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International Commission on Irrigation and Drainage

Commission Internationale Des Irrigations Et Tu Drainage

Draft: Position Paper on Water Accounting as a Sustainable Agricultural Water Management Framework, 2019

Abstract

Owing to fast-paced demographic and climate changes, water scarcity has become a critical issue that needs to be quantified in a systematic manner at various spatial and temporal levels. Unfortunately, the present global water demand is projected to increase by 55% with increased competition among various sectors of the economy by the year 2050 which could result in a reduced share for agriculture. Most countries lack coordination between water governance, management and technological upgrades due to lack of appropriate water information systems resulting in inefficient agricultural water management. Furthermore, water governance is not based on scientific analysis and the outcome is inconsequential policies. To remedy this, based on the water balance approach, a framework for water accounting and auditing is proposed to systematically report the water resources and associated hydrological information comprehensively to facilitate the decision-making for sustainable agricultural water management (AWM). As a consistent, reliable and transparent source of water information, water accounting (WA) can play a key role in resolving environmental, economic, political and social issues at individual, organizational, state, national and even international levels by providing necessary water information to the respective stakeholders in agriculture as well as other sectors. Water Accounting Framework can also serve as the potential stepping stone to accomplish higher economic growth and responsive water governance and consequently contribute towards the sustainable development and management of water resources for all.

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Background

Food and Agriculture Organization of the United Nations (FAO) organized an online discussion on "Water Accounting and Water for Food" from 9 June to 21 July 2017 in which International Commission on Irrigation and Drainage (ICID) and several of its stakeholders participated actively. This discussion, facilitated by FAO, was organized as part of the World Water Council (WWC) Members' initiative on water accounting (WA) for decision-making in the agricultural sector. It aimed to raise the profile of WA for water strategy and policymaking and demonstrate the value addition that WA can bring in smart planning processes in water governance and management. The main objective of this initiative was to raise the awareness of the significance of WA for decision-making and planning and gather evidence and experiences through a process consisting of expert consultations and interactions. The online discussion covered topics starting from how to define WA, how it should be implemented to who can benefit from it and how.

Few WA examples from around the world were also shared during the e-discussion and in coordination with the topic of the discussion, ICID organized webinars on water accounting and Australian experiences of using WA in national water management. The Webinars were very well attended by both ICID members and the participants of the above online discussion. During the online discussion, ICID also got an opportunity to state briefly its position on the whole issue of WA through various contributions and this paper further elaborates on these contributions and updates on ICID activities in this area.

As a follow up of the above e-discussion, WWC members, including ICID, prepared a White Paper on WA for policymakers. Considering the potential utility of WA as an agricultural water management tool, ICID has developed this detailed position paper parallelly, based on the ICID work on "water balance approach" over the last several years and its ongoing activities, for sharing with its national members as well as international partners including WWC and FAO. The WWC White Paper was launched at the 8th World Water Forum in March 2018. It should also be noted that this initiative further contributes to the work plan of the Global Framework on Water Scarcity[1] (currently named as Water Scarcity in Agriculture, WASAG) launched at the Marrakech climate conference in 2016.

The main objective of this ICID paper is to initiate a discussion and evolve a consensus among ICID stakeholders on WA and its potential benefit in AWM through national-level planning. ICID as a multi-country professional group is committed to improving the status of agricultural water management and water governance through its various avenues such as facilitating research and technology, raising awareness and water stewardship through knowledge exchange and knowledge dissemination. The concept of water accounting and auditing is gaining popularity amongst the technical experts in the field of hydrology and water resources management. However, it is equally important for the other stakeholders to appreciate the water data democracy offered by WA process and consider it as a legitimate tool for decision-making in the agricultural sector.

To this end, ICID is organizing events and activities with the active participation of hydrology experts, irrigation managers, policy-makers, extension community, farmers and other relevant stakeholders on the same table to discuss the topic at length and various avenues through which it can contribute to a sustainable AWM. Such events include triennially organized congress, world irrigation forum and regional conferences organized all over the world. These events focus on the sustainability of irrigation where international and national experts participate and discuss strategies to combat global water and food security issues. ICID has also conducted multi-lingual educational Webinars on WA topics for a wider audience from different fields of expertise. In addition to English, the most recent ICID Webinars were conducted in Spanish and Arabic for the benefit of

[1]Water Scarcity is defined as the excess demand of water over the supply (FAO, 2012).

professionals from Latin America and the Middle East. ICID believes this approach will encourage better worldwide participation of water experts in the formulation of a transparent water governance system.

To design appropriate AWM strategies, consistent hydrological information and appropriate decision-making tools should be available which can form the basis of sound policies. This institutional decision-making process entails participation from different institutions involving multiple stakeholders such as researchers, lawyers, environmentalists, and so forth. Technical experts from international organizations such as IWMI, IHE-Delft, FAO, and UNESCO-WWAP are advocating WA as a robust, integrated and standardized concept for effective and sustainable AWM. Another important objective of this paper is to establish a common understanding of the basic terminology used by practitioners from different sectors working to avoid confusion during decision-making towards a common goal of efficient water management. In this regard, ICID's Multi-lingual Technical Dictionary is being updated as a validated repository of technical terms pertaining to irrigation, drainage and agricultural water in general.

Water Sector and Current Issues

Amongst the vital natural resources, water is rapidly becoming the most critical topic of discussions centered on environmental management, food security, climate change impacts and adaptations, future industrial development, human health and sanitation issues, and global sustainable development. Although freshwater is a renewable source, in the present scenario, the rate at which freshwater resources are being consumed/withdrawn/used is much higher than the rate of its natural replenishment resulting in closing/closed river basins[2]. Due to changes in the human consumption pattern and standard of living, the water demand is much higher than its present supply in most sectors, making it a scarce natural resource. Coupled with global warming, the increase in population worldwide and their competing demands, the stress on water resources is becoming even more unbearable. Other critical challenges faced by freshwater resources are chemical and thermal contamination, eutrophication, tourism and excessive consumption in all sectors (Box 1).

Box 1: Major Water Consumption Sectors

Agriculture	food, livestock, feed, fishery, fibre, timber, energy crops, etc.
Environment and Ecosystems Services	biodiversity, greenhouse gas emissions, carbon sequestration, etc
Industry	majorly including harbours, navigation, beverages, and energy generation (hydropower and thermal plants), and smallholder enterprises
Domestic Usage	drinking, sanitation, cooking and other activities, etc.
Leisure Activities	lakes, parks, riverfronts, etc.

