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Economic value of water for irrigation in the Nile Basin

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The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

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CONTENTS

EXECUTIVE SUMMARY

This study estimated the value of irrigation water using publicly available datasets, such as IMPACT model, FAOSTAT and other data sources, using the Residual Imputation Method. The novelty of this study is, estimating basin-wide economic value of water for 14 crops in four typologies where the intensification and value of water are different. Given the prevailing heterogeneity of agricultural systems in the Nile Basin, in terms of intensity and associated productivity, this study proposed four typologies involving the intensive system of Egypt, semi-intensive system of Sudan, extensive highland of Ethiopia and extensive lowland of the equatorial lakes region. The study used farm-gate prices and global prices; the later scenario to account the effect of price distortion, in estimating the value of irrigation water in these four typologies. The report presents the estimated value of water for each crop, in each typology, categorized into food crops; perennial crops; vegetables; root crops; and industrial crops.

The results, for all typologies, using farm-gate prices, indicated that perennial crops showed a very high value of water (ranging between 0.20 - 0.74 USD /m^3). Value of irrigation water for vegetables, ranging between 0.05 – 0.37 USD /m^3, was the second highest value. The water value for root crops, including potato, sweet potato and cassava, was ranging between 0.03 – 0.58 USD /m^3 and, the lowest was recorded for sweet potato. Value for staple crops have generally low economic estimation of water ranging between 0.01 - 0.38 USD /m^3, except for maize in Burundi whose value is estimated at 2.69 USD /m^3. Among the examined crops the least value was recorded for industrial crops, cotton and sugarcane; ranging between 0.01 - 0.31 USD /m^3.

Using global prices perennial (only banana) crops showed very high variation of the value of water (ranging between 1.20 - 3.88 USD /m^3). Value of irrigation water for vegetables, ranging between 0.03 – 0.37 USD /m^3, was the second highest value. The water value for root crops, including potato, sweet potato and cassava, was ranging between 0.21 – 1.56 USD /m^3 and, the lowest was recorded for sweet potato in Uganda. Value for staple crops have, generally, low economic value of water ranging between 0.01 - 0.15 USD /m^3. Among the examined crops the least value was recorded for industrial crops, cotton and sugarcane; ranging between 0.02- 0.31 USD /m^3.

The results are comparable to earlier studies, though the current estimates are on the higher side, especially for some crops. The value of irrigation water across different typology showed wide ranges. Irrigation water value of a crop is affected by several on- and off-farm factors, including productive use of water and market prices. The quality of the data, together with its availability, was the major hurdle in this study and, as such, future direction of research investment needs to focus on primary data generation. One obvious recommendation is, thus; for farms in different typology to improve the water productivity of their crops together with devising incentives for increased exports and enhancing stronger regional integration.

1. BACKGROUND

The agricultural sector is of significant importance to all Nile Basin (NB) countries as it is the major contributor to GDP, employment and food security (FAO 2000; NBI 2012; Tesfaye et al. 2016). Over 87% of the land cultivated is under rain-fed agriculture, characterized by subsistence-level production and crop yields lower than 2 tons/ha (NBI 2012). In 2018, the total area irrigated (cropped) and equipped for irrigation in the Nile Basin (NB) countries was about 6.96 and 6.26 million ha, respectively. The total cropped and equipped area in the NB had increased by 9.5% and 16.1%, respectively, compared to the 2015 baseline data (NBI 2019). Of the cropped area, 97% of the area is in Egypt and Sudan while the remaining 3% is distributed across the other NB countries (NBI 2012).

Agriculture is the single-largest water consumer in the Nile Basin. Total withdrawals for irrigated agriculture is about 78% of the peak flow of the Nile River at Aswan (NBI 2012). Yields are typically high in Egypt, e.g. FAOSTAT 2016 (http://www.fao.org/faostat/en/#data) (see Table 2) indicating that the yields for rice, wheat, maize, cotton and vegetable are 9.4, 4.5, 7.4, 1.4, and 24.6 t/ha, respectively. In Sudan, wheat, sorghum, cotton and vegetables yields are 3.2, 1.5, 0.6 and 11.2 t/ha. In Ethiopia, wheat, maize, cotton vegetable and sorghum yields are 1.7, 2.8, 0.6, 5.2 and 2.6 t/ha, respectively. More details on description of typology are given below.

In the past, the countries in the headwater regions of the basin (especially in the Equatorial Lakes Plateau) had high and reasonably well distributed rainfall for crop production. Hence, they tended to rely on rain-fed agriculture; paying little attention to the development of irrigation infrastructure. This situation has changed, and many upstream countries now plan to expand their irrigated areas (see Countries' master plans). The planned expansion of irrigation in the basin leads to an increase in water demand, and this requisite could not be met by surface water available in the basin (Paisley and Henshaw 2013; Degefu and He 2016). This situation is further exacerbated by factors such as inequitable distribution, over irrigation, and the cultivation of water consuming crops (El-Gafy and El-Ganzor 2012), in both upstream and downstream riparian countries.

The Nile Basin is thought to be sensitive to climate change and prone to climate-induced water scarcity (Eckstein 2009). Higher temperatures will increase evaporation rates from existing and new reservoirs, leaving less water available in storage for agricultural, industrial and municipal use. An increase of 3° C (corresponding to what most models forecast for the next 50–100 years) will increase crop water requirements for the existing crop mix in the basin by approximately 10 % (Jeuland 2009). Increased evaporation, crop water use and household water use will tighten the balance of water supply and demand throughout the Nile Basin (Whittington et al. 2014) coinciding with an increasing uncertainty in precipitation and, hence, surface water availability. Furthermore, the Nile Delta is at risk due to sea level rise because of climate change, which would entail catastrophic loss of agricultural land and require massive population resettlement or considerable investment in protective infrastructure (Whittington et al. 2014).

This mismatch between supply and demand may require technological solutions such as increased groundwater use (which was not considered in this study), augmenting supply through increased rainwater harvesting and conservation, improve water retention properties of soil in the upstream countries, and improve productivity and water-use efficiency in both upstream and downstream countries. While actions are taken to meet the water demand; pollution control measures are equally important as surface and groundwater pollution, soil erosion, and salinity development, are severe in the basin (NBI 2012).

Water access, demand, usage and management is complex due to its transboundary nature in the basin (Choudhury and Islam 2015; Paisley and Henshaw 2013), requiring collective water management action. Escalation of tensions between the upstream and downstream riparian countries (Whittington et al. 2014) are common; although there are trends talking more on multilateral cooperation, equity and sustainability, resulting cooperation among riparian countries in sharing transboundary water (Choudhury and Islam 2015). Some authors talk about the Grand Renaissance Dam (GERD) as being catalyst of change (Cascão and Nicol 2016), triggering further cooperative management of the basin. Cooperation in the Nile Basin will be important to meet future water demand and share water related scarcity risks among riparian countries (Blackmore and Whittington 2008).

In the NB countries water is considered a free resource (El-Gafy and El-Ganzor 2012). Water pricing, whether by administrative mandate or by market forces, is an important way to improve water allocations and to encourage conservation (Johansson 2000). It is, however, a major policy challenge in scarce water resources such as the NB (Johansson 2000; Johansson et al. 2002; Dinar et al. 2015; World Bank 2005; FAO 2004; Dinar et al. 2015).

In the literatures, various reasons are advocated why irrigation water pricing is important. 1) Water pricing is an important way to improve water allocations and to encourage conservation (Johansson 2000); 2) Users facing water shortage/scarcity may be encouraged to improve management or invest in capital that yields more efficient irrigation systems (Gibbons 1986). Water pricing enables a transition towards water systems that enhance conservation by adoption of efficient irrigation and application technologies, improving water delivery systems, and improving the efficiency of water allocation (Zilberman and Schoengold 2005). 3) Another strategy involves changes in the crop mix to maximize the value per unit of water, crop rotation, etc. (Gibbons 1986); and 4) Water pricing could enhance the financial capacity of Irrigation Water Users Associations (IWUAs) to offer better services to their members (Tardieu 2005; Lempériere et al. 2014).

Hitherto studies on water valuation in the NB are few. Whittington et al. (2005) estimated the economic value of cooperation. They assumed the same economic value of water for agriculture for all the NB countries. The information on the value of water disaggregated per crop /typologies is missing in the NB. There are some studies in parts of Egypt and Ethiopia (El-Gafy and El-Ganzor 2012; Hosni et al. 2014; Tesfaye et al. 2016) on economic valuation of irrigation water. Although estimates could be available from other basins, adopting those values is problematic because the value of water varies from scheme to scheme, not to mention at the basin scale. This study aims to fill this research gap and could be the basis to initiate a discourse in the economic value of water among the Nile riparian countries (Whittington et al. 2005).

1.1 Objectives of this Work

The key activities of this assignment include the following:

i. Review available methodologies on economic valuation of water in agriculture;

ii. Propose appropriate typology/classification of values of water in agriculture and methodology to be used in this study;

iii. Collect, review and process existing data on economic valuation of water for agriculture in the Nile Basin;

iv. Use appropriate methodologies to provide estimates of the economic value of water in irrigated agriculture. Estimation of economic value of water in irrigated agriculture shall be made based on available information (public domain, country reports, IWMI database or other sources that are accessible to the study team). The draft estimates shall be presented in the regional workshop from February 23 – 25, 2019; and

v. Prepare and submit a Technical Note on economic value of water in irrigated agriculture in the Nile Basin. The Technical Note will document the methodology adopted, brief description of data used and detailed results of the study.

The output of this component shall support the hydro-economic modeling/optimization planned by the NBI Secretariat. This economic valuation shall be developed for major crops by typology of the irrigation/production systems (high intensity, low intensity, commercial, smallholder schemes, etc.,).

1.2 Scope of this Assignment

The scope of the assignment was not to collect primary data and run a production function. Thus, the scope is to derive a specific (point) estimate of crop-specific economic value of water in each typology for major crops using a desk review. Hence, to estimate the value of irrigation for priority crops in each typology, secondary data from the IMPACT model, FAOSTAT 2016, IWMI database or other sources were used. The valuation approach required not only marketed inputs (fertilizers, seed, agro-chemicals, farm machinery, hired labor) but also non-marketed inputs like land value (rental price), and family labor (opportunity cost).

1.3 Relation with other Components

This component (economic valuation of irrigation water) is part of the benchmarking study, alongside irrigation suitability mapping, and scenario analysis. This component gained some insights related to the scope of irrigation and cropping pattern in the basin from the benchmarking study. The benchmarking study will further create an opportunity for follow up study to temporarily revise the economic value of water by monitoring changes in the cropping pattern and state of irrigation. Moreover, if water evaluation is used as a tool for implementing water tariff in the NB, the later will serve as a demand management tool. The demand scenario analysis could depict the impact of water charges on water saving and efficiency.

