A Conceptual Framework For Water Use Accounting Based on Water Balance Approach, Crop Rotation And its Economics

Presented by

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Water is likely to be the single most important regional and global resource issue in the coming years. Its “wise” use is becoming an immediate necessity. A criterion that perhaps is generally accepted to evaluate a wise use of water is what is referred to as Water Use Efficiency (WUE).

Due to vastly different types and scales of use, communicating about water between professionals and non-water professionals is quite difficult. Policy decisions are often taken without a clear understanding of consequences on all water users. As competition for a limited supply of water increases, it becomes increasingly important to clearly communicate about how water is being used, and how water resource developments will affect present use patterns

As irrigation is a large consumer of water, developments in irrigation have profound impacts on farm-wide water use and availability. Yet, planning and execution of on-farm irrigation interventions often take place without consideration of other uses.

One of the main reasons for this restricted view of irrigation workers is inadequate means to describe how irrigation water is being used.

On-farm irrigation efficiency is the most commonly used term to describe how well water is being used. But increases in irrigation efficiency do not always coincide with increases in overall basin productivity of water.

The investigation aimed to raise awareness of the seriousness of the water scarcity issues in the region and about the urgent needs and commitments for regular assessment and monitoring of the current status of water-use efficiency in order to identify practical ways of improving water-use efficiency at the farm levels, as well as in the agriculture sector at large, with a focus at participatory approaches.

The investigation tackled issues such as the challenges of water scarcity in agriculture; conceptual issues in water productivity and water-use efficiency, and country-specific experiences with a focus on policies enacted, innovations introduced, good practices, and improving on-farm water use efficiency with the active participation of stakeholders.

The investigation concluded with the expectation that water accounting and provides generic terminologies and procedures approaches in the field in order to improve on-farm water-use efficiency and ensure a positive impact in their respective countries.

The objectives of this paper are to present concepts and definitions necessary to account for water use, depletion, and productivity. The accounting procedures and standards given here are designed to be universally applicable for evaluating water management within and among all sectors.

A goal of this approach is to develop a generic, common language for accounting for uses of water. This conceptual framework provides.

1) The terminology and a procedure that can be applied to describe the present status and consequences of water resources related actions carried out in agriculture and other water sectors;

1) Examples of water accounting at two levels of rotations to test and demonstrate the utility of the methodology; and to determine which scheme can achieve the highest yields compared to the amount of water applied while maximizing profit.

Water Balance Approach

The water accounting methodology is based on a water balance approach. Water balances consider inflows and outflows from field. Water accounting components at field are inflow, storage change, process depletion, non-process depletion and outflow. The inflow components are irrigation application, rainfall, subsurface contributions, and surface seepage flows.

Storage change component is soil moisture change in active root zone. Process depletion components are actual evapotranspiration, outflow components are deep percolation, seepage and surface runoff. Estimates of actual crop consumptive use at a regional scale are questionable.

And drainage outflows are often not measured, as more emphasis has been placed on knowledge of inflows to irrigation systems.

In spite of the limitations, experience has shown that even a gross estimate of water balances for use in water accounting can be quite useful to managers, farmers, and researchers

Water Accounting Definitions

The water accounting is to classify water balance components into water use categories that reflect the consequences of human interventions in the hydrologic cycle. Water accounting integrates water balance information with uses of water as visualized in figure

1. Inflows into the domain are classified into various use categories as defined below.

Gross inflow is the total amount of water flowing into the field from rainfall and surface and subsurface sources.

Net inflow is the gross inflow plus any changes in storage. If water is removed from storage over the time period of interest, net inflow is greater than gross inflow.

If water is added to storage; net inflow is less than gross inflow. Net inflow water is either depleted, or flows out of the field of interest.

plant tissues Process depletion is that amount of water diverted and depleted to produce an intended good. For agriculture, it is water transpired by crops plus that amount incorporated into plant tissues.

Water accounting performance indicators are presented in the form of fractions, and in terms of productivity of water.

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.

- $DF_{nt} = \dfrac{Depletion}{NetFlow}$

- $DF_{gross} = \dfrac{Depletion}{Gros\ \sin\ flow}$

Productivity of Water (PW) can either be related to the physical mass of production or the economic value of produce per unit volume of water. Productivity of water can be measured against gross or net inflow, depleted water, or process depleted water. Productivity of water has a broader basis than water use efficiency (Viets 1962), which relates production of mass to process depletion (transpiration or evapotranspiration for irrigated agriculture). Here it is defined in terms of net inflow, depleted water, and process depletion.

$$3.\ PW_{inflow} = \frac{\Pr oductivity}{Netflow}$$

$$4.\ PW_{depleted} = \frac{\Pr oductivity}{Depletion}$$

$$5.\ PW_{process} = \frac{\Pr oductivity}{\Pr ocessDeple\quad tion}$$

The following relationships exist between productivity and water indicators.