According to FAO, sector-wise water withdrawal has been the highest (nearly 70%) for agricultural production in the last century globally (FAO, 2012). This data is much higher in Asian and African regions, where agriculture plays an imperative role in the national economy from an employment point of view. Such high amount of water withdrawal in the agricultural sector and growing competition from other sectors coupled with climate change have created water scarcity, which is expected to worsen in many parts of the world resulting in more hardships. According to de Fraiture et. al. (2010), the annual agricultural water use is expected to increase by 20% globally to satisfy the projected food demand by 2050. Additionally, water governance is under pressure due to variable supply, conflicting demands from all sectors and declining water quality. The problems with water governance exist due to weaker infrastructure, poor institutional arrangements, inadequate skills to address the emerging problems, limited financial budgets and gaps in water information resulting in poor decision-making. Additionally, the water sector, especially agriculture, is facing several other challenges such as environmental, technological, management, economic and social issues as listed below:

- Increasing water scarcity, especially in closing basins and limited reserves for supply
- Imbalance in supply, demand and distribution of water equitably and sustainably
- Higher competition among different sectors such as agriculture, industry, municipalities, etc.
- Undesirable polarization within the water sector such as irrigation v/s environment, urban v/s rural and so forth
- Higher water variability and shortages due to climate change and other factors
- Inability to control flooding and supply augmentation using infrastructure
- Lower water productivity in agriculture
- Mismanagement of river basins because of over-irrigated agriculture

[2] Closing/closed river basins are basins where the demand for the water exceeds the supply.

- Lack of strong infrastructure leading to poor water use efficiency
- Incoherence between the water-food-energy nexus and other trade-offs and their correlation with SDGs
- Negative effects of non-water policies on the water sector, especially agriculture
- Less priority on the national agenda because of the information gap
- Lack of awareness amongst users to save water or optimize the usage.

Need for Water Measurement

In general, the management approaches are based on the belief that if it cannot be quantified, it cannot be managed. The same should hold true for sustainable management of our natural capital (water) for future generations. Since water is considered a social good in most countries, there is a lack of a mechanism for water pricing leading to frequent overuse and wide-spread mismanagement of the resource. Just like for saving on financial capital, we need sound financial planning where we essentially require the knowledge of availability and flow of funds to identify critical points where money-saving is possible; similarly, it is evident that for effective planning and management of water resources, an extensive knowledge of water balance, water availability, consumption, water wastage and return flow within a specific region/catchment is of utmost importance.

Keeping in mind the critical nature of issues that water sector is facing, advancements in technology solely cannot curb the problem, prudent governance, best management practices, and other factors (e.g., pricing of water services, long-term investments in the infrastructure projects) also need to be brought into effect to improve the current status of water resources, especially in agriculture.

Furthermore, the water abstraction at one location in the basin affects the water availability in another part of the basin, making the local management efforts ineffective and therefore, demanding for an integrated approach for smart water management across the basins. While climate change mitigation and adaption strategies are already a focus area of policymakers, a robust and integrated framework to design more efficient AWM policies and contribute to sustainable solutions for food insecurity and water scarcity.

A typical smart water management process requires the participation of multiple-stakeholders from various disciplines to evaluate management strategies based on multiple criteria decision making as shown in Figure 1. A "Measure; assess; evaluate; improve," approach promotes an investigative water balance approach to improve water use efficiency in irrigation and the adapted water balance framework assists managers and designers alike to apply it at any level to improve the system's performance (ICID Webinar on Water Use Efficiency, 2017). A detailed analysis of water status of various hydrological systems (e.g., nation-wide, river basins, irrigation scheme level, or farm level) based on near real-time available data is the first essential step for water resources planning (Bastiaanssen, W. G. M., et. al., 2003).

To establish a robust water information system as a first step towards smart water management, measurements of hydrological parameters are required:

- To assess the amount of water available, and to balance the supply and demand according to availability, apt dynamic and robust management strategies need to be devised
- To choose appropriate interventions such as the need for modernization, new infrastructure and/or rejuvenation, etc.
- To evaluate the SDG target indicators to identify the progress in sustainable development
- To increase the priority of water on the national agenda. Lack of appropriate data reduces the priority of water resources management by the decision-makers in the national development agenda (WWAP, 2014)
- Generating awareness amd moving towards a water-wise society. Similar to financial accounts, water accounts can inform users for judicious use of water at the sector and individual levels

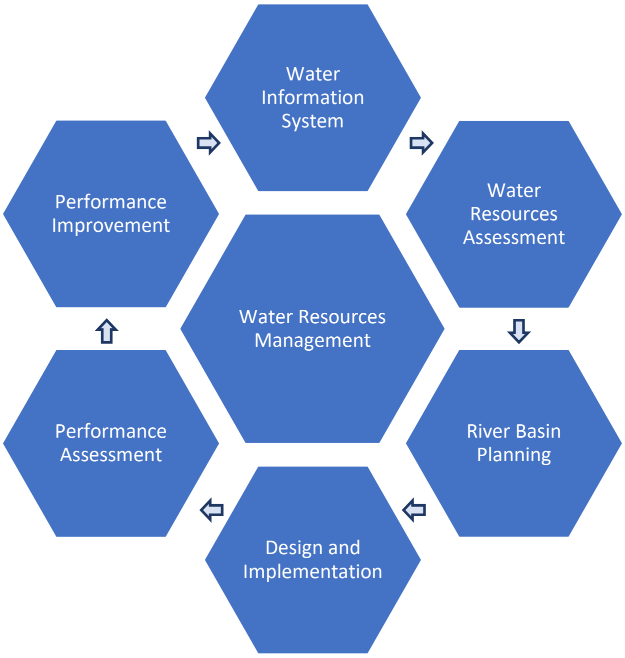

Figure 1 A typical schematic proposed for Water Resources Management Process

Inconsistent Terminologies

The main focus of AWM is improving irrigation efficiency and productivity. However, the term 'efficiency' in irrigation can mislead the policymaking while looking at the economic, hydrological and ecological aspects (Perry, 2011). Since the agricultural revolution, the definition of the term 'irrigation efficiency' has evolved and defined in many ways creating ambiguity. While the generic aim is to improve the water-use efficiency in agriculture, the terminologies used within the concept are somewhat divergent, which creates confusion amongst different stakeholders. The definition of the term 'irrigation efficiency' is often used synonymously with 'water-use efficiency' which can cause ambiguity amongst the decision-makers. Irrigation efficiency, originally, did not discount the water which is returned back to the system and hence counted twice, the losses are also somewhat misleading. The ICID webinar on the SDG 6.4 (water-use efficiency) also points out this difference of how water diversion and water consumption are considered identical in most cases and the difference between them is overlooked. Hence, the water use in irrigation is divided into change in storage, consumed fraction (beneficial and non-beneficial consumption) and non-consumed fractions (recoverable and non-recoverable flow). Among these, the beneficial consumption fraction needs to be optimized in the context of irrigation (ICID Webinar on Water Use Efficiency, 2017).