2. WHY VALUATION IS NEEDED

Zilberman and Schoengold (2005) indicated that determining water allocation rules and pricing are closely related. Ward and Michelsen (2002) and Whittington et al. (2005) indicated that conceptually correct and empirically accurate estimates of the economic value of water are essential for rational allocation of scarce water across locations, uses, users, and time periods. This information can support the management and administration of water resources and can contribute to setting fair and reasonable water tariffs that can improve its allocation between competing uses, and encourage irrigators to use water efficiently (Homero Yedra et al. 2016). This is more important as riparian countries are undertaking joint planning through the NBI (Nile Basin Initiative) by taking regional and cooperative framework, achieving system-wide, economically optimal management of the shared resource (Whittington et al. 2005).

In other sectors, in this study we will focus on valuing the economic value of water in agriculture and without considering the value of water.

Broadly the estimation approaches could be classifies as direct and indirect ones. We focus in this study on one direct approach it, described below.

3. DIRECT WATER VALUATION APPROACHES

3.1. Farm Crop Budget Analysis

Residual Imputation Method (RIM) is the most frequently used approach applied to estimate the shadow price of irrigation water (Young 2005). According to Ashfaq et al. (2005), the technique for determining the shadow prices (for unpriced input) is called the 'Residual Imputation'. The method is simple and, under certain specified conditions, is applicable for estimating the value of resources used in production.

Young (2005) explained that if appropriate prices can be assigned to all inputs but one, and certain other assumptions are met, then the residual of the total value of product is imputed to the remaining resource. Mesa-Jurado et al. (2008) also explained that this method evaluates irrigation water as the residual of total value of output after deducting the whole outlay for the inputs included in the production system, except the water input. Mathematically this is explained as eq. 1.

$$(P_W.X_W) = (Y.P_Y) - (P_M.X_M) - (P_{lab}.X_{lab}) - (P_K.X_K) - (P_L.X_L) \tag{1}$$

Where $P_W.X_W$ is value of irrigation water, $Y.P_Y$ value of irrigated yield[1] net of rain-fed yield $P.X_M$ is the value of all material inputs, which includes seed, fertilizer and pesticide, $P_{lab}.X_{lab}$ is value of both family and hired labor, $P_K.X_K$ is value of capital like machinery (draught) power and $P_L.X_L$ value of land. In this approach, not only marketed inputs (fertilizers, seed, agro-chemicals, farm machinery, and hired labor) but also non-marketed inputs like value of land (land rental price), and family labor (opportunity cost) and corrected for market distortions, if possible.

Through straight forward computation, the price of water, thus, becomes

$$P_W = \frac{(Y.P_Y)-(P_M.X_M)-(P_{lab}.X_{lab})-(P_K.X_K)-(P_L.X_L)}{X_W} \quad (2)$$

This method has certain limitations, just to mention the basic ones, the problem of omitted variables and problems of estimation when price supports, subsidies, or other exogenous influences are working. However, this method is suggested, because of its ease and low data requirement (Tesfaye et al. 2016), given the scope of the assignment.

In developing countries, price distortions, due to input subsides and output price controls, mainly to the benefits of urban consumers, are prevalent. Many of the NB countries have Input (fertilizer and seeds) subsidies: Burundi, Egypt, Kenya, Rwanda and Tanzania have input subsidies, while Ethiopia, the Republic of Sudan and South Sudan have no input subsidies (Druilhe and Barreiro-Hurlé 2012). To minimize the effect of market distortions, we used world prices of marketed inputs and outputs in place of farm-gate prices, to assess if the value of irrigation water varies accordingly.

Depending on whether fixed costs are included, such values can be short-run or long-run average values. If water procurement costs are further subtracted, the net value for irrigation is comparable to at-site rather than at-source water values. This is the dollar sum, divided by the total quantity of water used on the crop, which determines the maximum average value or willingness to pay, for water for that crop (Gibbons 1986).

3.2. Change in Net Rent Approach

The change in net rent approach (CNR) is an extension of the residual imputation method (RIM) for approximating the value of water. It is used, particularly, for valuating policies targeted at improving the irrigation of agricultural crops (Young 2005). This model defines the increment in net producer income associated with adding water to a production process as the willingness to pay for incremental water (Young and Haveman 1985).

Production inputs Z_j and products Y_i are indexed either with 0 to denote a production scenario without additional water and with 1 if additional water is available. If both input (*PZ_j*) and product prices (*PY_i*) are unaffected by the change from 0 to 1, the change in net rent (income) $\Delta\pi$ associated with a discrete addition to water supply per unit of time (Young and Haveman 1985).

$$\Delta\pi = \pi_1 - \pi_0 = \left[\sum_{i=1}^{m} Y_{1i}.P_{Yi} - \sum_{j=1}^{n} Z_{1j}.P_{Zj}\right] - \left[\sum_{i=1}^{k} Y_{oi}.P_{Yi} - \sum_{j=1}^{l} Z_{oj}.P_{Zj}\right] \quad (3)$$

where $\sum_1^m Y_{1i}.P_Y$ and $\sum_1^k Y_{0i}.P_Y$ the first revenue from production in scenarios 1 and 0; $\sum_1^n Z_{1j}.P_Z$ and $\sum_1^l Z_{0i}.P_Z$ are the cost of production in scenarios 1 and 0.

Commonly, the input and output variables are parametrized for a representative observational unit, regularly, a single typical farm using official normalized crop prices.

The data requirement of this approach is the availability of data on rain-fed and irrigated production systems and may require collecting household data on rain-fed and irrigated production. This approach could be used to estimate the value of water for a single or multiple crop.

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[1] We used the irrigated yield net of rain-fed yield as suggested by Marc Jeuland" here following the Rwanda workshop that was held from February 23 – 25, 2019.

3.3. Value of the Marginal Product

Another frequently used alternative to estimate the economic value of water in agriculture is the value of the marginal product method (VMP) (Boggess et al.1993). The VMP of any input is the additional revenue generated by a marginal increase in the use of this input. In the absence of an undistorted market price for water, the VMP of water reflects the shadow price of water (Young 2005) because if water provision is constrained to an initial level W, then the maximum willingness to pay to marginally relax the water constraint by ΔW is equal to the additional revenue from the increased input use, i.e., the VMP for an infinitesimally small increase in W. For discrete input changes, VMP can be estimated by $P_y.\left[Y\left(W+\Delta W\right)Y\left(W\right)\right]$where Y is level of output and P_Y is the price of output. For very small ΔW, this provides a reasonable approximation to the shadow price of water (Johansson 2005).

The major challenge lies in the estimation of the functional relationship between inputs and the final product; direct calculation from real world data is seldom possible because of simultaneous changes in the other inputs. This problem can be avoided if observational data are used to estimate a production function, which is straightforward once a functional form for the production function (also accounting interaction effects) has been decided upon (Husseinzadeh and Salami 2004).

3.4. Linear Programming Analysis

The residual imputation method (RIM) could be extended to linear programming (LP) models that portray optimal allocation of water and other resources (land, materials and labor), among several potential crops. Mathematical programming allows much more realistic modeling of irrigation decisions than simple budgeting (Young 2005). In mathematical modeling, the analyst requires to make several prior judgments or assumptions about crop species, land area allocated to each crop, the crops' response to alternative amounts of and timing of water, and irrigation water distribution technology.

In LP the objective function is to maximize the net return for a farm of a specified land area, subject to constraints that may be economic or physical, such as land area limitation of the crop, input costs per unit, available technology, constant water requirement set for each crop, crop price, and so forth (Gibbons 1986; Young 2005). In LP solutions, limiting the land area of certain risky crops is one way to incorporate the desired level of the risk of the farmer.

Average water values are estimated by driving a series of LP solutions for a range of water costs; all other constraints on the representative farm remain constant. The solutions specify the combination of inputs and crops that maximize the net farm returns, including total irrigation water used for crop production, at each water cost. The set solutions give water demand schedules for the farm. When it is assumed that each crop has a set of irrigation water requirements for cultivation and an all-or-nothing land area, the LP demand schedule is a step function with each horizontal segment representing a specific crop. As water costs go up, crops drop out of production one by one as they become uneconomic to produce.

The water cost associated with each segment represents the maximum amount the farmer is willing to pay for water in producing that crop. Variations on this very basic approach is possible, crop mix combinations, land allocation by crops, estimate marginal values of irrigation water (not by crop type), several levels of water use and several technologies etc. This requires collecting primary data that covers many farm households in a scheme(s), different irrigation technologies within country(s).

Given the data availability and outputs needed from the task, the team decided to apply RIM (see Section 6 on limitations).

4. DATA USE AND SOURCES

The data required to determine the economic value of water for major crops produced in each typology (Nile Basin part of each country) constitute crop yield, amount of irrigation water used, and other inputs used to produce each crop. Data were collected from various sources.

Irrigation water use for each crop in each typology used in this study is based on results from the version of the IMPACT model used by Nelson et al. (2010). The data covers all the Nile Basin countries except South Sudan, which was part of the Republic of the Sudan when the data was first generated in 2000. To our knowledge, it is the most comprehensive data available covering the NB countries providing detailed facts on both rain-fed and irrigated agriculture in the Nile Basin. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model was developed by the International Food Policy Research Institute (IFPRI) in the early 1990s, to address the long-term challenges facing policymakers in feeding the world and reducing poverty in a sustainable manner (Rosegrant et al. 2008). Details of the IMPACT methodology are thoroughly documented in Rosegrant et al. (1995), Rosegrant et al. (2002), and Rosegrant et al. (2008). The model has been updated and improved over time and the model now constitutes an integrated modeling system that links climate models, crop simulation models, and water models linked to a core global, partial equilibrium model focused on the agriculture sector (Robinson et al. 2015; Nelson et al. 2010; Calzadilla et al.,2010; Calzadilla et al. 2011; Calzadilla et al. 2013; Kahsay et al. 2017a; Kahsay et al. 2017b).

The FAOSTAT provides observed data on crop yields (http://www.fao.org/faostat/en/#data) reported in Table 4), while yield data from the IMPACT are based on linear interpolation of 2000 baseline and simulation data for the year 2050. The FAO crop yield data for 2016/17 are considered for the analysis in this study while the interpolated IMPACT yield data are used for verifying the FAO yield data. For Ethiopia, more reliable irrigation water and yield data are obtained from Agide et al. (2016) and LIVES (2015) and Hagos et al. (2008). For crops where information was missing in the FAOSTAT, (e.g., cotton), the IMPACT model results were used.

