Draft: Only for discussion

WATER PRODUCTIVITY AND WATER USE EFFICIENCY BRIEF

[December, 2015]

ABSTRACT

The brief is an attempt to survey the literature on water productivity and efficiency with regard to the various forms of calculations and methods used and contribute to the discussion on how to arrive at the best possible method of calculating and improving water productivity.

Vision Management Unit

APSDPS, Planning Department, Government of Andhra Pradesh

BRIEF: POSSIBLE MEASUREMENTS OF WATER PRODUCTIVITY AND EFFICIENCY

A water productivity and efficiency index across sectors for Andhra Pradesh is important to understand how productively and efficiently water is allocated and underutilized or over-utilized across various sectors, how to economize on water, and where water can be reallocated for alternative valuable uses. An increase in agricultural and industrial production can be achieved with the same quantity of water, or more water can be released for irrigation or domestic consumption.

In the scenario of meeting the competing demands of water in the face of its limited supplies, it is peremptory for the state to undertake the initiative of developing a Water Productivity Index on the lines of the Water Productivity Report followed by International Water Management Institute (IWMI) and Central Water Commission (CWC).

Agriculture currently consumes 96% of the total water resources of Andhra Pradesh. The water use efficiency (WUE) for agriculture stands at 29%. By improving the efficiency of water used for agriculture to 60%, it is possible to reduce the amount of additional freshwater withdrawals needed for each sector.

The water use efficiencies of our irrigation systems are around 30% at present. In comparison, developed states like Gujarat and Maharashtra are running their irrigation systems at 45% efficiency. Also, some of the same irrigation systems have demonstrated much higher efficiencies in the past for the state. The water efficiency of industries in Andhra Pradesh is much lesser when compared to other developed states such as Maharashtra. While Maharashtra us able to produce Rs. 31,337 Cr per TMC of water, AP is only able to produce half of it. This implies that there is a vast scope and potential of the existing systems to perform more efficiently by improving their productivities, which illustrates the need for the index.

The brief is an attempt to survey the literature on water productivity and efficiency with regard to the various forms of calculations and methods used for different aspects in productivity and efficiency measurements. The aim is to contribute to the discussion on how to arrive at the best possible method of calculating and improving water productivity.

BASIC CONCEPT OF WATER PRODUCTIVITY (WP):

Productivity is expressed as a ratio of output to input. Therefore, WP is a measure of output of a particular sector/use in relation to the water it consumes.

Water Productivity in Industries:

- Physical Water Productivity:
  - Total Industrial Output (Tonnes) / Quantity of Water used

- Economic Water Productivity:
  - Total Industrial Output (Cr) / Quantity of Water used

Water Productivity in Agriculture:

Water productivity for agriculture is generally defined as crop yield per cubic metre of water consumption. For the rain-fed areas, it includes 'green' water (effective rainfall) and for the irrigated areas it includes both 'green' and 'blue' water (water which is diverted from water systems). The following is the method as used by IWMI:

$$\mathrm{WP}\ (\mathrm{kg\ m^{-3}}) = \frac{\mathrm{P\ (kg)}}{\mathrm{WC\ (m^3)}}$$

$$\mathrm{WC} = \mathrm{BWC} + \mathrm{NBWC} = \frac{\mathrm{BWC}}{\mathrm{BE}}$$