This clear distinction of consumed and non-consumed fraction of water usage in different sectors, especially agriculture, is crucial to identifying the actual amount of water used by the respective sector and thus defining the water measurements. The water balance approach, within defined boundaries, or across different levels of irrigation systems is crucial to assess the performance of the systems within the Water Management Area. The fraction of the water abstracted from the source that can be utilized by the crop, can be called the beneficial water use component and optimized irrigation water supply is therefore aimed at maximizing this component (ICID Webinar on Water Use Efficiency, 2017).

ICID Definitions

According to ICID's Irrigation and Drainage journal, a peer-reviewed publication, the following standardized definitions/terminologies have been recommended for water use and water withdrawal (Perry, 2007; Willardson et. al., 1994 and Allen et. al., 1997). ICID's Multi-Lingual Technical Dictionary (MTD) is currently being updated with standardized terminologies in the context of irrigation and drainage, and the following terms (Table 1) are under active consideration.

Table 1 Terms and Definitions

Term	Definition
Agricultural Water Management	Application of right amount of water on a crop at the right time according to the vegetative state of plants.
Integrated Water Resources Management (IWRM)	A process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.
Irrigation Efficiency	The ratio of the volume of water beneficially used to the volume of water delivered to the field. During each stage of irrigation water delivery from source to the soil, there is a loss of water and the volume coming out is less than the volume entering.
Sustainable	S*ustainability* promotes principles of durability, equity, affordability, sufficiency and efficiency, whilst a) not undermining social and natural resources and b) managing multiple risks such as drought, flood, declining water quality and increasing resource competition (FAO White paper, 2018).
Water Accounting	Water Accounting (WA) is an analytical tool to quantify inflows, outflows and changes in storage as a function of time (including agricultural drainage systems) in any given hydrologic system/sub-system such as an agriculture field, a canal system or a river basin. WA should address quantitative, qualitative, associated potential energy characteristics of the water fluxes and storage and the uncertainties related to the measurements.
Water Auditing	Verification of water accounts conducted by an independent agency consisting of hydrologists, water resource managers, engineers, consultants and analysts. Two kinds of audits should be conducted, i.e., auditing of the process of WA and auditing of the performance of the WA.
Water Use	Any deliberate application of water to a specified purpose. The term does not distinguish between uses that remove the water from further use (evaporation, transpiration, flows to sinks) and uses that have a little quantitative impact on water availability (navigation, hydropower, and most domestic uses).
Water Withdrawal	Water abstracted from streams, groundwater or storage for any use – irrigation, domestic water supply, industry, etc. The water withdrawn from these systems is further categorized as: changes in storage, consumed fraction and non-consumed fraction
Changes in storage (positive or negative)	Changes in storage include any flows to or from aquifers, in-system tanks, reservoirs, etc. The key characteristic of storage is that the water entering and leaving is of the same quality.
Consumed fraction (evaporation and transpiration)	The quantity of water used by the vegetation in transpiration and building of plant tissue, plus that evaporated from the soil or from intercepted precipitation, at any specified time. It is further divided into beneficial and non-beneficial consumption
Beneficial consumption	Water evaporated or transpired for the intended purpose – for example evaporation from a cooling tower, transpiration from an irrigated crop.
Non-beneficial consumption	Water evaporated or transpired for purposes other than the intended use – for example evaporation from water surfaces, riparian vegetation, and waterlogged land.
Non-consumed fraction *(return flows)*	The fraction of water that is not consumed by the plant and is returned to the system. This return flow is further divided into recoverable and non-recoverable fraction.

Recoverable fraction	Water that can be captured and reused – for example, flows to drains that return to the river system and percolation from irrigated fields to aquifers; return flows from sewage systems.
Non-recoverable fraction	Water that is lost to further use – for example, flows to saline groundwater sinks, deep aquifers that are not economically exploitable, or flows to the sea.
Water Governance	Water governance is the arrangement of infrastructure, technologies, institutions, finances and operations to manage water (FAO White Paper, 2018).
Water Scarcity	The excess demand for water over the supply.

Water Accounting

In general, there is a lack of coordination amongst the different institutions and stakeholders within and outside the government when formulating sectoral policies on agriculture, industry, municipality, and river systems. This disintegrated institutional approach towards water resources management (WRM) has proved to be counter-productive in many countries. Furthermore, unavailability of standardized spatial and temporal data makes it difficult for practitioners to strategize and coordinate efficiently with a certain degree of confidence. Thus, for a sustainable AWM to be implemented efficiently on a national level, the effect of which can be measured at the grassroots level (field scale), there is a strong need of knowledge amalgamation from all the relevant stakeholders from science, engineering, management, political, social and economic disciplines and sectors.

Water Accounting presents the "water balance analysis" and informs the stakeholders for designing best management practices in agriculture and a reliable water governance fabric to achieve equitable allocation to all users while maintaining the sustainability of the resource for current and future generations. From AWM point of view, WA is an analytical tool to quantify inflows, outflows and changes in storage in any given hydrologic system/sub-system such as an agriculture field, a canal system or a river basin during a cropping season, annual hydrologic cycle or given time period, distinguishing between the beneficial and non-beneficial consumption. Final WA should be closed at the river basin level, working from parts to the whole. Its purpose or objective can be an equitable/rational allocation for various human activities, understanding various paths for environmental services, or formulating a response to climate change, etc. WA should also include agricultural drainage systems as they are an integral part of an irrigation cycle. Mechanisms within WA should be available to address quantitative, qualitative, associated potential energy characteristics of the water fluxes and storage and the uncertainties related to the measurements. WA can quantify water resources, the performance of the management and governance of water, and the links between water and economic, human and environmental development (FAO, 2018).