The data on irrigation water applied per hectare for each crop in each typology is depicted in Table 3. As crop yield and water use were obtained from different sources, i.e., from FAOSTAT and IMPACT models, yield data from the two sources are compared to examine their differences and their potential effect on the estimation of the economic values of water for the selected crops. The higher the difference, the higher will be the effect on the estimated water values for the crops. As shown in Table.1, the differences are not that significant, except for Egypt; where relatively higher differences exist between IMPACT and FAOSTAT yield values. More importantly, the comparison results reveal that IMPACT yield is higher than that of the FAOSTAT and, as such, the estimated water values would be slightly overstated if the IMPACT yield was used for the analysis. Using FAOSTAT data thus results with lower and, hence, reasonable estimates but still not significantly different from the results that would be generated if the IMPACT yield data were used.

Table 1: The difference between FAOSTAT and IMPACT yield data (ton/ha)

	Egypt	Kenya	Burundi	Rwanda	Uganda	Tanzania
Rice	1.9	1.5	-0.8	-0.6	0.9	0.7
Wheat	-1.8					
Maize	-1.3		0.0			-0.5
Sorghum	-2.3		0.4			
Cotton						
Vegetables	-2.3	0.9				-0.5
Potato	-10.8					
Banana						
Apple						
Millet				0.0	-1.4	
Sweet potato		-2.6		-3.1		2.9
Sugar cane		-34.9		-0.2		
Groundnut						
Cassava					-15.9	

Source: Own computation

Crops are priced in a common currency, US dollars, in order to avoid the variations in the value of local currency units of the countries. We used two scenarios in valuation of water, using farm-gate and global prices, where the effect of global prices on marketed inputs and output on the value of irrigation water for corresponding crops are reported to provide alternative scenarios of estimates of value irrigation water. Farm-gate prices are obtained from FAOSTAT while global prices are obtained from the World Bank (2016) and IMF (2017).

Quantities of fertilizers used and their prices for each typology are derived from AfricaFertilizer.org (https://africafertilizer.org/national) and FAOSTAT (2002-2016) (http://www.fao.org/faostat/en/#data).

Cost of pesticides is determined based on data on import values of pesticides and the size of arable land obtained from FAOSTAT) (http://www.fao.org/faostat/en/#data).

Seed input for cereals is from FAO crop calendar (http://www.fao.org/agriculture/seed/cropcalendar/welcome.do). Due to lack of data on price of seeds, producers' price from FAOSTAT is used to estimate seed cost.

A combination of family and hired labor is commonly used by farmers in the Nile Basin countries. While hired labor is paid in cash, determining the reward for family labor is not straightforward. Moreover, available data don't distinguish between hired and family labor. Accordingly, number of farm workers per hectare is determined using FAO data on agricultural works and the size of arable land. Data on daily labor cost from AFDB (2019) are then used to obtain the cost of labor per hectare. Properly functioning land markets are not expected in many of the Nile Basin countries. However, a rental market for land does exist in these countries. Therefore, the cost of land for this study is based on the rental value of land in each country obtained from AFDB (2019). Capital costs of crop production are estimated using annualized value of imports of agricultural machinery obtained from FAOSTAT.

Inputs other than irrigation water considered in this study include fertilizer, pesticides, seeds (for cereals), labor, land and capital. Although aggregate data was relatively available, getting input use per crop was difficult. Hence, we made certain assumptions.

5. DESCRIPTION OF THE MAIN TYPOLOGIES CONSIDERED

Nile Basin farming system, be it rain-fed or irrigation, is complex and heterogeneous (Haileslassie et al. 2008). Decomposing the system into a homogeneous unit is appropriate, but the task is data intensive (Haileslassie et al. 2016). Classifying farming systems into typologies requires information/data on crop production, land size and ownership, input use, (e.g., fertilizer, seed, and pesticides) and other agricultural production characteristics, such as mechanization and labor as well as information on livestock resources, market infrastructure, etc. For this work we are focusing only on irrigation water, agricultural inputs (including fertilizers and other agro-chemicals), mechanization, farm labor cost, land rental price and outputs for different crop types.

After exploring available data and details needed for this study, IFPRI's IMPACT classification was adopted. The version of the model employed by Robinson et al. (2015) was found to be appropriate for the study under consideration. Nelson et al. (2010) provided detailed baseline data for the year 2000 and simulation data until the year 2050 with respect to irrigation water use, crop yields and cropped area.

For this assignment, we used four typologies: intensive irrigation, semi-intensive irrigation, extensive highlands and extensive lowland equatorial lakes. (Table 2). We considered Nile Egypt (out of four typologies) representing intensive irrigation; Nile Sudan representing semi-intensive irrigation, Nile Ethiopia representing extensive highland (both out of two typologies) Nile Uganda (out of three typologies), Nile Kenya (out of two typologies), Nile Tanzania (out of three typologies), and Burundi and Rwanda both representing extensive lowland. We considered major crops covering about 80% the land area in the valuation. The IMPACT typology for Egypt is presented by distinguishing between summer and winter crops. However, irrigation water use in Ethiopia is modified as the IMPACT data on irrigation water use and productivity were very low by using data from Agide et al. (2016), LIVES (2014) and Hagos et al. (2008), based on which we developed case studies of small-scale irrigation and commercial (sugar) estates.

Table 2: Region and typologies in the NB

Region- Country	Typologies
Nile Egypt	Intensive irrigation
Nile Sudan	Semi-intensive irrigation
Nile Ethiopia	Extensive highlands
Nile Uganda	Extensive lowland equatorial lakes
Nile Kenya	Extensive lowland equatorial lakes
Nile Tanzania	Extensive lowland equatorial lakes
Nile Burundi	Extensive lowland equatorial lakes
Nile Rwanda	Extensive lowland equatorial lakes

Source: Authors classification

Thus, four major typologies are suggested for this study to capture differences in bio-physical conditions (agro-ecology, cropping pattern, irrigation water use in m^3/ha, etc.), productivity (yield in tons / ha), and degree of mechanization. Given the data limitation, because irrigation systems might change and the data might be obviously outdated, there is no as such clear-cut boundaries between different typology, particularly between the extensive equatorial lake region and extensive highland. The following sections describe these typologies.

5.1. Intensive Irrigation in Egypt

Intensive systems are generally marked by high inputs and higher level of efficiency, in relative term as there is no standard value globally. Among the NB countries Egypt is marked by the highest water use, highest productivity (in most of the crops grown in the typology), highest input and farm machinery use. The dominant winter crops are cotton, rice, fruit trees (like apple, banana etc.), and sorghum; while low water demanding summer crops cultivated are vegetables, wheat, maize and potato. To irrigate 1 ha, the average water used for winter crops is 8,764 m^3 and ranges from 5,737m^3 for sorghum to 20,038m^3 for rice; while the average for summer crops is 7,178 m^3 and ranges from 5,878m^3 for wheat and 8,479m^3 for potato. According to Table 3, irrigation water used in this typology is almost twice compared to the semi-intensive, more than three times compared to the extensive highland typology and almost four times compared to extensive lowland equatorial lakes typology, except water use for sugarcane in Ethiopia and Kenya, which is higher. Put differently water input increases along intensification gradient.

Table 3: Irrigation water applied by crop and typology in the Nile Basin countries (M^3/ha)

Crops	Egypt		Sudan	Ethiopia	Kenya	Burundi	Rwanda	Uganda	Tanzania
	Winter Crops	Summer Crops		Nile Basin					
Rice	20,038				5,883	455	1,377	3,746	2,923
Wheat		7,881	8,050	4,385					
Maize		6,473		1,972		25			1,175
Sorghum	5,737		4,677	1,972		1,285			
Cotton	6,001		5,014	3,271					3,850
Vegetables		5878	4,883	4,382	3,939				3,862
Potato		8,479		838[2]					
Banana	5,962		4,973	1,863	2,923	1,336			
Apple	6,080								
Millet			5,016						
Sweet potato				838	3,862		334	1,278	1,002
Sugar cane				20,3732	11,848				
Groundnut							2,165		
Cassava								1,243	

Source: IMPACT DATA and Agide et al. 2016

[2] LIVES, 2014 and Hagos et al. 2008

In the intensive system, as we can see from Table 4, rice, wheat, maize, sorghum, cotton, vegetables, potato, banana and apple yields are 9.4, 4.2, 7.4, 4.5, 1.4, 24.6, 27.2, 43.3, and 25.7 tons/ha, respectively. This amounts the highest yield compared to all typologies.

Data on input use by typology are very scarce. Although we estimated input use per hectare basis in calculating the value of irrigation water use, we express it here in terms of share each typology (country) has, in input use; namely, fertilizers, agro-chemicals and seed. According to Africa Fertilizer Organization (https://africafertilizer.org/national) and FAOSTAT (http://www.fao.org/faostat/en/#data) about 69% of the total fertilizer use in all typologies, NPK, DAP and UREA combined, is applied in the intensive irrigation typology. Similarly, about 58% of the agro-chemicals is used in this typology and 11% of the seed quantity is also used in this typology. Moreover, land rental prices are 95 USD/ ha in Egypt (AFDB 2019). Finally, there is high degree of mechanization where 360.9 tractors per 100 km^2 are used in this typology (World Bank 2015).

5.2. Semi-intensive Irrigation in the Sudan

Another typology considered is Nile Sudan, which is marked by relative to the extensive highland and low-land typologies, higher water use, higher productivity and machinery use. The dominant crops in this typology are cotton, vegetables, banana and low water demanding crops, including wheat, sorghum and millet. The average water use in the semi-intensive typology of Sudan according to IMPACT data is 5,436 m^3 /ha ranging from 4,677 m^3 for sorghum to 8,050m^3 for wheat (Table 4). Related to the extensive highland and low-land typologies, irrigation water use in this typology is higher by 1,000 m^3 per ha and almost twice, respectively, except water use in Ethiopia and Kenya, which is higher for rice and sugarcane.

