	500	0.0	500	1000
Subsurface (m^3 ha^{-1})	0.0	0.0	0.0	
Lateral seepage flows (m^3 ha^{-1})	0.0	0.0	0.0	
Gross inflow (m^3 ha^{-1})	6210	15200	6210	37140
Storage change (m^3 ha^{-1})	170	0.0	170	510
Net inflow (m^3 ha^{-1})	6380	15200	6380	37650
Depletion				
ET (process and no process) (m^3 ha^{-1})	3900	8400	3900	
Total depletion (m^3 ha^{-1})	3900	8400	3900	16200
Outflow				
Surface runoff (m^3 ha^{-1})	0.0	0.0	0.0	
Deep percolation (m^3 ha^{-1})	1810	6800	1810	13230
Total outflow	1810	6800	1810	13230
Performance indicators				
Depleted fraction (gross)	0.63	0.55	0.63	0.60
Depleted fraction (net)	0.61	0.55	0.61	0.59
Production (kg ha^{-1})	7200	9840	6350	
Production per net flow (kg m^{-3})	1.1	0.65	1.0	
Production total depletion (kg m^{-3})	1.8	1.2	1.6	
Total Production in USD	1143	1290	1000	3433

$$DF_{net} = \frac{\text{Depletion}}{\text{Net inflow}}$$

$$DF_{gross} = \frac{\text{Depletion}}{\text{Gross inflow}}$$

$$DF_{available} = \frac{\text{Depletion}}{\text{Available water}}$$

Applying Water Accounting to Water Productivity at Farm Level: Results of agricultural trials based on field experiments carried out in farmers' farms of the command area in North Delta in Egypt are reported in water accounting (Tables 1 and 2). In this area, the water duty falls short of potential crop requirements as water is scarce relative to land. In response, farmers have a strategy of deficit irrigation, or giving less water than the potential crop requirement, thus giving them the opportunity to irrigate more land.

Yields in intercropping crops sequence were 64.7, 52.9 and 15.000t ha^{-1} for faba bean intercropped with sugar beet, tomatoes intercropped with maize and clover, respectively as shown in Table 1. While yields were reported as 7.2 tons per hectare for wheat, 9.8tons per hectare for rice, 6.3 tons per hectare for wheat in sole crops sequence (Table 1). All of the irrigation and rainfall applied is depleted leading to a depleted fraction gross of 0.95, 0.83 and 0.56, respectively, for faba bean intercropped with sugar beet, tomatoes intercropped with maize and clover (Table1) and they were 0.63, 0.55 and 0.63 for wheat, rice and wheat to a depleted fraction gross (Table 2), The depleted fraction net of 0.73, 0.82 and 0.54 for faba bean intercropped with sugar beet, tomatoes intercropped with maize and clover, respectively as shown in Table1 and they were 0.61, 0.55 and 0.61, respectively for wheat, rice and wheat as presented in Table 2.

On a two annual basis, the depleted fraction net is quite middle at 0.70 in the intercropping system and 0.59 in solid crops sequence, due to a high amount of evapotranspiration and small amount of rainfall in winter season. The depletion fraction of net inflow was, with an average of 0.70 lower than 1.0 as a result of the practice of deficit irrigation used. In this case, evapotranspiration is reported so that productivity per total depletion and per process depletion can be calculated.

The water application by crop for winter cropping is $7520m^3$ ha^{-1} for faba bean intercropped with sugar beet and $571m^3$ $ha^{-1}$for clover. For summer cropping, water application, as an average for the sample farms, is $13170m^3$ ha^{-1} for tomatoes intercropped with maize, $15200m^3$ ha^{-1} for rice.

Cropping systems evaluated were intercropping and solid crops sequence. Net inflow and depletion in intercropping system was 30400 m^3 ha^{-1}, and $21820m^3$ ha^{-1}, respectively, lower than solid one which was $37140m^3$ ha^{-1}, $37650m^3$ ha^{-1}, respectively; however, the depleted fraction for gross and net increased by 30% and 19% compared with solid system.

The intercropping crops sequence had the highest production, about US$17183 ha^{-1} compared with US$3433 ha^{-1} for a solid cropping system.

Water productivity according to the defined in technical terms used, is the highest for faba bean intercropped with sugar beet and clover, compared to wheat in winter cropping and rice compared to tomatoes intercropped with maize in summer cropping.