Water auditing is suggested as a further step to analyze the authenticity of the WA results and provide a comprehensive information system for further planning by placing trends. Within the concept of water auditing, two kinds of audits should be conducted, i.e., auditing of the process of WA and auditing of the performance of the WA. This auditing should be carried out by hydrologists, water resource managers, engineers, consultants and analysts from an external independent agency. WA should provide the physical distribution of water and auditing provides the basis for the formulation of policies, together which provides a clearer picture of the water balance, not only at the irrigated field but of the entire irrigation system or the basin, and consequently, a framework on agriculture water resource management can be designed and implemented efficiently and effectively.

Water accounting and auditing provide a transparent assessment of water in the specified spatial boundaries within a certain timeframe, and in a similar format as financial accounts. This data democracy provided by WA facilitates a direct communication channel between government institutions, research institutions and other non-governmental organizations including policymakers, hydrologists, agronomists, economists, lawyers, farmers and other stakeholders without any external assistance.

Through the years, with the experts working on the subject from premier institutes, many tools have been developed based on the WA concept to account for water abstraction and usage, its flow and its availability within the catchment with a higher precision in a standardized format which can be applied to any given country/region or river basin. Physical accounting of water requires quantifying water flows in the hydrological system which is regulated through the dynamic hydrological cycle and its various components (precipitation, evapotranspiration, interception, surface runoff, infiltration and groundwater storage). The hydrological data varies extensively in both temporal and spatial dimensions, and physical measurements for each parameter is impossible and sometimes may result in double counting of water. Moreover, the data obtained from different sources might be inconsistent resulting in the biased outcome to different stakeholders and creates confusion among them. Hence, the experts recommend implementing WA concept to establish an independent consistent source of information and produces standardized and reliable results. WA tools can be developed which furnish data obtained mostly through easily available field measurements, remote sensing, GIS and other hydrological models which are open source and the background information is available to different institutions and individuals. There is an urgent need to introduce standardized WA procedures that quantify the watershed processes, assess a safe level of exploitable water volumes and fix the maximum amount of water that could be withdrawn and consumed by the agriculture sector sustainably.

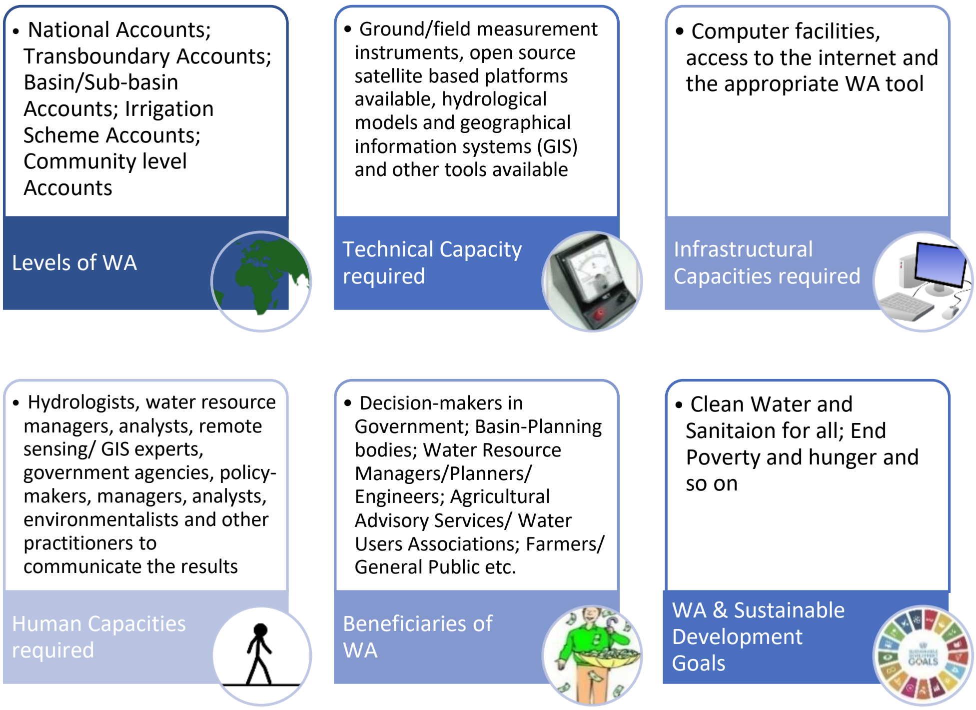

Figure 2: An Overview of Water Accounting

Water Accounting Framework

WA should be based on the best possible scientific and engineering measurements to begin with and improving upon them (the tolerance levels) according to the end objectives. Institutional framework and its mandate to implement WA should be clearly defined and agreed upon by all the actors. There should be a prescribed common/standard format for reporting by diverse agencies within a basin. International organizations, governments and other regional institutions active in agriculture water management have to create an appropriate knowledge base to steer the national entities within the countries through their respective national focal points/agencies to take WA from experimental to operational mode.

Remote sensing, GIS and other hydrological models are very powerful tools which can help in bringing standards to the WA process. Apart from field measurements, with the help of remote sensing, the spatial and temporal variations of hydrological data can be evaluated. And this data derived from satellites is publicly accessible at all times. Some WA tools already make use of this data and simulate the hydrological processes of a given area. While the policymakers and stakeholders from non-technical background might not be well-versed with the concepts and the underlying processes, the results generated by the WA tools provide consistent information required for taking better-informed management decisions on agriculture and water stress. The methodology adopted for WA makes a clear distinction between the consumed and non-consumed fraction of water (Perry, 2007). A general water accounting framework can be summarised as below in Figure 3:

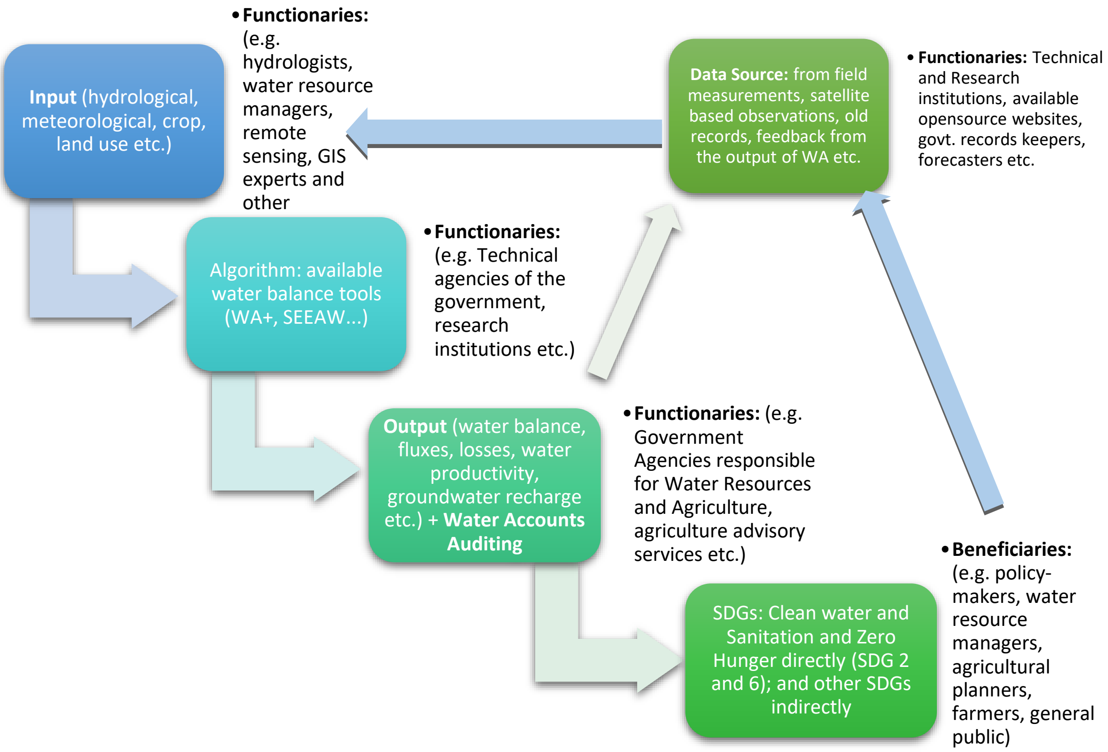

Figure 3: Water Accounting Framework for Agricultural Water Management

Lack of information on water availability, water rights and allotment, groundwater withdrawal and recharge prove to be a hindrance to the projects which provide long-term investments in infrastructure. Also, in the case of development projects, there is often miscommunication in terms of proper accounting. A well-established framework acceptable to all the stakeholders from different sectors will help in expediting the process and better planning for the required infrastructure and trade. To address the issue of water scarcity and other water-related problems through institutional reforms, the approach to WA aims to standardize this so as to have a reliable, high quality and consistent source of information available and communicate this information to the different actors of the water sector. This standardization of concepts, definitions and processes consolidated through WA are a significant value addition contributing to the process of decision-making. Decision-makers and stakeholders from different institutional levels are dependent on this information for better water governance.

Since the demand for water is time-specific, the temporal aspect of the water information helps us in understanding the past and current patterns of water usage and predict the trends of future availability and consumption. Since the water yield is not constant throughout the year, and thus it impacts the water availability and consumption seasonally. Hence, understanding of these temporal changes in the water supply and demand need to be considered in the WA. Similarly, for different spatial scales, different planning strategies need to be designed and hence, the experts from ICID are suggesting to define the WA concept at different spatial scales, as given below in Table 2 based on different data requirements.

Table 2 Different Modules of Water Accounting

No.	Spatial Extent	Stakeholders and Beneficiaries	Input Data requirements
1	National Accounts	Policy-makers in ministries of Water Resources, Agriculture, Natural Resources, and Industry	Low
2	Trans-boundary basin accounts	Government Technical Agencies responsible for water resources management	Medium
3	River-basin accounts	Basin-planning bodies	Medium
4	Sub-Basin accounts	Sub-basin planners and managers	Medium
5	Irrigation Scheme accounts	Water Resource planners and managers, Agricultural advisory services, Scheme operators, etc.	High
6	Community-level accounts	Water User Associations, Farmers, Rural Development agencies and population	High

Water Accounting Tools

Maintaining natural capital is essential to ensure a sustainable environment (Winrock, 2015). For evaluation of the natural capital, water resources as considered in this paper, some of the tools available which provide water accounts are: System for Environmental-Economic Accounting (SEEA-Water); National Water Accounts Australia; and Water Accounting Plus (WA+) provided in Annexure 1. Implementation of such standardized tools across countries would ensure cohesive and integrated results since similar concepts, definitions and methodologies are used for assessing the accounts. The raw hydrological data required for these tools is obtained either through field experiments or through hydrological and remote sensing/GIS models, or a combination of these.

The input requirements, algorithms used for processing and accordingly the output of all the tools are defined for each of the models separately. However, commonly, the boundaries need to be specifically defined for each spatial scale, i.e., national, state/district/regional, irrigation scheme and/or project level. The output of water accounting quantifies hydrologically relevant information such as rainfall, evapotranspiration, crop yield, consumptive use, crop water productivity; water withdrawals, consumptive use, river flow, lateral flow, base flow, outflow, return flow, drainage, recharge, storage changes, surface runoff, water yield, water storage capacity, soil moisture and so forth.

Benefits and Beneficiaries of Water Accounting

A tool is as useful as its artisan who uses it. Usefulness and reliability of WA would depend on the capacity of the national agencies to integrate the WA tools in water planning, policy and operational decision-making. The smart water management process develops specific connections between water scarcity, variability, productivity, efficiency, water governance and water accounting (FAO, 2018). The smart water management attributes to:

- Mitigating water scarcity, especially in closing and closed river basins.
- Balancing the distribution of water supplies, demands and benefits equitably between rural and urban sectors to safeguard and boost economic productivity and human and ecological health.
- Balancing hydrological variability.

– Balancing water with other inputs (such as energy) to optimize water productivity and minimize externalities.
– Balancing the range of water interventions so that institutional, political and technological solutions fit together and to the problem.
– Balancing is a long-standing financial accounting principle of determining a balance sheet of credits and debits (thereby in water resources respecting the law of conservation of mass).

There are several avenues through which WA can contribute to achieving smart water management (FAO, 2016):

– to provide a common source of information so that all the stakeholders are on the same platform;
– to provide the basis for water distribution and allocation and facilitate stakeholder's dialogue for resolution of any conflict;
– to identify and analyze problems related to water and strategize accordingly;
– to modify existing and design new water policies;
– to provide a suitable framework for planning for varying political, social and biophysical environment;
– to form water regulatory frameworks between different stakeholders to avoid conflicts; and provide unbiased information from an open source.