Table 4: Total crop yield by typology in the Nile Basin countries (ton/ha)

Crops	Egypt Winter Crops	 Summer Crops	Sudan	Ethiopia	Kenya	Rwanda	Burundi	Tanzania	Uganda
Rice	9.4				4.0	3.3	2.2	2.5	2.7
Wheat		4.5	3.2	1.7[2]					
Maize		7.4		2.8[2]			1.3	1.5	
Sorghum	4.5		1.5	2.6			2.0		
Cotton[1]	1.4		0.6	0.6				0.5	
Vegetables		24.6	11.2	5.2	13.5			6.8	
Potato		27.2		4.5[2]				5.3	
Banana	43.3		11.0	8.8	18.3		4.7		
Apple	25.7								
Millet			0.3						1.4
Sweet Potatoes				9.6	9.4	6.7			
Sugarcane				132.5[2]	81.7				
Groundnuts						0.5			
Cassava									3.4

Source: FAOSTAT,

[1] IMPACT DATA

[2] LIVES, 2014 and Hagos et al. 2008

Wheat, sorghum, cotton, vegetables, banana and millet yields are 3.2, 1.5, 0.6, 16.6, 11.2, 11.0 and 0.3 tons/ ha, respectively. Wheat, vegetables and banana productivity is higher than what is produced in extensive highland and lowland typologies, except Kenya. About 4.6 % of the total fertilizer uses in all typologies, NPK, DAP and UREA combined, are used in Sudan, indicating lower use in this irrigation typology. About 10% of the agro-chemicals are used in this typology. About 31% of the seed quantity is also used in this typology, perhaps indicating the importance of cereals. Moreover, land rental price in Sudan is 69 USD / ha indicating the availability of land (AFDB 2019). Finally, there is a moderate degree of mechanization where 13.2 tractors per 100 km^2 are used in this typology (World Bank 2015). The semi-intensive system of Sudan tends to show higher value of input and productivity than the upstream highland system of Ethiopia and the lakes region; and could be considered as a transition between an intensive and extensive system.

5.3. Extensive Highland in Ethiopia

Another typology considered is Nile Ethiopia, which is characterized by relative to the intensive and semi-intensive typologies, lower water use, lower productivity and low machinery use. Contrastingly the highland extensive system has higher input compared to the semi-intensive and extensive equatorial region. Intensive agriculture is an agricultural production system characterized by the significant use of inputs and seeking to maximize the production. In this line, the fact that the maximum yield objective in Ethiopia context is still not achieved indicates that higher input use alone does not guarantee Ethiopia to be grouped under intensive systems. Although it can be comparable with lowland equatorial lakes region in many aspects, the Ethiopian system has also a unique bio-physical setting that enables different crop selection and, thus influence inputs use.

The extensive highland typology is on the higher side related to these parameters compared to extensive low-land equatorial lakes typology. The dominant crops, in this typology, are vegetables, potato, sweet potato, cotton, banana and low water demanding cereal crops such as wheat, maize and sorghum. The study also presents a case study of smallholder irrigation and commercial sugar estates from Ethiopia using IWMI datasets (Agide et al. 2016; LIVES 2014; Hagos et al. 2008). The average water use in the extensive highland typology is 2,669 m^3 /ha ranging from 4,385m^3 for wheat to 835m^3 for potato/sweet potato. The irrigation water use for sugarcane, however, is 20,373 m^3/ha.

Wheat, maize, sorghum, cotton, vegetables, potato, banana, sweet potato and sugarcane yields are 1.7, 2.8, 2.6, 0.6, 5.2, 5, 8.8, 9.6, and 132.5 tons/ha, respectively. In his typology, wheat, maize, sorghum, cotton, sweet potato, and sugarcane productivities are higher than what is produced in extensive lowland typology. However, in Kenya, productivity of vegetables and banana is higher than the extensive highland. About 15 % of the total fertilizer use in all typologies, NPK, DAP and UREA combined, and 15% of agro-chemicals are used in extensive highland, indicating relatively higher use in this irrigation typology compared to the lakes region. But, only 5.3% of the seed quantity is used in this typology according to IMPACT data. Moreover, land rental price in Ethiopia is 82 USD / ha (AFDB 2019), perhaps indicating growing land pressure as a result of fast population growth. Finally, there is non-existent degree of mechanization where no tractors per 100 km^2 is used in this typology (World Bank 2015).

5.4. Extensive Lowland Equatorial Lakes Region

The last typology considered is the equatorial lakes region, which is characterized by extensive irrigation marked by relative to the intensive and semi-intensive typologies, lower water use, lower productivity, lower input and machinery use. This typology is also on the lower side related to these parameters compared to the extensive highland typology. The dominant crops, in this typology, are rice, vegetables, sweet potato, sugarcane, banana and low water demanding cereal crops such as maize, sorghum, groundnut and cassava. The average water use in the extensive low-land typology is about 2,482m^3/ha ranging from 5,883m^3 for rice and 334m^3 for sweet potato. The average irrigation water use in Kenya is 5,691 m^3/ha, exceptionally higher, ranging between 11,848m^3 for sugarcane and 2,923 m^3 for banana. Related to the extensive highland, irrigation water use in low-land typology is lower by 500 m^3 per ha, except water use in Kenya, as already mentioned.

Rice, maize, sorghum, cotton, vegetables, banana, millet, sweet potato, sugarcane, groundnut and cassava are grown in extensive lowland equatorial lakes typology. Rice, vegetables, banana, sweet potato and sugarcane in Kenya yield 4.0, 13.5, 18.3, 9.4 and 81.7 tons/ha, respectively. In this typology, maize, sorghum, cotton, sweet potato, and sugarcane productivity is lower than what is produced in extensive highland typology. Vegetables and banana, in this typology and particularly in Kenya, yield 13.5 and 118.3tons/ha, higher than semi-intensive and the extensive highland typologies. About 4 % of the total fertilizer use in all typologies, NPK, DAP and UREA combined, are applied indicating lower use of these inputs in this irrigation typology. The exception is Kenya, where combined fertilizer use is about 10% of the total. About 8% of the total agro-chemicals are used in this typology, about 6% in Kenya. About 30% of the seed quantity is also used in Kenya but less 16% in the other equatorial lake countries. Moreover,

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[2] We broadly categorized crops into staples consisting cereals, including rice, perennial crops consisting banana and apple, vegetables, root crops consisting potato, cassava, groundnut and sweet potato; and industrial crops consisting cotton and sugar cane. We assume the same crops growing in different typologies are the same regardless of differences in water demand, input use, yield and prices.

land rental prices in Tanzania, Rwanda, Uganda, Kenya and Burundi are 102, 86, 77, 76 and 65 USD/ ha (AFDB 2019). Finally, 8.4 tractors per 100 km^2 is applied in this typology, where 25.2 and 24.7 tractors per 100 km^2 are reported in Kenya and Tanzania, indicating relatively higher degree of mechanization in this typology (World Bank 2015).

6. VALUE ADDED BY THIS STUDY AND MAJOR LIMITATIONS

The current study estimates the value irrigation for 14 major crops[1] in four typologies. The most serious limitation of the RIM is that the cost of any inputs omitted from the analysis is valued as being part of the value of water. The list of inputs accounted for in this study is not exhaustive so that, the value of water derived in this analysis is expected to be overstated and must be considered to represent an upper limit. In addition, any errors in data input, including the prices and quantities of inputs or outputs, crop yield and water used in crop production are accumulated in the value of water. Besides, water valuation based on this method is vulnerable to an aggregation problem. As a result, studies based on aggregated basin level secondary data, like the current study, are expected to be less accurate compared to studies based on survey data for specific locations, (e.g., schemes).

The study used snapshot data for each typology for the year 2016/17 following the FAOSTAT data and interpolated IMPACT data. In estimating the economic value of irrigation water, we considered irrigated yield net of rain-fed yield (as reported in the Annexes I and II) to know the added value due to irrigation in all typologies, except the intensive system where rain-fed yield doesn't exist. The estimated water values are point estimates related to current conditions on crop yield, price and crop water consumption. Agricultural practices in the Nile Basin countries are, however, expected to improve overtime. These parameters and, hence, the value of water will change over time. Therefore, the results cannot correctly reflect the value of water over a longer period into the future. Verifying this data through various studies and continuous monitoring of selected schemes in the typologies is critically important. Thus, the estimated water values need to be updated regularly based on changes in the stated parameters that underpin the magnitude of the values.

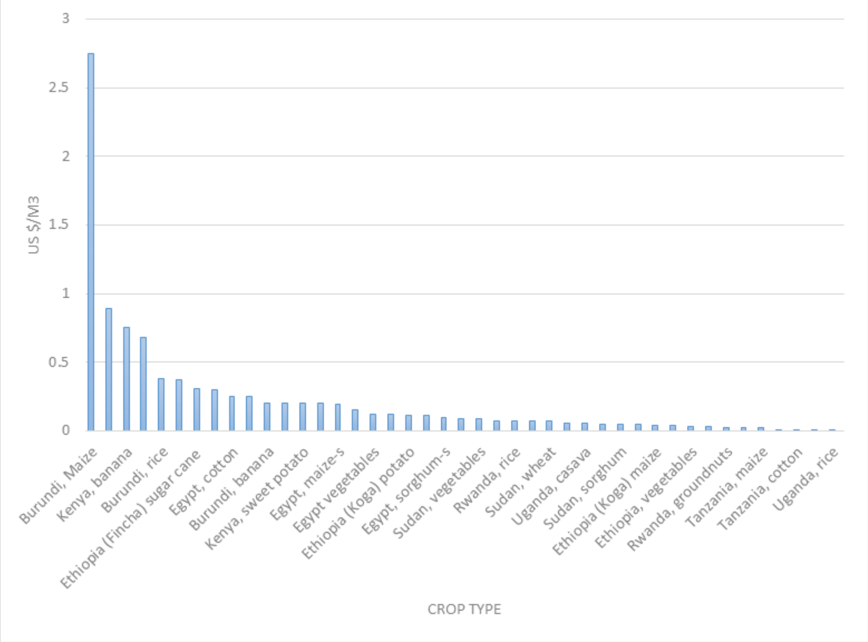
In pricing water, it is important to consider the provision costs of the water, the cost of dynamic adjustment associated with water supply, conveyance costs and environmental costs (Zilberman and Schoengold 2005). However, these costs were not accounted in the valuation for lack of data on these costs. Hence there is a possibility of overestimation of the economic value of water estimated in the study.