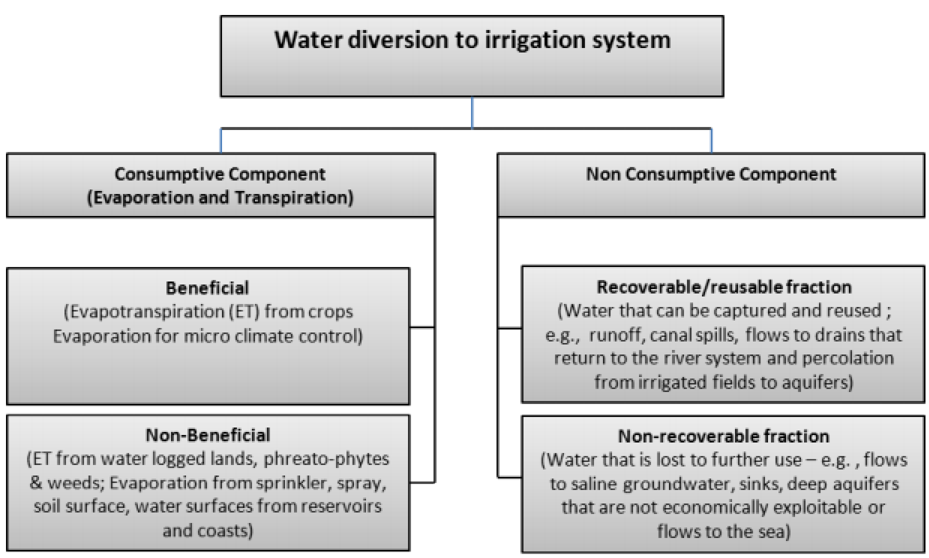
WC includes beneficial water consumption (BWC) and non-beneficial water consumption (NBWC).

$$P = A \times Y$$

$$A = A\ (\mathrm{BWC}|\mathrm{ETC},\ \text{crop prices, irrigation investment})$$

$$Y = Y\ (\mathrm{BWC}|\mathrm{ETC},\ \text{crop prices, input prices, agricultural research investment})$$

where A is the crop harvested area, Y is the crop yield and ETC is the crop evapo-transpiration requirement.



Source: Water conservation and Irrigation, ICID, New Delhi, India, http:/www.icid.org

VARIATIONS IN METHODOLOGY:

The term water productivity (WP) is also defined and used in a variety of ways. While, the most encompassing measure of productivity used by economists is total factor productivity (TFP), which is defined as the value of all output divided by the value of all inputs. Other than this, the concept of partial factor productivity (PFP) is also widely used.

The following are the measures of partial factor productivity:

1. Pure physical productivity is defined as the quantity of the product divided by the quantity of the input. Examples include crop yield per hectare or per cubic metre of water either diverted or consumed by the plant. This is followed by organizations such as IWMI in their objective of 'increasing the crop per drop'.

2. Another is productivity which combines both physical and economic properties. It is defined in terms of either the gross or the net present value of the product divided by the amount of the water diverted or consumed by the plant.

3. Economic productivity is the gross or net present value of the product divided by the value of the water either diverted or consumed by the plant, which can be defined in terms of the value or opportunity cost in the highest alternative use.

POSSIBLE NUMERATORS FOR WATER PRODUCTIVITY
Yield (kg) of total biomass, or above ground biomass, or grain, or fodder.
Gross value of product, or net value of product, or net benefit of irrigated production compared with rainfed production.
Any of the above valuations including those derived from raising livestock, fish or agro-forestry.
Monetary value of all direct and indirect economic benefits minus the associated costs, for all uses of water in the domain of interest.

POSSIBLE INDICATORS USED IN WP	INDICATORS
Water productivity-based indicators	Average product per unit of water
	Average gross value of product per unit of water
	Average gross margins per unit of water
	Average gross net value of product per unit of water

Commonly used denominators for calculating water productivity based indicators are amount of water diverted/supplied, water applied, gross inflow of water (rainfall plus irrigation), and crop evapotranspiration (Et).

World Bank uses the term Single-factor productivity index for partial productivity.

1. SINGLE FACTOR OR PARTIAL PRODUCTIVITY:

Typical Features:

• **Input Factors:** One input (water), one output (usually crop yield or revenue)

• **Scale:** Any scale, from field and basin level (and global)

• **Water Variable:** Water withdrawn, applied, consumed (as quantity)

• **Prices:** Sometimes considered for output, not for input; variable and fixed costs are not taken into account

• **Economic Approach:** Implicit water-crop production function (yet usually without consideration of other inputs); no underlying economic model

• **Focus:** Partial productivity

• **Aim:** Maximizing "crop per drop" ratios

Pros:

- Simple approach

- Ratios easy to compute and compare

Cons:

- All variations in output attributed to one input

- Average, not marginal productivity

- No consideration of possible input or output substitution

- No prices or costs considered

- No insight into variables that cause differences

- Little value for policy analysis

2. TOTAL FACTOR PRODUCTIVITY:

Typical Features

• **Input Factors:** "All"/multiple inputs, "all"/multiple outputs

• **Scale:** Usually whole agricultural sector at the national level

• **Water Variable:** Water usually only indirectly taken into account (for example, by distinguishing between irrigated and non-irrigated cropland); irrigation fees are sometimes included

• **Prices:** Used for aggregation of inputs and outputs (though prices are not required for some indices); for water only irrigation fees included (if at all)

• **Economic Approach:** Growth theory

• **Focus**: Technological progress

• **Aim:** Gauging technological progress over time and/or across countries

Pros:

- Analysis of overall performance of a country's agricultural sector across

Cons:

- Difficulty of including water (data lacking at national level, both for quantity and price), and thus little insights into effect of water on productivity.

- Typical assumption of technically efficient firms may not be true.

BASIC CONCEPT OF EFFICIENCY:

The term water use efficiency (WUE) implies performance of the water from the point water is delivered for a specific use till it is consumed.

Irrigation WUE:

The Central Water Commission has provided guidelines for calculating WUE in irrigation which are widely considered to be the standard definition of WUE, as follows:

WP= WR X WC X WF X WD

where WP = Overall Efficiency of Project

WR = Reservoir filling Efficiency/Diversion Efficiency/Operational Efficiency

WC= Conveyance Efficiency

WD = Drainage Efficiency

VARIATIONS IN METHODOLOGY:

Drinking-water distribution efficiency:

Calculations of Water Productivity for drinking water are difficult, and instead WUE is considered to be a suitable method for the purpose.

WUE in domestic sector as used by Mediterranean Countries is the fraction of drinking water produced, and distributed that is paid for by users:

Epot = V1 / V2 where

V1= volume of drinking water billed and paid for by users in km3 per annum

V2 = total volume of drinking water produced and distributed in km3 per annum (drinking water demand)

The index measures both the physical efficiency of the drinking-water distribution networks (loss rates or efficiency) and the economic efficiency, i.e. the ability of network managers to recover costs from users.

Irrigation-water efficiency

The physical efficiency of irrigation water is equal to the efficiency of the irrigation-water conveyance and distribution networks multiplied by the plot efficiency:

Eirr = E1 x E2, where

• E1 = the efficiency of the irrigation-water conveyance and distribution networks, upstream of the agricultural plots, measured as the ratio between the volume of water actually distributed to the plots (V3) and the total volume of water allocated to irrigation (V4) upstream of the networks, which includes the losses in the networks (i.e. V4 = irrigation-water demand):

E1 = V3/V4

• E2 = plot-irrigation efficiency, defined as the sum of the (plot) efficiencies of each irrigation method (surface irrigation, sprinkler irrigation, micro-irrigation and other methods), weighted according to the respective proportions of the various methods in each country and estimated as the ratio between the quantity of water actually consumed by the plants and the quantity of water brought to the plot:

$$E_2 = \sum_1^n \frac{S_m \times E_m}{S}$$

• n: number of irrigation methods used

• Sm: surface area irrigated using method

• Em: efficiency of method

• S: total surface area irrigated in the country (all methods combined)

Other methods such as the International Commission on Irrigation and Drainage takes the definition of efficiency for irrigation systems a stage further and take into consideration the fact that water "lost" from canal conveyance might be later be reused when a farmer pumps from groundwater. In this context ICID argues that improving irrigation efficiency needs to focus on increasing beneficial consumption and reducing non-beneficial consumption and the non-recoverable fraction.