While WA facilitates the outcomes as shown in Figure 4, according to FAO, the potential beneficiaries and stakeholders in the water accounting and auditing processes consist of water users from different sectors (agriculture, industry, urban, environmental and municipality), diverse mix of experts/professionals/administrators/policymakers from various government departments and agencies; elected representatives at different institutional levels; non-government organizations; regulatory organizations; private sector organizations; water engineers and managers, deliverers and users of water services; research organizations and academics; water industry professionals; media (traditional and social); general public using the water; training or capacity building organizations (Batchelor et. al., 2016).

Figure 4: Outcomes of Water Accounting

With the availability of such a tool, alternate scenarios of management and their impact on the environment can be easily simulated and studied. Some of the decisions include information regarding sustainable increase in water yield from upstream areas, implications of construction of new infrastructure, groundwater depletion and artificial recharge during high intensity rains, impact of agroforestry on food security, various scenarios of crop productivity and find a suitable crop accordingly, effect of urban settlements on the water balance in the region and so forth.

As of now, the concept of WA and auditing is not adopted by most countries on a national level. A better understanding of water balance, including water supply and water demand across the different regions at different times is required through proper communication channels. Through a series of events and webinar, ICID has continually emphasized the importance of WA for AWM. During these sessions, ICID also provided the provision to the participants to have a discussion with the experts. In collaboration with the Bureau of Meteorology of Australia, ICID organized a Webinar on the first successfully working model of Australia's National Water Account on how the WA process has been implemented in Australia and how other countries can learn from it and can adopt similar accounting model or replicate/calibrate this accounting model in their own countries. The experiences shared during various ICID and other fora and the other evidence reported elsewhere will be collated and compiled to assess the utility of WA as a framework for longer-term water management planning and future development of water resources.

Water Accounting to Support Water Governance

Policy formulation for any kind of development has traditionally been considered the domain of economists, sociologists and political analysts, who rarely get adequate exposure to physical concepts and ideas such as "water balance approach." Consequently, water governance is not always based on scientific analysis. Under the WA framework, the scientific term "water balance approach" has now assumed a new alias "water accounting," so that it becomes more palatable to the non-engineering stakeholders, especially decision-makers. The concept of water balance envelops hydrological processes with different management of water flows, water consumptions on various land use classes including rainfed and irrigated agriculture within a system. WA follows the scientific principles of the water-balance approach and informs the results similar to the well-established guidelines of financial accounting. The result is an exhaustive report of all-inclusive water-related information to assess the status of water resources within a specific system for policy formulation.

WA also supports water governance at different levels of varying spatial resolution, i.e., at the national level, state or district level, basin level, irrigation scheme level and field level. The policies for water and the capacities required for water management at each of these levels might differ. The knowledge provided from this advanced comprehensive water information system for a given system can help the decision-makers for better planning, formulate new policies or reform the existing ones for modernization in irrigation for improving water productivity in agriculture.

The WA provides answers to specific problem issues such as the imbalance between supply and demand, water allocation between different sectors, over-exploitation of groundwater in a region, large investment infrastructures projects in agriculture. It is considered an indispensable step in the MASCOTTE approach adopted for the modernization of irrigation (FAO, 2007). The MASCOTTE approach has been successfully implemented in many countries, including India, Argentina and Kyrgyzstan for many years (ICID Webinar on Planning for Modernization: MASSCOTE Approach, 2017). Thus, WA should be a part of inter-sectoral or intra-sectoral planning since it can help in setting-up of a benchmarking process, in comparing feasibility of different management options in a particular environmental, political and social scenario and guide the policymakers for efficient governance accordingly (ICID Webinar on Practical Benchmarking for Improving Performance of Irrigation and Drainage Schemes, 2017).

Water Accounting and Water Policy for Agriculture

To boost the land and water productivity, the policymakers need to devise water policies pertaining to agriculture in such a way that it addresses the provision, allocation, consumption and management of water resources in agriculture as well as among different users sustainably so as to control the aquifer depletion and preserve the water reservoirs. WA assists the policymakers and other stakeholders in achieving the following goals:

- Manage nexus connections and trade-offs
- Distribute water more equitably within domains
- Allocate water between sectors
- Achieve and monitor SDGs
- Manage and regulate rising water demands arising from economic growth
- Manage supply. Cope with and benefit from increased variability – droughts and floods

Some of the important policies that need focus are incentivising the water use efficiency, investments in infrastructure for agriculture and water harvesting, disaster risk management related with water (floods and droughts), improved wastewater treatment and access to water supply and sanitation, improved/revised water allocation plans through water rights reform and pricing, and improvements in water governance through stakeholder participation (OECD, 2011). Some measures, suggested by Perry (2011) and agreed upon by ICID, to achieve higher water-use efficiency through smart management practices are:

- To reduce the non-consumed fraction of water by deducting the irrigation deliveries to minimize the excessive runoff of irrigation water and deep percolation of water in the field;
- To reduce the consumed fraction through drip irrigation to minimize the non-beneficial evaporation of water, wherever possible; and
- To increase the productivity of beneficial consumption by fully irrigating at specific crop growth stages

Capacity Requirement for Water Accounting

At the recently organized ICID Congress (Mexico, 2017), many ICID member countries discussed the ground level issues indicating lack of water accounting and relevant institutional reforms as a major barrier in smooth functioning of Water User Associations (WUAs) to achieve equitable water distribution and sustainable use of water.

Several international organizations, governments and research institutions are fairly well equipped to carry out WA for national, regional and basin levels. The WA and auditing reports can be developed by a wide range of practitioners such as hydrologists, water resource managers, engineers, consultants and analysts. However, at the sub-basin or micro-basin levels, capacities need to be built to carry out WA. In this regard, institutional policies need to be developed for capacity development within the WUA's and extension services at the micro-basin levels.

The technical capacity required for the input data measurements includes ground/field measurement instruments, open source satellite-based platforms, hydrological models and geographical information systems (GIS) and other related tools. For the water assessment and monitoring stage, the infrastructural and institutional requirements include computer facilities, access to the internet and the WA tool. In terms of human and intellectual capacity, the requirements vary at different stages of WA which includes hydrologists, water resource managers, analysts, remote sensing/ GIS experts, government agencies, policy-makers, managers, analysts, environmentalists and other practitioners, all working through an agreed multi-disciplinary institutional framework or structure. A proper reading of WA accounts, awareness building and sensitization of policymakers are some of the factors which are crucial while strategizing for long-term water policies.