7. RESULTS AND DISCUSSIONS

7.1. Irrigation Water Values for Nile Basin by Typology

In this study, the economic value of crops that are dominant in each typology is assessed. Crops considered in the analysis account for about 80% of the irrigated area in the Nile Basin. The share of the chosen crops in total irrigated land is relatively lower for some countries, (e.g., Egypt and Tanzania) because a composite crop termed as 'other crops' was not considered in the study. This crop is disregarded due to lack of data, (e.g., price, yield and input use) as it is composed of several crops that couldn't be identified based on available data. The study includes 9, 6, 9, 5, 4, 4, 3 and 5 (in total 45 crops) major crops for analysis from Egypt, Sudan, Ethiopia, Kenya, Burundi, Rwanda, Uganda and Tanzania, respectively. Three Nile riparian countries, namely DR Congo, South Sudan and Eritrea were not included in the study due to lack of relevant data for South Sudan, and the insignificance of irrigated land in the Nile basin area of the other two countries. Four crops were not cultivated in the extensive lowland; namely apple, potato, wheat, and millet, compared to the other typologies.

Figure 1: Value of irrigation water considering farmgate prices in USD/m³

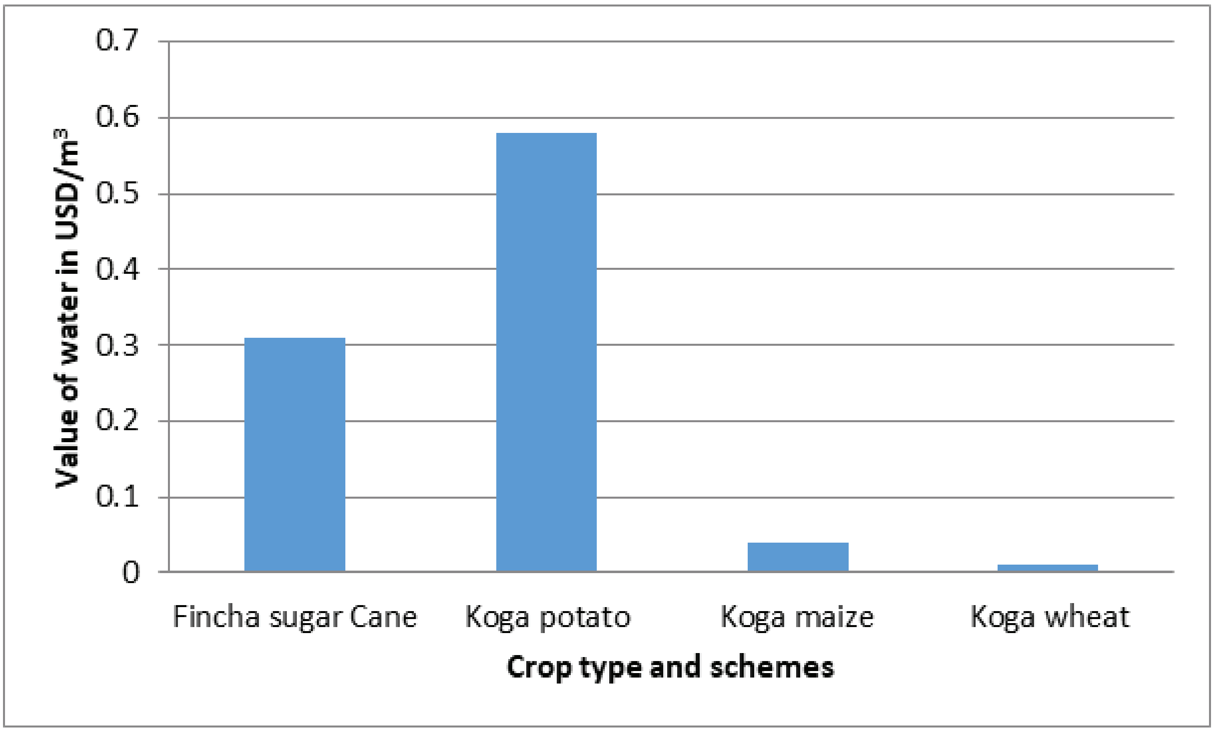


Source: Based on authors' computation

The estimated value of irrigation water for 14 crops in the Nile Basin (in eight countries considered) is reported in Figure 1 and Figure 2. Following farm-gate prices (as reported in Annex I Tables A 1-A11), in the intensive typology, apple, the only crop reported in this typology, has the highest water value followed by banana, cotton, potato, maize, wheat, vegetables, sorghum, and rice with 0.89, 0.68, 0.25, 0.20, 0.19, 0.15, 0.12, 0.10 and 0.09 USD /m^3, respectively. In the semi-intensive system, banana and vegetables showed the highest water value followed by cotton, wheat, sorghum and millet with 0.20, 0.09, 0.07, 0.07, 0.05 and 0.01 USD / m^3, respectively. In the extensive highland system, sweet potato had the highest water value followed by banana, sorghum, cotton, and vegetables with 0.25, 0.11, 0.05, 0.04 and 0.03 USD /m^3, respectively.

Value of water for selected crops of smallholder irrigation from the Koga Scheme and the Fincha Sugar Plantation in Ethiopia, showed that sugarcane has the highest value of water followed by potato, maize and wheat with values of 0.31, 0.11, 0.04 and 0.01, respectively (Figure 2). In the extensive equatorial lakes region, the values of irrigation water for banana was 0.75 and 0.20 USD /m^3 for Kenya and Burundi, respectively. The values of irrigation water for vegetables were 0.37 and 0.05 USD /m^3 for Kenya and Tanzania, respectively. The value of irrigation water for maize was staggeringly high in Burundi and low in Tanzania, with values 2.75 and 0.02 USD /m^3, respectively. Sweet potato is grown in Kenya, Rwanda, Tanzania and Uganda with water values of 0.20, 0.3, -0.21 and 0.03 USD /m^3, respectively. Similarly, rice is grown in Kenya, Rwanda, Burundi, Tanzania and Uganda with water values of 0.07, 0.07, 0.38, 0.01 and 0.01 USD /m^3, respectively. Groundnuts are grown only in Rwanda, while cassava is grown in Uganda with values of irrigation water for these crops are 0.02 and 0.09 USD /m^3, respectively.

Figure 2: Estimated value of water for some crops in Ethiopia

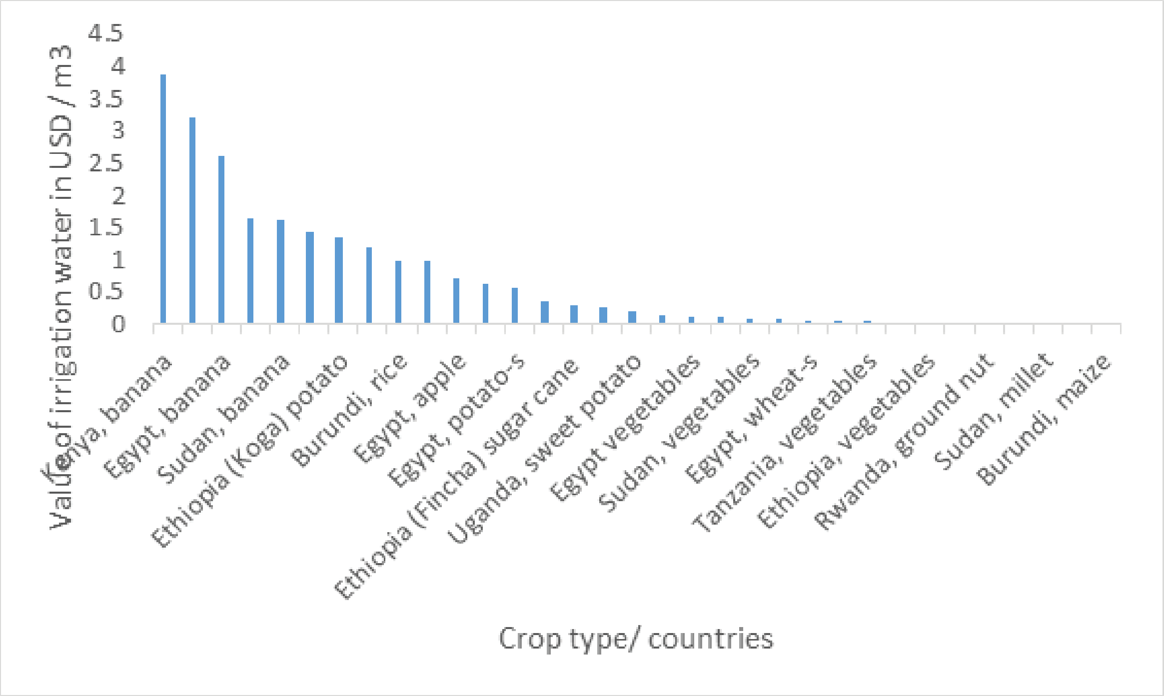


Source: Authors' computation

Compared across typologies, using farm-gate scenario, the value of irrigation water for rice, one of the crops grown across typologies, in Egypt, Burundi, Kenya, Tanzania and Uganda is 0.09, 0.07, 0.38, 0.01 and 0.01 USD /m^3, respectively. The value of irrigation water for rice is lower in the lowland typologies compared to intensive typology, except for Tanzania. The value of water vegetable in the extensive highland (0.03 USD /m^3) is lower than the one estimated in intensive (0.12 USD /m^3) and the semi-intensive typology (0.09 USD /m^3), and in the extensive lowland in Kenya (0.37 USD /m^3) and Tanzania (0.05 USD /m^3). The estimated value of irrigation water for banana in the intensive system is 0.68 USD /m^3, higher than semi-intensive (0.21 USD /m^3) and extensive highland (0.11 USD /m^3)and in Burundi (0.20 USD /m^3), but lower than lowland typologies in Kenya (0.75 USD /m^3). The value of water for cotton in Egypt, Sudan, Ethiopia, and Tanzania is 0.25, 007, 0.04, and 0.01 USD /m^3, respectively, implying that it is economical to grow cotton in extensive highland and lowland typologies than intensive and semi-intensive typologies. The value of water for sweet potato in Ethiopia, Kenya, Rwanda and Tanzania is 0.25, 0.37, 0.30, and -0.21 USD /m^3, respectively, implying that it is economical to grow sweet potato in extensive highland typologies compared to lowland typologies.