6. PW depleted = $PW_{net\ inflow} / DF_{net}$

Accounting Components at Field Level

A field experiments was conducted during four successive seasons of summer 2008, winter 2008/2009, summer 2009 and winter 2009/2010 in Agricultural research station (North Delta). Two cropping rotations were applied to measure water productivity indicators on crop rotations of wheat. All cropping sequences were selected as a dominant in North Nile Delta region.

1- Rice Sugar beet – Cotton – Wheat (RSCW)

2- Cotton – Wheat- Rice - Wheat (CWRW)

Each year's crop rotation treatments included rice- sugar beet – cotton – wheat (RSCW) and cotton – wheat- rice - wheat (CWRW). RSCW were compared to a two-year cycle of CWRW. The researchers used seeding rates, fertility and pest control practices common in the region.

Field-level Accounting Example

As a field-level example, results of agricultural trials based on field experiments (Mahmoud, 2010) carried out in farmers' farms of the command area in North Delta in Egypt are reported in a water accounting format (Table 1).

Yields were reported as 9.34 tons per hectare for rice, 63.87 tons per hectare for sugar beet, 2.26 tons per hectare for cotton, and 8.83 tons per hectare for wheat in RSCW rotation (Table1). While yields in CWRW rotation were 2.41 t ha-1, 7.17 t ha-1, 9.84 t ha-1, and 6.35 t ha-1 for cotton, wheat rice and wheat, respectively as shown in Table 2.

All of the irrigation and rainfall applied is depleted leading to a depleted fraction gross of 0.55, 0.89, 0.70 and 0.63 for rice, sugar beet, cotton and wheat, respectively, and they were 0.70, 0.63, 0.55, and 0.63 for cotton, wheat, rice, and wheat to a depleted fraction gross (Table2),. The depleted fraction net of 0.55, 0.81, 0.69, and 0.61 for rice, sugar beet, cotton and wheat, respectively, while they were 0.69, 0.61, 0.55 and 0.61 for cotton, wheat, rice and wheat in the second crop rotation. On a two annual basis, the depleted fraction net is quite middle at 0.65 in the RSCW and 0.61 in CWRW rotations, 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 0.65 lower than 1.0 as a result of the practice of deficit irrigation used.

The water application by crop for winter cropping is 860 mm for sugar beet and 571mm for wheat. For summer cropping, water application, as an average for the sample farms, is 952 mm for cotton, 1520 mm for rice.

Cropping systems evaluated were rice- sugar beet – cotton – wheat (RSCW), and cotton – wheat- rice - wheat (CWRW). Net inflow and depletion in RSCW was 3883 mm, and 2511 mm, respectively, greater than CWRW which was 3765 mm, 2291 mm, respectively; however, the depleted fraction for gross and net decreased by 6.1% and 6.2% compared with RSCW.

Net inflow of rice was 1520 mm greater following cotton and sugar beet than wheat in RSCW and wheat in CWRW. Total outflow was higher in RSCW than CWRW (1323vs. 1212 mm). Irrigation cost was higher (US$486 vs. 451) in RSCW compared to CWRW. The RSCW rotation had the highest net returns, about US$2286 ha-1 compared with US$2003 ha-1 for a CWRW rotation.

Table 1. Field level water accounts in North Delta: RSCW rotation.

	Rice	Sugar beet mm	Cotton	Wheat	Two annuals
Inflow					
Irrigation	1520	680	952	571	3723
Effective rainfall	0.0	50	0.0	50	100
Subsurface	0.0	0.0	0.0	0.0	0.0
Lateral seepage flows	0.0	0.0	0.0	0.0	0.0
Gross inflow	1520	740	952	621	3833
Storage change	0.0	16	17	17	67
Net inflow	1520	756	969	638	3883
Depletion					
Actual Evapotranspiration (process)	840	610	671	390	2511
Total Depletion	840	610	671	390	2511
Outflow					
Surface runoff	0.0	0.0	0.0	0.0	0.0
Deep percolation	680	70	281	181	1212
Total outflow	680	70	281	181	1212
Performance					
Depleted Fraction (gross)	0.55	0.89	0.70	0.63	0.66
Delectated Fraction (net)	0.55	0.81	0.69	0.61	0.65
Production (kg ha^{-1})	9341	63874	2261	8830	468
Production per net inflow (kg mm^{-1})	6.1	83.6	2.1	13.6	2286
Production per total depletion and process (kg mm^{-1})	11.1	104.7	3.4	22.6	
Production per net flow per depletion fraction (net)	11.1	103.2	3.0	22.3	
Irrigation cost in US$	223	84	94	67	
Net return in US$	587	652	405	643	

Table 2. Field level water accounts in North Delta: CWRW rotation.