Equally important is a correct reading of WA outputs and translating them into long-term water policies, and for this awareness building and sensitization of policy makers is crucial.

Water Accounting in Agriculture and other Sectors

While the focus of this paper is mainly agriculture, WA is equally beneficial in other sectors, namely, industry, domestic, environment and ecosystem services. Since planning for water resources is equally crucial in other sectors, the outcome of WA can prove to be extremely useful for other sectors as well. The framework developed for the WA in agriculture can be replicated and altered based on the indicative parameters from other sectors. Accordingly, the policies need to be developed to inform other sectors, especially industry and municipal uses with special attention to the quality of the water emissions (i.e., grey and black water). Since pollution is one of the major environmental concerns, overlapping sectoral policies should be developed to curb water quality degradation.

In the environmental and ecosystem services, broadly classified as provisioning (e.g., food, water), regulating (e.g., climate regulation, hydrological cycle, flood retention), supporting services (e.g., soil formation) and cultural services (e.g., recreation), WA quantifies several crucial indicators pertaining to these environmental and ecosystem services such as water yield, soil erosion, carbon sequestration, resilience to floods and droughts, greenhouse gas amount in the atmosphere among others.

Water Accounting Case Study

A very successful example of WA implementation was shared during the ICID Webinars on Australian National Water Accounts managed by the Bureau of Meteorology, Australian Government in collaboration with the Australian water industry. The National Water Account is Australia's most comprehensive water information report. It provides a picture of water resources management for the previous financial year for ten nationally significant water regions: Adelaide, Burdekin, Canberra, Daly, Melbourne, Murray–Darling Basin, Ord, Perth, South East Queensland and Sydney. It is a systematic process of identifying, recognizing, quantifying, reporting, assuring and publishing information about water and people's rights and obligations with respect to it. The National Water Account discloses information about water stores and volumetric flows, water rights and water use. It also reports on the volumes of water traded, extracted and managed for the economic, social, cultural and environmental benefit.

One of the main concerns of water allocation between different sectors is the issue of conflicts for a claim on water rights. To plan for this water allocation justly and sustainably, information regarding water availability, water consumption, current allocation, how much water is traded, change of water in the aquifers and rivers, water loss through evaporation and other leakages is needed from the involved actors. The Australian Bureau of Meteorology considers the actors involved in the water sectors as the central government, state and local government, water utilities, industry, agriculture and public. Some of the significant outcomes of this water accounting report provides information regarding cyclone warning, flood warning, marine weather warning, heat wave warnings, El Niño and La Niña, water resource assessment and account, sea temperature and currents, climate monitoring, temperature and wind, rainfall and sunshine, UV protection, coral bleaching, aviation forecasts, disaster mitigation, commercial weather services, information infrastructure, etc.

The management strategy based on this WA report suggested water sharing in a cyclic pattern (planning, implementation, monitoring and evaluation; and then further planning to improve the process). The strategy is subjected to review every 10 years to account for biophysical, institutional and social changes in the region. Another important characteristic to be considered while the formulation of policies is integrated management approach of natural resources water, soil, land and vegetation based on these water accounts with shared responsibility between the government and the community considering environmental, social, economic, cultural and heritage aspects.

The main benefits of the national water accounting include the availability of water-related information (water available, entitled and used, traded and lost) in a standard format for all basins, transparent water management and accountability, spatial and temporal information, guidance to policymakers, regulating authorities and actors involved on WRM, awareness of water issues among general public and also identification of gaps and inconsistencies in data and knowledge. For example, the Australian national water accounts provide integrated, detailed, standardized water information. It also addresses water security issues in the basins and changing supply and use of water in metropolitan cities and irrigation areas, provides data check and quality control for national comparison (ICID Webinar on National Water Accounts: Australian Experience, 2017).

While the accounts of successful implementation of WA has been given in this section, Box 2 provides an example of the reality of not accounting for water resources in the northern states of India.

Box 2. The Real Cost of Not Accounting Groundwater. Access to subsidized agricultural electricity has led to the promotion of an unsustainable cropping system (Rice-Wheat) in North India's agro-ecological zones as almost freely available power is used to pump groundwater excessively to grow water-intensive and non-native paddy crop, a lucrative export commodity, but an environmental disaster for the region. Every October Delhi becomes the SMOG capital of the world as in a hurry to prepare their fields for winter wheat sowing, farmers resort to stubble burning after paddy harvest. Satellite images show the accumulation of smoke from this burning activity over this densely-populated foggy area, a leading cause of respiratory diseases in the millions of children and elderly during this month, an incalculable health cost for the national economy. Stagnant October winds and other sources of air pollution rub the salt over this wound because groundwater was not accounted when power subsidies were calculated.

Water Accounting (WA) and Sustainable Development Goals (SDGs)

As discussed in this paper, WA can help make better decisions for sustainable AWM, economic growth, poverty reduction and environmental protection. A systematic approach to AWM requires actions at all levels, from farms to irrigation schemes, and from local to national action and strategies. Reallocation of agricultural water share, modifying or changing crop patterns, and water charges are among the self-control policies. However, effective capacity development at various levels, appropriate national/local guidelines and transparent regulations are major pre-conditions for incentivizing the self-control. A thoroughly worked out "water law" can definitely promote more effective use of water to support the SDGs, particularly goal 2 and 6 by providing a transparent legal framework to ensure equality and social justice in rural areas of many developing countries. WA can also provide a way to determine the combined effect on SDGs or the possible trade-offs in the SDGs using long-term water-food-energy nexus, e.g., to fulfill SDG 7 on energy, overuse of water can lead to water scarcity and affect SDG 6 negatively (FAO, 2018).

The dependence of societies on water resources makes it a key factor in the achievement of sustainable development expressed through outputs such as water and food security, biodiversity, and so on. The sustainable development goals (SDGs), laid by the UN, provide a comprehensive and internationally accepted framework for achieving development of society, economy and environment sustainably for current and future generations, measurable through various indicators. According to Vision 2030 (ICID, 2015), the experts of different technical working groups have established that agricultural water management directly or indirectly influences seven SDGs out of the seventeen, i.e., no poverty (goal 1); zero hunger (goal 2); good health and well-being (goal 3); ensure availability and sustainable management of water and sanitation for all (goal 6); decent work and economic growth (goal 8); climate change adaptation (goal 13) and partnership for the goals (goal 17).