The estimated value of irrigation water (when global prices are considered) is reported in Annex II Tables B1-B11, Figure 3). As indicated, banana has the highest value of water followed by apple, potato, cotton, rice, vegetables, wheat and maize; and rice with values 2.61, 0.71, 0.56, 0.26, 0.15, 0.12, 0.07, and 0.02 USD /m^3 respectively. Sorghum is identified as an infeasible crop in the intensive irrigation. In the semi-intensive system banana has the highest water value of 1.61 USD /m^3 followed by crops like vegetables, cotton, sorghum and millet having values of irrigation water of 1.61, 0.09, 0.07, 0.01, and 0.01 USD / m^3 respectively. Wheat is found infeasible crop in the semi-intensive irrigation system, In the extensive highland system, banana has the highest water value of 3.22 USD / m^3, while sweet potato, potato, cotton, and vegetables have values of 3.22, 1.65, 1.35, 0.04, and 0.03 USD /m^{3,} respectively. Sorghum, wheat and maize are found as infeasible crops in the highland extensive typology. In the Fincha Schemes, sugarcane has a water value of 0.31 USD /m^3. In the extensive equatorial lakes region, banana in Kenya and Burundi record 3.88 and 1.20 USD /m^3, respectively. The value of irrigation water of vegetables in Kenya, and Tanzania are 0.37, and 0.05 USD /m^3 respectively. Rice in Kenya and Burundi has a water value of 0.03 and 01.0 USD /m^3 while it is found infeasible in Rwanda and Tanzania. However, Sweet potato in Kenya, Rwanda, and Uganda have 0.63, 1.45, and 0.21 USD /m^3, respectively, but it is infeasible in Tanzania. The values of irrigation water for groundnuts in Rwanda and for cassava in Uganda are 0.03 and 0.09 USD /m^3, respectively. The values of irrigation water for sugarcane in Kenya is 0.12 USD /m^3.

Figure 3: Value of irrigation water considering global prices in USD/m^3 (omitted negative values)



Source: Based on authors' computation

When compared across the typologies, the value of irrigation water for rice in Egypt, Burundi and Kenya is 0.15, 1.00, 0.03, USD /m^3, respectively, but it was found infeasible in Tanzania and Uganda. The value of irrigation water for rice is lower in Kenya compared to that of the intensive typology. The value of water vegetables in the extensive highland (0.03 USD /m^3) is lower than the one estimated in Tanzania (0.05 USD /m^3), in the intensive typology (0.12 USD /m^3), in the semi-intensive typology (0.09 USD /m^3) and in the extensive lowland Kenya (0.37 USD /m^3, implying that it is water-expensive growing vegetables in the intensive and the semi-intensive typologies in comparison to cultivating the same in the extensive highland The water value estimates for banana in the intensive, semi-intensive, extensive highland and extensive lowland are 2.62, 1.61, 3.22, 0.20 and 2.54 (average) USD /m^3, respectively, indicating it is water-expensive to grow banana in the intensive typology, extensive highland and lowland extensive highland compared to the semi-intensive typology. It is still economical to grow banana in Burundi compared to the intensive, extensive highland and semi-intensive typologies. The value of water for cotton in Egypt, Sudan, Ethiopia, and Tanzania is 0.26, 0.07, 0.04, and 0.02 USD /m^3, respectively, implying that it is economical to grow cotton in the extensive lowland typologies than in the intensive, semi-intensive typologies and extensive highland. The value of water for sweet potato in Ethiopia, Kenya, Rwanda and Tanzania is 1.65, 0.63, 1.45, and 0.31 USD /m^3, respectively.

Analysis of trends in both scenarios indicate that the value of water for crop categories in almost all typologies are higher under global price scenarios. The value of water for perennial crops (banana only) is highest in the intensive typology (the exception is Kenya from the lowland extensive) and lowest in the extensive highland under farm-gate scenario, but the reverse is true under global price scenarios. The value of water for vegetables is highest in intensive typology (the exception is Kenya from the lowland extensive) and lowest in the extensive highland under both farm-gate and global price scenarios. The value of water for staple crops (including rice), under farm-gate and global price scenarios was the highest for intensive irrigation typology and extensive lowland (particularly Burundi), while the lowest was for extensive highland, semi-intensive and lowland extensive (particularly Tanzania). The water value for root crops was highest in Uganda and lowest in extensive highland under farm-gate scenarios. Under global price scenarios, water value for root crops was highest in extensive highland and lowest in Uganda. The water value for industrial crops was the highest under intensive and lowest in lowland extensive (particularly Tanzania) under both under farm-gate and global price scenarios. Moreover, the value of water of many staple crops, especially in the extensive highland and lowland, was negative under global price scenarios.

7.2. Factors Influencing Differences in Economic Values of Water

Zilberman and Schoengold (2005) indicated that high-value crops such as fruits and vegetables are profitable with a water price of several hundreds of dollars per 1,000 m3. The authors indicated that the irrigated field crops in many regions are economically viable as well.

Whittington et al. (2005) assumed that the economic value of water for irrigation is typically in the range of USD 0.01 – 0.25 per meter^3. According to the model results (Figure 1, Figure 2 and Annex I and Annex II), the economic value of water for the same crops varies considerably across typologies and the estimates are generally on a higher scale.

The economic value of irrigation water is essentially determined by the crop yield and the amount of water applied in production. Despite a very high rice yield in Egypt, the country is found to have quite a high value of irrigation water for the crop due to the very high amount of irrigation water applied in the production of the crop compared to countries in other typologies. The positive contribution of a high yield to economic value of water is counterbalanced by the very high-water consumption of the crop. Similar reasoning explains the differences in the economic values of water for banana across the countries. Crop prices also significantly contribute to the differences in the economic value of water across crops within the same typology as well as similar crops in other typologies/countries. Since crop prices positively influence economic value of water, producer prices of crops used in this study that apparently differ across crops and countries are expected to have significant effect on the estimated water values. Accordingly, perennial and vegetables (cash) crops that command higher market prices tend to generate higher value of water compared to food crops that command relatively lower prices. Besides, yield differences between cash and food crops, differences in water consumption across crops determine the differences in economic value among crops.

7.3. Reliability of the Estimated Water Values

From a study in Egypt, El-Gafy and El-Ganzor (2012) indicated that the economic value of irrigation of the same crop varies from one governorate to the other even in the same region, despite having a similarity in agro-ecology; or between different governorates, due to differences in the cost and revenue of crop production and the quantity of irrigation water. Their estimates for different crops in 2009 are as follows: wheat, maize, sorghum, rice, cotton, sugarcane, tomatoes and potatoes are 2.5, 0.9, 0.6, 0.5, 0.8, 5.5, 4.8 and 4.7 LE[3]/m^3). Hosni et al. (2014) provide recent estimates of the economic value of several winter, summer and nili crops for three governorates in Egypt (Dakhlia, Qaliobia and Sharkia). The authors calculated the economic value of water as the net return from crops in each governorate divided by water input applied to the respective crop in the respective governorates. Net return is computed as the difference between total return, (i.e., total production multiplied by farm-gate price) and the total costs, including land preparation, seeds, fertilizers, irrigation, agricultural services, pest resistance, harvest crop transportation and public expense costs. Tesfaye et al. (2016), using RIM estimated the water value for cereals and vegetables in Ethiopia as USD 0.03 and 0.1/ m^3, respectively, where the estimates for cereals are on the higher side while the value for vegetables are on the lower side compared to our estimates.

For comparison, we report evidences from other continents. Al-Karablieh et al. (2012), using RIM reported that cucumbers had the highest water values, i.e., about Jordanian Dinar (JD)[4] 6.05/ m^3, followed by string beans with JD 2.64/ m^3, and sweet pepper with JD 2.54/ m^3. The lowest returns per m^3 were provided by squash, radish and hot pepper. For fruit trees, banana has the highest water value JD 0.79/ m^3 and olive trees have the lowest with only JD 0.069/ m^3. From Pakistan, Ashfaq et al. (2005) reported the economic value of irrigation water for wheat, rice, sugarcane and cotton as Pakistan Rupees (Rs.)[5] 1.13, 0.63, 0.30 and 1.52 m^3, respectively. For the minor crops, i.e., potato, onion, and sunflower, the economic value of irrigation water was Rs. 6.60, 13.10, and 0.53 m^3, respectively. Finally, in Mexico Homero Yedra et al. (2016) reported focusing on the banana crop, that irrigated farms are 34–37% more profitable than rain-fed ones, with corresponding water values of 1.48–1.75 USD/m^3.

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[3] Egyptian Pound ~ 0.057 US Dollar.

[4] Jordanian Dinar ~ 1.41 US Dollar

[5] Pakistan Rupee ~ 0.0072 US Dollar

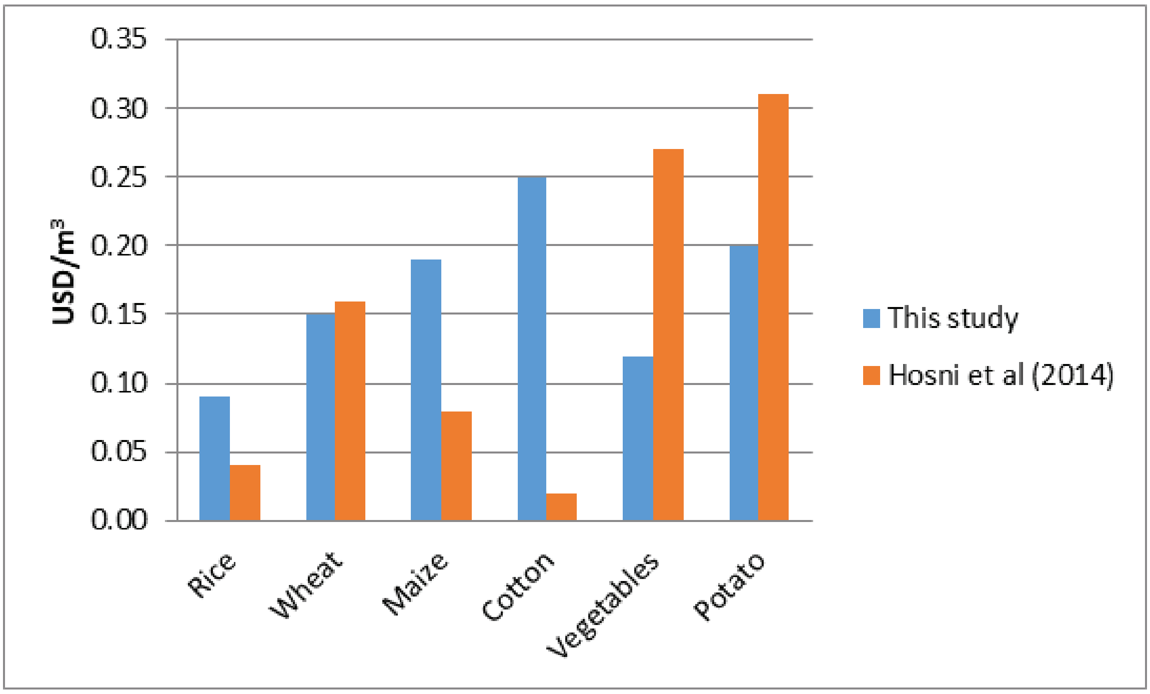
Table 5: Comparison of estimated results for Egypt with previous study (Hosni et al. 2014)

Crops	**Estimated Economic Values of Irrigation Water (USD/m³)**		
	This study (A)	**Hosni et al. (2014) (B)**	**Difference C=A-B**
Rice	0.09	0.04	0.05
Wheat	0.15	0.16	-0.01
Maize	0.19	0.08	0.11
Cotton	0.25	0.02	0.23
Vegetables	0.12	0.27	-0.15
Potato	0.20	0.31	-0.11

Source: Results of this study and Hosni et al. 2014

With a view of assessing the reliability of our results, the current estimated water values, using farm-gate prices, for Egypt are compared with results of Hosni et al. (2014). The method applied by Hosni et al. (2014), as indicated above, is similar and, hence, comparable to the current study. Table 5 and Figure 4 show the results of this study and the average value of the results for the three governorates. The comparison is made for two winter crops (rice and cotton) and four summer crops (wheat, maize, vegetables, and potato) that are common to both studies. The results show some difference between the estimates of the two studies for all crops except for wheat and rice where the estimates do not vary much. The results of this study show higher estimates of economic value of water for the winter crops (rice and cotton) as well as the summer crop (maize); while Hosni et al. (2014) found the water value of wheat, vegetables and potato to be higher varying on average by 0. 02 USD/m³.