Seasonal irrigation water use efficiency was highest in crops sequence of intercropping and the current status of on-farm water use efficiency of wheat under specific farm conditions in the Kafr El-Sheikh province, northern delta, Egypt, where the recent use of irrigation deficit has been expanded to increase wheat production in areas through intercropping. The resulting indicators of on-farm water use efficiency are very useful in guiding policies toward improving irrigation efficiency. Improving water use efficiency to sustain and improve intercropping production in Northern Delta, Egypt is vital especially that the country has been classified as irrigation deficit.

It is aimed to compare values of mass of production per unit of water depleted, when comparing similar crops. But when different crops are compared, mass of output is not as meaningful. There is a clear difference between1kg of faba bean intercropped with sugar beet and 1 kg of clover produced per m^3ha^{-1} of water depleted within the same crops sequence of intercropping and between 1 kg of wheat yield and 1kg of rice in sole crops sequence.

This investigation was made to establish a decision tool with user interaction to examine crop rotation and limited water allocations within land allocation constraints to find optimum net economic returns from these combinations. This decision aid is for intended producers with limited water supplies to allocate their seasonal water resource among a different crop. But, it may be used by others interested in decisions concerning allocating limited water to crops. Decisions are intended as a planning tool for crop selection and season allocations of land and water to crop rotations.

In the various crops sequences, price determines profitability. Crops sequence of intercropping consistently provides higher profit than sole crops sequence. One of the objectives of this investigation is to improve the growers' ability to make such investment decisions and to provide them with decision aids irrigator to better manage irrigation based on economics yield.

To get the required amount of water to produce the average yield levels, the estimated crop water balance are used. This is done by calculating the amount of water required for each crop at the mean levels of the independent variables appearing in that water balance. Growers depend on several factors such as proper irrigation methods, good crop rotations and effective marketing to secure the best price for the product.

Enhancing Water Productivity at Plant Level: Options of plant level rely mainly on germplasm improvements, e.g. improving seedling vigor, increasing rooting depth, increasing the harvest index and enhancing photosynthetic efficiency. The most significant improvements in yield stability have usually resulted from breeding programmes to develop an appropriate growing cycle such that the duration of the vegetative and reproductive periods are well matched with the expected water supply or with the absence of crop hazards. Planting, flowering and maturation dates are important in matching the period of maximum crop growth with the time when the saturation vapor pressure deficit is low. The periods of maximum crop growth may be optimized by means of breeding technology. Improved cultivars with a deeper rooting system contribute to drought avoidance and the effective use of water stored in the soil profile. Drought escape and increasing drought tolerance are also significant strategies for enhancing water productivity. Day length-insensitive varieties of short to medium duration (90-120 d) enabled crops, such as wheat, rice and maize varieties developed as part of the green revolution, to increase water productivity by escaping late-season drought that adversely affects flowering and grain development. The modern rice varieties have about a threefold increase in water productivity compared with traditional varieties [8]. Progress in extending these achievements to other crops has been considerable and will probably accelerate following the recent identification of the underlying genes [9]. Genetic engineering, if properly integrated in breeding programmes and applied in a safe manner, can further contribute to the development of drought tolerant varieties and to increasing the water use efficiency.

Applying Water Accounting to Water Productivity, at Basin Level: Water accounts are shown for the Nile River downstream of the High Aswan Dam (HAD) and groundwater in Egypt (Figures1 and 2). Figures used in the accounts are based on water balance studies by [9] for the water year 1989- 90 and the water accounting study by [10]. The information provides a sufficiently adequate profile to characterize water productivity and use of Egypt's Nile River and groundwater. The gross inflow into the Nile system is 55.2 km^3 consisting of 53.7 km^3 of releases from the high Aswan dam plus 1.0 km^3 of precipitation and 0.5 groundwater for the water year 1989-1990 while the gross inflow into the Nile system is 63.2 km^3 consisting of 55.5 km^3 of releases from the high Aswan dam plus 0.9 km^3 of precipitation, 0.1 km^{3}desalination water and 6.7 km^3 groundwater for the water year 2012-2013. It is assumed that over the one year time period there are no storage changes, so gross inflow is equal to net inflow. Major process uses of Nile water are for municipal, industrial, agricultural and navigation uses while the groundwater for agriculture in the Newlands. The total water consumed by crop evapotranspiration is estimated at 34.8and 41.0km^3 for the water year 1989- 90 and 2012-2013, while process consumption by municipal and industrial (M&I) use is estimated at 2.3 km^3. During much of January, when the Nile irrigation system is closed for maintenance, 1.2 km^3 of outflow goes to the Mediterranean Sea because water has been released to the Nile to keep levels high enough to allow navigation. This amount is categorized as beneficial process depletion by navigation. Some water is required to flow out of the Nile basin to the sea for environmental reasons: to drain out salts, to carry out pollutants that would otherwise concentrate in the Nile waters and to maintain fisheries in coastal estuaries. With our present knowledge it is difficult to give an estimate for the volume of outflow required, but there are indicative values [11], [12] and [13]. At first estimate of minimum outflow in the order of 8 km^3 is made here for illustrative purposes, but it is recognized that further research is required to quantify this number.