Industrial-water efficiency:

This is the fraction of industrial water that is recycled (recycling index):

$$Eind = V5 / V6$$

V5= volume recycled water (km3 per annum)

• V6 = volume of raw water used in the industrial processes, which is equal to the volume newly entering an industrial facility + the volume of water recycled (km3 per annum)

Total efficiency:

The total physical efficiency of water use is defined as the sum of the ratios of the quantities of water used in each sector (demand less losses) to the demand of this sector, weighted by the fraction of total demand used by each sector (drinking water, irrigation and industry).

$$E = \frac{(Epot \times Dpot + Eirr \times Dirr + Eind \times Dind)}{D}$$

Dpot : domestic demand (drinking water),

Dirr: irrigation-water demand,

Dind : industrial-water demand,

D: total water demand

Water demand is defined as the sum of the volumes of water mobilised (excluding "green water" and "virtual water") to satisfy the various uses, including the volumes lost during production, conveyance, distribution and use; it corresponds to the sum of the volumes of water extracted and non-conventional production (wastewater reuse and desalination), all reduced by any exports.

Engineering and agronomic perceptions to water use efficiency

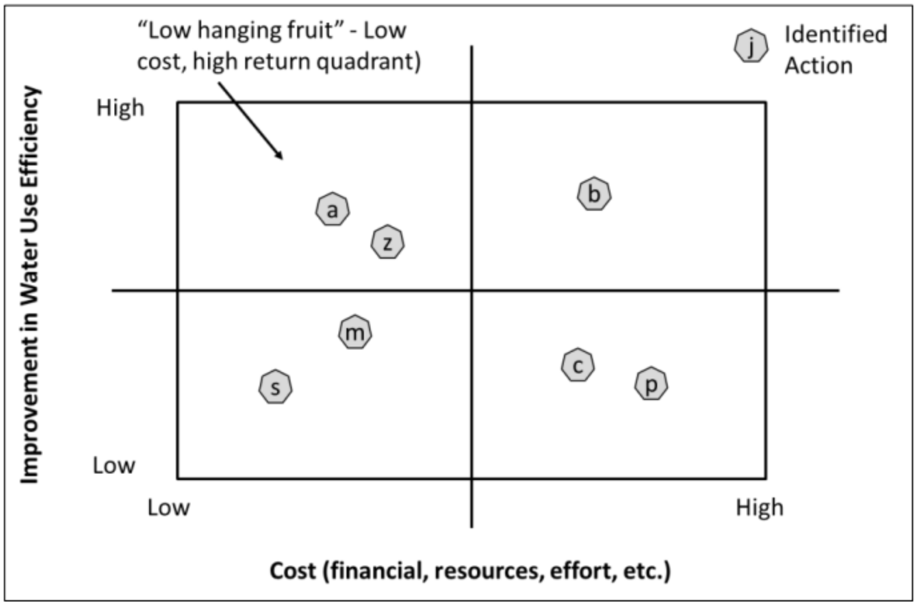
Term	Engineering Perception
Overall project efficiency (Ep) = Ec*Ed*Ea	Irrigation water available to crop / Total inflow into the system
Conveyance efficiency (Ec)	Total outflow from the system supply / Total inflow into the system supply
Distribution efficiency (Ed)	Water received at the field inlets / Total outflow from system supply
Field application efficiency (Ea)	Irrigation water available to crop / Water received at fields inlet
Term	**Agronomic Perception**
Overall irrigated crop use efficiency (Ep , c) = Ep*Ecrop	Beneficial Water used by the crop / Total inflow into the system
Crop water use Efficiency (Ecrop)	Beneficial Water used by the crop Irrigation water available to crop

PRODUCTIVITY VERSUS EFFICIENCY:

Productivity of any process refers to an amount of any resource that must be spent (input) to produce one unit of another substance (output). Higher productivity is contingent on lesser input spent per unit of output. In all calculations of productivity, the numerator and denominator are taken to have different units, such as the yield or crop productivity could be kg/ha of the cropped area or Kg/m3 of water applied. Productivity is often referred to as a performance index and productivity of water use may be referred as water use productivity (WUP).

Efficiency on the other hand is simply ‘productivity’ where the numerator and denominator have the same units and its measure is thus a ratio or a dimensionless index. Amount of water spent by a crop per unit of water delivered is thus efficiency.

Often the terms efficiency and productivity are used synonymously. While WUE is used more appropriately in an engineering sense, productivity is used in a physical or economic sense. An irrigation scheme consists of two distinct processes, starting from where water is provided from the source to each field and the other being ensuring optimum production through available water within the field. Thus, water use efficiency is concerned with the engineering performance of the conveyance system till field inlet and productivity is synonymous with agronomic productivity of the crops grown in the field.