Figure 4: Comparison of estimated results with previous study (Hosni et al. 2014)



Source: Results of this study and Hosni et al. 2014

Possible causes of the variations in water values for winter and summer crops in Egypt, reported in this study and in Hosni et al. (2014), could be due to differences in spatial and temporal conditions and the range of inputs considered in both studies. While Hosni et al. (2014) confine their study to three governorates, this study considers the broader Egyptian part of the Nile Basin. That is, the aggregation effect could be one cause of the difference. Besides, the former is based on revenue (yield and crop prices) and costs (price and amount of inputs) that prevailed in 2014, while the latter is based on data for 2016/17. Considering the variations in the water values reported in the two studies, it is evident that values vary by location and time of the study. Due to lack of data, this study considered limited number of inputs compared to that by Hosni et al. (2014). By the very nature of the model used, the cost of omitted input is reflected in the residual value of water.

According to Al-Karablieh et al. (2012) the water value 0.60 USD/ m^3 for banana in Jordan was on the higher side, except for the estimated value in intensive irrigation. This study's estimates on the water value for cereals and vegetables in Ethiopia are on lower and higher side respectively, compared to estimates by Tesfaye et al. (2016). Finally, compared to Whittington et al. (2005) our estimates in intensive irrigation are on the higher side while estimates in other typologies are within the range, except for few exceptions.

8. CONCLUSION AND POLICY IMPLICATIONS

Water demand for irrigation is steadily growing in the Nile Basin because of 1) planned irrigation expansion; 2) inefficient water use along all the riparian countries; and 3) poor water allocation problems between the upstream and downstream countries. The supply is becoming uncertain due to climate changes influencing precipitation, temperature, surface water flow and the rise in the sea level. Overcoming this mismatch between demand and supply calls for technological solution like groundwater use, augmenting supply, conservation, improved irrigation management etc., and institutional solutions introducing water tariffs to encourage users to conserve and save water. The focus of this study is valuing water using publicly available data.

The economic value of irrigation water by crop categories, namely food, perennial, vegetables, root and industrial crops, is estimated and reported. The results, under farm-gate scenarios, for all typologies, indicated that perennial crops showed relatively first highest value of water (ranging between 0.20 - 0.89 USD /m^3). Value of irrigation water for vegetables ranging between 0.09 and 0.37 USD /m^3 was the second highest value. Water value for root crops, manly potato, sweet potato and cassava ranging between 0.03 – 0.37 USD /m^3 the lowest was recorded for sweet potato. Value for food crops, generally, have a low economic value of water ranging between 0.01 –2.75 USD /m^3, except for maize in Burundi whose value is estimated at USD 2.75/m^3. Among the examined crop the least value was recorded for industrial crops ranging between 0.01 - 0.31 USD /m^3.

The results, under global price scenarios, for all typologies, indicated that perennial crops showed very high value of water (ranging between 1.20 – 3.22 USD /m^3). Value of irrigation water for root crops, manly potato, sweet potato and cassava was ranging between 0.21 - 1.65 USD /m^3, and it was the second highest value. The value for industrial crops range between 0.02 - 0.31 USD /m^3; water value for vegetables, range between 0.03 – 0.12 USD /$m^3$and, the value for food crops that generally have a low economic value of water ranging between 0.01 –0.15 USD /m^3 were the third and fourth highest value respectively.

Considering global scenarios, Burundi from the lowland extensive, followed by Sudan and Egypt from semi-intensive and intensive typologies, respectively, have the lowest value of water implying that they may be able to export banana to countries in other typologies. Ethiopia, Tanzania and Sudan from the extensive highland, lowland and semi-intensive irrigation, respectively, have the lowest value of water for vegetables implying that they may be able to export vegetables to countries in other typologies. Only Egypt, from the intensive typology, has the lowest value of water for maize and wheat, while other producing countries having zero and negative values, it could consider for exporting. Sudan and Burundi from the semi-intensive and lowland extensive, respectively, having the lowest value of water for sorghum, may consider exporting it to other countries. Uganda, Egypt and Ethiopia have the lowest value of water for root crops implying that they may be able to export these crops to countries in other typologies. Tanzania, Ethiopia and Sudan from lowland extensive, highland extensive and semi-intensive irrigation typologies have the lowest value of water for cotton implying that they may be able to export these crops to countries in other typologies. Regarding sugarcane, Kenya from the lowland extensive has the lowest value of water compared to Ethiopia from the extensive highland implying that Kenya may export it to Ethiopia and probably to countries in other typologies.

The value of irrigation water across the different typologies showed a wide range as illustrated earlier and the accuracy of the estimation is adversely affected by poor data availability. As uncertainty of the data was the major hurdle in this study, future direction of research investment needs to focus primarily on generating reliable data. Estimation of basin-wide economic value of water is the value addition of this study. This study is indicative of why more data collection across schemes and countries is essential and provides a good start for regularly updating these estimates. However, using these estimates as a tool for water allocation across countries is dangerous. Countries will be encouraged to start communicating about the need of water valuation, improve data sharing arrangements between countries and data management at the basin scale and gradually introduce water tariffs. Instead of focusing on water allocation, sharing benefits and improve irrigation management in each riparian country is more important. Paisley and Henshaw (2013) recommend focus should be on generating more data and information for the shared resource and enhance collective expertise.

On the development side, maximizing water productivity together with devising incentives for increased exports and enhancing stronger regional integration is crucial.

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ANNEX 1

Table 1 - A1: Revenue, input costs, water use and economic value of irrigation water for winter crops in the Nile Basin, Egypt

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Rice	5.23	277.70	129.39	19.87	29.16	651.22	36.73	1.26	20,037.58	585.34	0.03
Sorghum	4.78	307.90	131.06	20.13	6.93	659.58	37.20	2.94	5,737.22	613.79	0.11
Cotton	1.02	1,840.00	163.12	25.05		820.94	46.30	7.70	6,001.00	805.09	0.13
Banana	23.08	393.30	808.48	124.17		4,068.88	229.50	251.39	5,961.86	3,595.93	0.60
Vegetables	39.76	133.90	474.14	72.82		2,386.24	134.59	1.57	5,878.46	2,254.74	0.38
Apple	19.14	342.70	584.01	89.70		2,939.21	165.78	95.43	6,079.61	2,683.73	0.44

Source: IMPACT DATA, FAOSTAT,

Table 1 - A2: Revenue, input costs, water use and economic value of irrigation water for summer crops in the Nile Basin, Egypt

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Wheat	9.41	286.3	9.87	1.52	53.88	49.67	2.80	2.94	7,880.82	1,814.82	0.23
Maize	12.83	253.3	160.60	24.67	9.69	808.25	45.58	0.66	6,472.69	233.74	0.04
Potato	32.86	166.3	551.36	84.68	320.28	2,774.90	156.51	9.06	8,479.11	1,568.21	0.18

Source: IMPACT DATA, FAOSTAT

Table 1 - A3: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Sudan

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Millet	0.14	583.2	2.55	1.69	4.08	30.27	9.51	0.5	5,015.81	34.47	0.01
Sorghum	1.46	286.3	12.77	3.6	2.72	151.82	20.21	2.65	4,677.05	222.89	0.05
Banana	11.04	253.3	126.84	23.75		1,507.35	133.50	26.41	4,973.05	978.58	0.20
Vegetables	16.64	133.9	124.31	23.27		1,477.28	130.83	29.42	4,883.22	442.52	0.09
Wheat	2.20	547.2	36.94	14.88	65.66	439.07	83.64	33.21	8,050.23	531.60	0.07
Cotton	0.35	1,840	19.15	9.02		227.59	36.31	14.5	5,014.20	330.51	0.07

Source: IMPACT DATA, FAOSTAT

Table 1 - A4: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Ethiopia

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Vegetables	3.66	305.13	32.88	9.86		827.43	106.35	7.76	494.77	131.3	0.27
Cotton	0.25	1,840.00	11.09	3.32		279.09	35.87	10.01	502.30	124.74	0.25
Banana	8.58	214.60	53.77	16.12		1,353.28	173.93	37.84	496.81	207.38	0.42
Sorghum	1.26	286.20	8.80	2.64	2.29	221.60	28.48	0.43	469.00	97.06	0.21
Sweet Potatoes	5.50	150.90	20.21	6.06		508.60	65.37	19.10	5,882.66	209.91	0.04

Source: IMPACT DATA, FAOSTAT

Table 1 - A5: Revenue, input costs, water use and economic value of irrigation water in the Koga Area, Ethiopia

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Wheat	-0.12	406.70	208.03	0.02	59.80	112.09	190.91	82.38	4,385.00	-703.53	-0.16
Maize	2.36	246.80	195.53	0.02	5.50	156.73	84.71	67.91	1,971.50	72.52	0.04
Potato	7.86	165.70	326.16	0.03		250.88	149.74	89.80	837.50	485.22	0.58

Source: IMPACT DATA, FAOSTAT, IWMI studies

Table 1 - A6: Revenue, input costs, water use and economic value of irrigation water in the Fincha Area, Ethiopia

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Sugar Cane	55.53	125.1	130.86	7.65		77.1	109.42	297.3	20373	6,324.18	0.31