This minimum outflow requirement is classified as committed water. Subtracting committed water from the net inflow yields a value of 43.9km^{3}and 52.5 km^3 for available water in the water year 1989- 90and 2012-2013, respectively. The majority of the outflow is through the drainage system. Some of this can be considered as water meeting the environmental commitment discussed above. The remainder of the water is considered a non-beneficial drainage outflow. The amount of drainage outflows to the Mediterranean Sea, the northern lakes and the Fayoum Depression was 14.0 km^3. Subtracting 8 km^3 of committed outflow from the drainage outflow yields 5 and 6.0 km^3 leaving the Domain classified as non-beneficial in 1989- 90 and 2012-2013, respectively.

Other non-beneficial depletion occurs as evaporation from fallow land evaporation from free water surfaces and evaporative use by halophytes and other non-agricultural vegetation. Certainly, some of this depletion is beneficial as it leads to the desirable green belt along the Nile. There may be other subsurface outflow into sinks, such as flow from the Nile Delta to the Qatara depression where further research is required [14], but here the value is assumed to be negligible. It was estimated that there was3.2km^3 (non-process evaporative depletion during the time period of interest).

Assume that 1.5 km^3 of this evaporative depletion is non-beneficial. Adding this to the 5 km^3 of non-beneficial drainage outflow yields a total non-beneficial depletion of 6.5 km^3.The beneficial utilization of basin water resources is 90% (the sum of beneficial depletions, 39.6 divided by

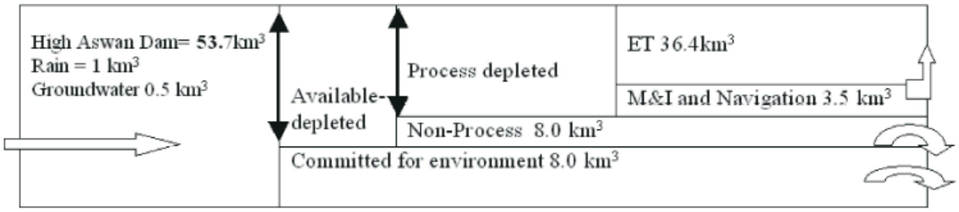

Fig. 1: Water accounting for Egypt's Nile River and groundwater for the agricultural year 1989- 90
Note: *High Aswan Dam. All figures are in km^3. Source of data: [11] ; [10]

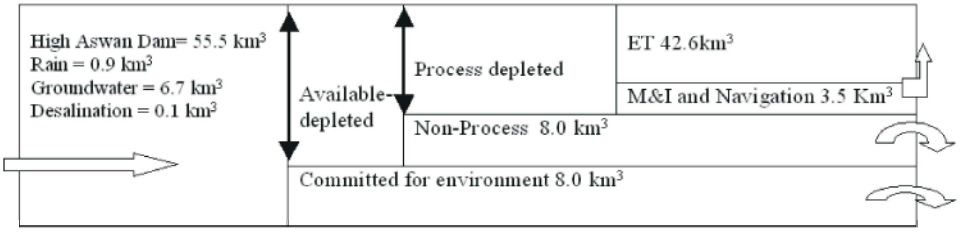

Fig. 2: Water accounting for Egypt's Nile River groundwater for the agricultural year 2012- 2013
Note: *High Aswan Dam. All figures are in km^3

the available water, 43.9) in year 1989-1990. In year 2012-2013, the beneficial utilization of basin water resources is 87% (the sum of beneficial depletions, 45.8 divided by the available water, 52.5). This shows that most of the water available for use is depleted beneficially indicating good performance. The gross value of production of the Nile system in 1989- 90 and 2012-2013was reported at US$6.5 billion and US$35.3 billion [15] and [16]. The productivity of water per unit of water depleted by irrigation, per unit of water available to irrigation and per unit in flow increased four times from 1989-90 to 2012-13 although water scarcity, expand irrigated areas, growing growth population and a comprehensive development in Egypt during this period.