	Cotton	Wheat	Rice mm	Wheat	Two annuals
Inflow					
Irrigation	952	571	1520	571	3614
Effective rainfall	0.0	50	0.0	50	100.0
Subsurface	0.0	0.0	0.0	0.0	0.0
Lateral seepage flows	0.0	0.0	0.0	0.0	0.0
Gross inflow	952	621	1520	621	3714
Storage change	17	17	0.0	17	51
Net inflow	969	638	1520	638	3765
Depletion					
Actual Evapotranspiration (process)	671	390	840	390	2291
Total Depletion	671	390	840	390	2291
Outflow					
Surface runoff	0.0	0.0	0.0	0.0	0.0
Deep percolation	281	181	680	181	1323
Total outflow	281	181	680	181	1323
Performance					
Depleted Fraction (gross)	0.70	0.63	0.55	0.63	0.62
Delectated Fraction (net)	0.69	0.61	0.55	0.61	0.61
Production (kg ha^{-1})	2412	7174	9840	6350	451
Production per net inflow (kg mm^{-1})	2.3	11.0	6.5	9.8	2003
Production per total depletion and process (kg mm^{-1})	3.6	18.4	11.7	16.3	
Production per net flow per depletion fraction (net)	3.3	18.0	11.8	16.1`	
Irrigation cost in US$	94	67	223	67	
Net return in US$	432	560	669	496	

Water productivity according to the defined in technical terms used, is the highest for sugar beet compared to wheat in winter cropping and rice compared to cotton in summer cropping.

Seasonal irrigation water-use efficiency was highest in rotation of RSCW 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.

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 wheat production in Northern Delta, Egypt is vital especially that the country has been classified as irrigation deficit.

It is meaningful to compare values of mass of production per unit of water diverted or depleted, when comparing like crops. But when different crops are compared, mass of output is not as meaningful. There is a clear difference between 1 kg of sugar beet and 1 kg of rice produced per mm of water depleted within the same crop rotation of RSCW and between 1 kg of cotton yield and 1kg of wheat in CWRW rotation.

One approach is to convert yields into value of production using local prices. A second approach is to use Standardized Gross Value of Production (SGVP). Standardized Gross Value of Production is used to measure economic productivity to allow comparisons across different agricultural settings by using world prices of various crops (Perry 1996, Molden et al., 1999). To calculate SGVP, yield of a crop is converted into an equivalent yield of a predominant, traded field crop using local prices. Then this mass of production is converted into a monetary unit using world prices.

In the various rotations, price determines profitability. But a rotation of RSCW consistently provides higher profit than CWRW rotation. One of the objectives of this research is to improve the growers' ability to make such investment decisions and to provide them with decision aids like Irrigator Pro to better manage irrigation based on economics and not simply yields.

The survey results also highlight the intensity of wheat production in Egypt. Wheat crop in rotation of RSCW produce US$643, while in the CWRW rotation, wheat crop produce UD$469. Wheat farmer harvests 8.83 metric tons of wheat obtained from RSCW rotation. While it was 6.35 metric tons of wheat obtained from CWRW rotation.

We got a higher return for our water with rotation of RSCW, and used its limited water more efficiently than CWRW rotation. Higher market prices for rice might swing the water-value factor in favor of the rice-wheat rotation in the CWRW and RSCW rotations.

Growers depend on several factors such as proper irrigation methods, good crop rotations, and effective marketing to secure the best price for the product. Researchers at Sakha Agricultural Research Station (SARC) in Kafr El-Sheikh, Egypt are conducting long-term, multicrop research at a farm location to define the best irrigation management practices for growers of rice, sugar beet, cotton and wheat crops. They have completed the two year of study to determine the impact on profitability of irrigation, crop rotation, and price.

For all iterations, net return to land, management, and irrigation equipment is calculated:

Net return = (commodity price X yield) – (irrigation cost + production cost)

where:

commodity prices were determined from user inputs, crop yields were calculated from yield-irrigation relationships based on field research, irrigation costs were calculated from lift, water flow, water pressure, fuel cost, pumping hours, repair, maintenance, and labor for irrigation, and production costs were calculated from user inputs.

User inputs including water supply, irrigation costs, crop production costs, commodity prices, and maximum crop yields can be tailored to user circumstances. These inputs directly influence the selection of the optimum crop rotation, water allocation among those crops, and ultimate net return of the cropping system.


Thank you