Source: IMPACT DATA, FAOSTAT, IWMI studies

Table 1 - A7: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Kenya

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Sugarcane	76.72	32.90	47.42	13.93		926.84	44.95	16.84	11,848.49	1,474.01	0.12
Sweet Potatoes	12.76	191.55	45.91	13.48		897.37	82.71	32.67	5,882.66	1,371.59	0.23
Vegetables	6.95	364.10	47.51	13.96		928.75	82.44	16.25	3,861.65	1,440.27	0.37
Banana	13.58	214.60	25.62	7.52		500.72	132.82	68.30	3,938.75	2,179.29	0.55
Rice	1.68	550.50	17.40	5.11	49.55	340.03	37.09	41.15	2,923.00	435.64	0.15

Source: IMPACT DATA, FAOSTAT

Table 1- A8: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Rwanda

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Rice	1.26	891.6	16.56	21.56		859.28	122.99	2.85	1,376.86	100.8	0.07
Groundnuts	0.33	1,401.3	6.49	8.45		353.21	50.55	0.56	2,164.53	42.77	0.02
Sweet Potatoes	3.93	266.4	12.16	15.83		801.20	114.68	1.54	334.22	102.65	0.31

Source: IMPACT DATA, FAOSTAT

Table 1 - A9: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Burundi

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Banana	2.12	259.90	12.16	13.26	1.95	144.37	107.71	1.08	1,335.63	270.52	0.20
Sorghum	0.56	488.80	6.04	6.58	43.99	71.66	53.47	11.06	1,284.69	80.74	0.06
Rice	1.63	226.30	8.13	8.87	9.62	96.54	72.03	1.41	454.71	171.9	0.38
Maize	0.45	307.80	3.03	3.30		35.91	26.79	0.38	25.16	67.66	2.69

Source: IMPACT DATA, FAOSTAT

Table 1 - A10: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Tanzania

	Yield (irrigated - rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Maize	0.63	302.90	2.79	4.39	4.95	129.47	26.73	0.03	1,174.90	23	0.02
Rice	0.79	464.76	5.38	11.36	27.99	249.09	51.42	0.24	2,923.00	22.69	0.01
Cotton	0.21	1,782.00	5.42	9.02		251.09	51.83	1.30	3,850.36	52.46	0.01
Vegetables	3.04	418.87	18.61	28.65		862.35	178.02	2.86	3,861.65	184.09	0.05
Sweet Potatoes	-0.59	191.00	12.76	10.09			74.87	0.41	1,001.94	-210.72	-0.21

Source: IMPACT DATA, FAOSTAT

Table 1 - A11: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Uganda

	Yield (irrigated – rain-fed) (ton/ha)	Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital costuse (USD/ha)	Irrigation water (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Rice	0.71	668.35	2.04	6.44	51.40	325.18	55.12	4.41	3,746.22	28.37	0.01
Sweet Potatoes	1.32	191.55	1.09	4.02		173.38	34.39	2.75	1,277.62	36.54	0.03
Cassava	3.88	336.60	5.62	13.49		897.66	115.38	9.23	1,143.25	264.23	0.23
Vegetables	1.80	418.87	3.26	12.05		519.78	103.11	8.25	769.94	109.55	0.14

Source: IMPACT DATA, FAOSTAT

ANNEX II

Table 2 - B1: Revenue, input costs, water use and economic value of irrigation water for winter crops in the Nile Basin, Egypt

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Rice	9.37	398.9	52.525	24.86	29.16	651.22	45.98	1.26	20,038	2,932.69	0.15
Sorghum	4.52	163	95.8	13.3	6.93	659.58	24.61	2.94	5,737	-66.40	-0.01
Cotton	1.38	1,840	74.075	23.85		820.94	43.57	7.70	6,001	1,569.07	0.26
Banana	23.08	890	102.71	203.76		4,068.88	376.84	251.39	5,962	15,537.62	2.61
Apple	25.71	300	102.71	81.9		2,939.21	151.46	95.43	6,080	4,342.29	0.71

*Rain-fed agriculture doesn't exist in Egypt

Source: IMPACT DATA, FAOSTAT

Table 2 - B2: Revenue, input costs, water use and economic value of irrigation water for summer crops in Nile the Basin, Egypt

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Wheat	4.52	178.2	71.5	13.3	53.88	49.67	24.61	2.94	7,881	589.564	0.07
Maize	7.39	154.5	102.05	21.05	9.69	808.25	38.93	0.66	6,473	161.123	0.02
Potato	27.24	300	155.4	49.06	320.28	2,774.90	90.73	9.06	8,479	4,772.57	0.56
Vegetables	24.62	133.9	102.71	31.51		2,386.24	58.28	1.57	5,878	716.31	0.12

*Rain-fed agriculture doesn't exist in Egypt

Source:IMPACT DATA, FAOSTAT

Table 2 - B3: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Sudan

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m³/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m³)
Millet	0.14	600	2.55	1.69	4.08	30.26857	9.51	0.5	5,016	35.40	0.01
Sorghum	1.46	163	12.78	3.6	2.72	151.8221	20.21	2.65	4,677	44.20	0.01
Banana	11.04	890	126.84	23.75		1,507.355	133.5	26.41	4,973	8,007.75	1.61
Vegetables	16.64	133.9	124.31	23.27		1,477.285	130.83	29.42	4,883	442.98	0.09
Wheat	2.2	178.2	36.95	14.88	65.66	439.0724	83.64	33.21	8,050	-281.37	-0.03
Cotton	0.35	1,840	19.15	9.02		227.5967	36.31	14.5	5,014	337.42	0.07

Source:IMPACT DATA, FAOSTAT

Table 2 - B4: Revenue, input costs, water use and economic value of irrigation water in Nile Basin, Ethiopia

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m³/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m³)
Vegetables	3.66	305.13	32.88	9.86		827.43	106.35	7.76	4,382	132.50	0.03
Cotton	0.25	1,840	11.09	3.32		279.09	35.87	10.01	3,271	120.62	0.04
Banana	8.58	890	53.77	16.12		1,353.28	173.93	37.84	1,863	6,001.26	3.22
Sorghum	1.26	163	8.8	2.64	2.29	221.6	28.48	0.43	1,972	-58.86	-0.03
Sweet Potatoes	5.5	364.23	20.21	6.06		508.6	65.37	19.1	838	1,383.93	1.65

Source:IMPACT DATA, FAOSTAT

Table 2 - B5: Revenue, input costs, water use and economic value of irrigation water in Koga Area, Ethiopia

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Wheat	1.69	178.2	208.03	0.02	59.8	112.09	190.91	82.38	4,385	-352.07	-0.08
Maize	2.36	154.5	195.53	0.02	5.5	156.73	84.71	67.91	1,972	-145.78	-0.07
Potato	6.49	300	326.16	0.03		250.88	149.74	89.8	838	1,130.39	1.35

*There is no rain-fed wheat production in the Koga area

Source: IMPACT DATA, FAOSTAT, Agide et al. 2016; LIVES, 2014 and Hagos et al. 2009

Table 2 - B6: Revenue, input costs, water use and economic value of irrigation water in the Fincha Area, Ethiopia

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Sugarcane	55.53	125.1	130.86	7.65		77.1	109.42	297.3	20,373	6,324.184	0.31

Source: IMPACT DATA, FAOSTAT, Agide et al. 2016; LIVES, 2014 and Hagos et al. 2009

Table 2 - B7: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Kenya

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m³/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m³)
Sugarcane	76.72	32.9	47.42	13.93		926.84	44.95	16.84	11,848	1,474.11	0.12
Sweet Potatoes	9.62	364.23	45.91	13.48		897.37	82.71	32.67	3,862	2,431.75	0.63
Vegetables	6.95	364.1	47.51	13.96		928.75	82.44	16.25	3,939	1,441.59	0.37
Banana	13.58	890	25.62	7.52		500.72	132.82	68.3	2,923	11,351.22	3.88
Rice	1.68	398.9	17.4	5.11	49.55	340.03	37.09	41.15	5,883	179.82	0.03

Source: IMPACT DATA, FAOSTAT

Table 2 - B8: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Rwanda

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m³/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m³)
Rice	1.26	398.9	16.56	21.56		859.28	122.99	2.85	1,377	-520.63	-0.38
Groundnuts	0.33	1,486.68	6.49	8.45		353.21	50.55	0.56	2,165	71.34	0.03
Sweet Potatoes	3.93	364.23	12.16	15.83		801.2	114.68	1.54	334	486.01	1.46

Source: IMPACT DATA, FAOSTAT

Table 2- B9: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Burundi

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Banana	2.12	890	12.16	13.26	1.95	144.37	107.71	1.08	1,336	1,606.27	1.20
Sorghum	0.56	163	6.04	6.58	43.99	71.66	53.47	11.06	1,285	-101.52	-0.08
Rice	1.63	398.9	8.13	8.87	9.62	96.54	72.03	1.41	455	453.61	1.00
Maize	0.45	154.5	3.03	3.3		35.91	26.79	0.38	25	0.12	0.00

Source: IMPACT DATA, FAOSTAT

Table 2- B10: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Tanzania

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Maize	0.63	154.5	2.79	4.39	4.95	129.47	26.73	0.03	1,175	-71.03	-0.06
Rice	0.79	398.9	5.38	11.36	27.99	249.09	51.42	0.24	2,923	-30.35	-0.01
Cotton	0.21	1,804	5.42	9.02		251.09	51.83	1.3	3,850	60.18	0.02
Vegetables	3.04	418.87	18.61	28.65		862.35	178.02	2.86	3,862	182.87	0.05
Sweet Potatoes	-0.59	364.23	12.76	10.09			74.87	0.41	1,002	-313.03	-0.31

Source: IMPACT DATA, FAOSTAT

Table 2- B11: Revenue, input costs, water use and economic value of irrigation water in the Nile Basin, Uganda

	Yield* (ton/ha)	World Price (USD/ton)	Fertilizer cost (USD/ha)	Pesticide cost (USD/ha)	Seed cost (USD/ha)	Labor cost (USD/ha)	Land cost (USD/ha)	Annualized capital cost (USD/ha)	Irrigation water use (m^3/ha)	Net value of production (USD/ha)	Value of irrigation water (USD/m^3)
Rice	0.71	398.9	2.04	6.44	51.4	325.18	55.12	4.41	3,746	-161.37	-0.04
Sweet Potatoes	1.32	364.23	1.09	4.02		173.38	34.39	2.75	1,278	265.15	0.21
Cassava	3.4	336.6	5.62	13.49		897.66	115.38	9.23	1,143	103.06	0.09

Source: IMPACT DATA, FAOSTAT

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