How can productivity of water be increased? First, it is worth noting that there are no utilizable, uncommitted outflows remaining to be tapped. There exists some non-beneficial depletion, the largest component of which is the drainage outflow to the sea in excess of environmental requirements. Cost-effective methods to reduce this drainage outflow and convert it into a process use will result in increases in water productivity. Other opportunities lie in increasing the productivity of water consumed by agricultural crops through activities that increase the value of production per unit ET, such as improved varieties, switching from low- to high-value crops and better agronomic or irrigation practices.

Water accounts are shown for the Nile River downstream of the HAD in Egypt and groundwater (Table 3).

Figures used in the accounts are based on data presented by [17] and estimates presented by [18] for the water year 1989–1990. Many of the figures and estimates require further scrutiny and the example is presented to illustrate the use of water accounting. The inflow is derived almost entirely from releases from the HAD and was recorded at 53.2 km^3 and 55.5 km^3 (cubic kilometers) in 1989-1990 and 2012-2013 respectively.

In the year of 1989-1990, inflow from groundwater was estimated at 0.5 km^3 while it was estimated at 6.7 km^3 in the year of 2012-2913. Rainfall and other sources were negligible during this year. The storage change of the groundwater was assumed to be zero for the annual cycle. Evapotranspiration was estimated at 36.4 km^3 and 42.6 km^3 in 1989-90 and 2012-2913, respectively. Depletive use by municipal and industrial (M&I) uses was estimated at 1.6 km^3 by assuming that 20 percent and 30 percent of diversions are depleted in the Nile Delta and Valley, respectively. There is considerable return flow from M&I back to the Nile water system. Other non-process depletion considered was evaporation from free water surfaces, fallow land and halophytes, estimated at 3.2 km^3. The total depletion of the net inflow of 53.7 km^3 and 62.2 km^3 are 39.6 km^3 and 45.7 km^3 in 1998-1999 and 2012-2013, respectively.

Measured outflows are 1.8 km^3 from the Nile River to the sea and 12.3 km^3 from the drains to the sea. But 1.8 km^3 of this outflow during that particular year was committed to maintain water levels for navigation. Some drainage outflow is required to maintain the environment at present

Table 3: Basin-level accounts of the Nile River downstream of the High Aswan Dam and groundwater in 1989–1990 and 2013-2014 agricultural years

	1998-1990		2013-2014	
Year	Component value (km^3)	Total (km^3)	Component value (km^3)	Total (km^3)
Inflow				
Gross Inflow		53.7		62.2
Surface diversions	53.2		55.5	
Precipitation				
Subsurface sources from outside domain	0.5		6.7	
Surface drainage sources from outside domain				
Storage change		0		0
Surface		0		0
Subsurface		0		0
Net Inflow		53.7		62.2
Depletive use				
Process depletion		36.4		42.6
Evapotranspiration	34.8		41	
Municipal and industrial uses.	1.6		1.6	
Non-process depletion		3.2		3.2
Flows to sinks	Not available		Not available	
Other evaporation (halophytes, free water surface)	3.2		3.2	
Total Depletion		39.6		45.8
Outflow				
Total Outflow		14.1		14.1
Surface outflow from rivers	1.8		1.8	
Surface outflow from drains	12.3		12.3	
Subsurface outflow	0		0	
Committed Water		9.8		9.8
Navigation	1.8		1.8	
Environment maintenance (assumed)	8.0		8.0	
Uncommitted Outflow	14.1–9.8	4.3	14.1- 9.8	4.3
Available Water	53.7 – 9.8	43.9	62.6-9.8	52.5
Available for irrigation	43.9–1.6 (M&I)	42.3	52.5-1.6	50.9
Indicators				
Depleted fraction (gross and net)	39.6/53.7	0.74	45.8/62.2	0.74
Process fraction (depleted)	36.4/39.6	0.92	42.6/45.8	0.93
Process fraction (available)	36.4/43.9	0.83	42.6/52.5	0.81
Gross value of production in US$	6, 450 million		35.304 million	
Productivity per unit of water depleted by irrigation	6.45/36.3	0.19	35.304/42.6	0.83
Productivity per unit of water available to irrigation	6.45/43.9	0.15	35.304/50.9	0.69
Productivity per unit inflow	6.45/53.7	0.12	35.304/62.2	0.57