Source: Amarjit S Dhingra and Martin A Burton (2014). Scoping Study for a National Water Use Efficiency Improvement Support Program.

DECISION MATRIX PRIORITISING ACTION TO IMPROVE PERFORMANCE & WUE:

The ideal quadrant of operation is the "low hanging fruit" which needs to be identified. This one represents the most effective interventions which can be introduced quickly and at low cost which will result in measurable improvements in performance, and thus user satisfaction with service delivery. This concept is likely to include the following steps as highlighted in the reports:

1. Technical

- Targeted maintenance work, including desilting
- Repair of old and installation of new control structures
- Upgrading of existing and installation of new measuring structures
- CAD works to improve water distribution at on-farm level, preferably with lined channels or buried pipes (head permitting)
- Selective lining of distributaries and minors
- Introduction of control and measurement structures for minor offtakes/outlets)
- Re-engage with participatory irrigation management

2. Institutional

- Strengthen WALMIs and NGOs to support PIM
- Educate the ID in benefits of farmer participation
- Strengthen WUAs in water management and maintenance.
- Support WUAs in employing field staff (water masters) by using
- Rebates from the water charge
- Setting performance targets

3. Management

- Measure performance, including crop production
- Establish modern data collection, processing and analysis
- procedures, based on ITES.
- Liaise and work with water users
- Train ID staff in MOM
- Improve scheduling to allow for rainfall
- Monitor deliveries, establish user feedback system
- Establish incentives and reward system for ID staff related to scheme performance and achievement of targets
- Amend the PIM Act to be more farmer-friendly and less prescriptive

4. Legal

- Amend the PIM Act to be more farmer-friendly and less prescriptive (involve water users in the redrafting)

5. Finance

- Carry out asset management surveys and prepare Asset Management plans (AMPs) for individual schemes
- Increase funding to match AMPs
- Assess the benefit/cost of increasing maintenance budget

6. Policy

- Focus on performance management
- Accept PIM and farmer involvement in scheme management
- Accept that management plays a central role in improving agricultural production and water use efficiency
- Change the culture of the ID, from construction to management focus
- Make the ID a multi-disciplinary organisation, with specialist
- Expertise in a wide range of disciplines (irrigation, groundwater, ITES, computing, PIM, agriculture, etc.)

REFERENCES

ADB (2012). Sector Study on Development of Synthesis and Draft Action Plan for improving Water Use Efficiency of irrigated Agriculture in selected Indian states; Amarjit S Dhingra and Rahul Sen.

ADB (2012). Sector Study on Development of Synthesis and Draft Action Plan for improving Water Use Efficiency of irrigated Agriculture in selected Indian states; Amarjit S Dhingra and Martin A Burton.

ADB (2014). India: Support for the Implementation of the National Water Mission by State Governments in India: Scoping Study for a National Water Use Efficiency Improvement Support Program; Amarjit S Dhingra and Martin A Burton.

Central Water Commission (2010). Handbook for Computing the Water Use Efficiency for Irrigation Projects, Central Water Commission, POMIO Directorate, Sewa Bhawan, R.K. Puram, New Delhi, India.

Plan Bleu (2012). Water Efficiency: More Efficient Water Use in the Mediterranean. M. Blinda

World Bank (2014). Water Productivity: Considering more carefully the farm-level perspective; Dennis Wichelns.

About the Vision Management Unit

Government of Andhra Pradesh established a Vision Management Unit (VMU) under the Planning Department for strategic management of vision programmes and projects to coordinate actions among all concerned stakeholders from within the government and outside in terms of planning, implementation and monitoring. Apart from integrating various vision initiatives and interventions into the annual planning and budgeting processes of the state government, the VMU also monitors and publishes periodicals and thematic studies on the transformation areas identified in the vision to provide an integrated picture of vision achievements.

The unit is a vibrant team of young professionals from diverse backgrounds who work together on data, targets, performance indicators, global studies, best practices and global standards to prepare recommendations to achieve the state's Vision 2029.

Our Office

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