Notes

1. The depleted fraction for M&I used was assumed to be 30% for the Nile Valley and 20% for the Nile Delta. That is, in the Nile Valley, 30% of the water diverted for M&I use is depleted through evaporative consumption, or through disposal outside the domain.
2. Water committed for downstream uses was estimated at 5% of the mean annual rainfall over the catchment area of the tank or the cascade of interest.
3. Developed a methodology for cascade planning taking into consideration the array of tanks [19]. See also [20], this issue

levels and is roughly estimated here at 8 km^3 based on the need to remove salts and pollutants from the Nile and to maintain freshwater fisheries. With this estimate for environmental commitments, the remaining uncommitted outflow is 4.3 km^3.

The depleted fraction of net and gross inflows for the basin is 0.74 and 0.74 (in this case gross inflow equals net inflow). The process fraction of depleted water is 0.92 and 0.93 the process fraction of available water is 0.83 and 0.81 in 1989-90 and 2012-2013. A very high percentage of both depleted and available water is depleted by the intended processes.

At the basin level, the reasons for increasing water productivity lies in the need to:

- Increase water availability to users and uses that are disadvantaged. For example the need to enhance water productivity in the upper reaches of rivers to decrease water depletion and hence increase water availability in downstream reaches;

- Reduce overall water demand and develop additional water resources such as groundwater exploitation, water transfers from regions with excess water to regions that experience water scarcity and dam development.
- Enhance the total benefits of basin level water through more productive use of the available water resources.
- Rive Nile basin is exploring options for increasing water productivity to achieve different social, economic and environmental goals.

Gains in water productivity are possible by providing more reliable irrigation supplies, e.g. through precision technology and the introduction of on-demand delivery of irrigation supplies. However, an increase in water productivity may or may not result in greater economic or social benefits. The social benefits represent the benefits to society resulting from the water-productivity enhancing interventions. Water in the rural areas of developing countries has many uses. Thus, water is public and a social good, a fact that complicates value calculations. These many uses of water include the production of timber, firewood and fibre; and raising fish and livestock. Non-agricultural uses of water include domestic (drinking and bathing) and environmental uses.

Aiming for the highest economic water productivity in agriculture may not mach with the political desire for national food security. In most cases, the economic water productivity in growing staple crops is less than that for growing vegetables or flowers for export markets. Crop substitution includes switching high water consuming crops for less water consuming crops or for crops with higher economic productivity. The approach provides a strategy for improving and enhancing crop water productivity at the agro-ecological system level as well as at the global level.

Incentives and policies are very important in the adoption of changes from traditional agronomic and cultural practices [21]. But, it is necessary to identify the types of incentives and policies that will do best. Experience with conservation agriculture indicates that the short term interests of the farmers differ from the long term interests of society and that the financial benefits that accrue from changes in cultural practices take a long time to materialize. Of particular importance is the fact that the inconsistent and sometimes contradictory results from studies on the adoption of new practices suggests that the decision making process is highly variable. This decision-making process needs to be understood more fully as it will affect the lead time from study to field practice. This lead time is often unacceptably long considering the urgent character of water scarcity problems.

Conclusions and Actions: The conclusion indicates that, unless national governments and funding agencies make several strategic choices regarding agricultural water management, the agriculture sector will not be in a position to maintain current water allocations for the strategically important food production produced by irrigation, as for national governments, the choices imply1) facilitating and supporting actively the development of improved cultivars as part of the solution for food security in the future2) finding the best options for specific conditions. All lands whether good or poor-fertility can be used for food crops production and other commodities3) adopting natural resource based on policies and institutions that encourage the integration of crop and natural resource management to identify the best location specific options.4) investing in irrigation modernization to make the water delivery system and its management flexible enough to take full advantage of new technologies and crop varieties 5) accepting the fact that when water is scarce, there is no single solution for maintaining food security. All sources of water such as rainwater, canal water, groundwater and wastewater are very significant. Water resources can be developed under the right set of conditions and additional storage capacity and recharge of groundwater resources form part of the long-term solution 6) supporting actively the application of seasonal climate forecasting to establish the best combination of crop and natural resource management for the expected climate conditions.

For donor agencies, the choices for strategic investments in agriculture imply1) accepting agriculture as the sector where the potential for generating water savings through productivity gains is greatest2) linking global goals and global finance with local initiatives and local needs.

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