The SDG 6 corresponds to sustainable development and management of water in all sectors and WA provides an integrated information base of water-use across sectors. A direct assessment of almost all SDG 6 indicators synergizing with other SDGs, which are also related to other SDGs can be facilitated through WA and auditing which helps in assisting the formation of sectoral policies. Additionally, WA also helps in addressing the impact of development programs and policies on the SDGs and other existing water governance reforms. FAO's online discussion also considered how WA outcomes help in monitoring SDG 6 directly and other indicators indirectly. This particular deliberation can be summarized as given below in Table 3.

Table 3: Role of Water Accounting towards Sustainable Development Goals

SDG Target Indicators	Goals	Indicators	Role of WA
Goal 6.1 [Also target 3.9]	To achieve universal and equitable access to safe and affordable drinking water;	Proportion of population using safely managed drinking water services	Accounts for different uses of water, i.e., agriculture, industry, drinking water, municipal water, etc. WA reporting on the water quality will directly contribute to safe and affordable drinking water
Goal 6.2	To achieve access to adequate and equitable sanitation and hygiene, particularly women;	Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water	
Goal 6.3 [Also target 14.1]	To improve water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Proportion of wastewater safely treated Proportion of bodies of water with good ambient water quality	Provides water budget and distinguishes between blue and green water. Assesses water quality degradation due to pollution. Water accounts provided by industries, municipality and agriculture combined can report on this SDG
Goal 6.4 [Also targets 1.4, 2, 8.4, 12.2, 12.4]	Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Change in water-use efficiency over time Level of water stress: freshwater withdrawal as the proportion of available freshwater resources	Differentiates between consumptive (beneficial and non-beneficial) use and non-consumptive (recoverable and non-recoverable) uses of water which helps in determining the actual amount of water used and more accurate estimations of water use efficiency and water productivity
Goal 6.5 [Also targets 2.4, 11.a and 15.9]	Implement integrated water resources management (IWRM) at all levels, including through trans-boundary cooperation as appropriate	Degree of integrated water resources management implementation (0–100) Proportion of trans-boundary basin area with an operational arrangement for water cooperation	Assesses integrated water stocks, uses and fluxes across spatial scales and thus provides the basis to implement IWRM at all levels
Goal 6.6	Protect and restore water-	Change in the extent of	Reports on ecosystem services

SDG Target Indicators	Goals	Indicators	Role of WA
[Also targets 15.1, 15.2, and 15.3]	related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	water-related ecosystems over time	such as estimating the exchanges between land and atmosphere, reduction of greenhouse gases due to land-use change and climate-smart agriculture, groundwater recharge, non-recoverable flow because of degraded water quality, decrease in soil erosion due to vegetation cover etc.
Goal 6.a [Also targets 12.a, 15.a, 15.b, 17.6 and 17.7]	Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	
Goal 6.b [Also targets 16.7, 16.8, and 17.9]	Support and strengthen the participation of local communities in improving water and sanitation management	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management	

Specific SDG indicators that can be calculated directly from the WA is water-use efficiency and/or productivity. For example, WA determines the beneficial consumption of agricultural water out of the total water abstracted which corresponds to the water-use efficiency. From source to the irrigation scheme to the field and ultimately to the crop, the water is conveyed through irrigation infrastructure incurring evaporation and seepage losses at each level. WA proves to be an important instrument in this aspect as it provides spatial and temporal water balance at each level and thus helps in assessing the status of the infrastructure by keeping a track of such losses. Long-term investment projects in water infrastructure are very critical with respect to the water-use efficiency to minimize such losses at each level from source to the crop. Another parameter that can indicate efficient water use and translate into agro-economic growth is water productivity, a direct concern for the field level farmer who pays for the cost of irrigation water and associated losses in terms of evaporation and nutrients due to over-irrigation.

While quantitatively an excess of water demand over the supply has created water scarcity, an acceptable quality of water is crucial for sustainable growth/development of water resources and subsequently fulfill relevant SDGs. Since water accounts provide the quantitative aspect of water, the qualitative aspect of water is not reported by several tools currently. Water quality is assessed by chemical, physical, and biological attributes. Estimation of some of the critical determinands[3] still remains difficult due to lack of standardized methods to evaluate them or standards for threshold amounts of determinands in the water bodies to define quality classes (SEEAW, 2012). While WA+ does not account for all the determinands for detailed assessment of water quality, SEEAW model can evaluate certain parameters pertaining to the quality of water. A possible solution of WA+ in collaboration with SEEAW can be explored to include the economic aspect of water use (Winrock, 2015).

Currently, there is no specific framework under which SDG target indicators related to water in agriculture are reported. Water reporting through WA provides quantifiable figures which can help directly or indirectly to identify the progress especially with respect to the SDG2 on food, SDG6 on water, SDG 7 on energy, SDG 13 on climate adaptation and SDG 15 on terrestrial ecosystems. For regular monitoring and reporting on the sustainable water use at different spatial levels (from local to national level), different outcomes of WA and auditing can be used for multi-criteria decision-making in the water sector. A common opinion shared by several experts is that the use of WA can be very beneficial to comprehensively report on several SDG target indicators related with water, sanitation, food security, ecology, economy and poverty for sustainable development. Hence, a strategic framework should be put in place considering WA as an essential feature of integrated water resources management (IWRM) at various spatial levels.

Conclusions

From agricultural production point of view, the importance of WA lies in the fact that the effect on water productivity with respect to different water users can be easily determined. WA also gives information about the consumptive and non-consumptive use of water, clearly providing information/knowledge where there is a scope to improve water productivity in food production. It gives information on water fluxes and flows in the basin; climate change variations can be evaluated; cost-benefit analysis of water services can be done; ecosystem and environmental services can be assessed based on modified, protected, utilized and managed water use. In addition, the trends in the water supply and demand can be analyzed for current status and future scenarios in specific social, political and institutional contexts.

The implementation of WA is recommended at various levels of water governance. However, certain gaps still need to be addressed. Quantitative indicators such as water productivity discussed in this paper largely concentrate on the quantity of water and how it can be better utilized across spatial and temporal dimensions; the quality of water (reporting on all the indicators of water quality) still remains a major concern to address some SDGs. The water quality assessment across space, especially from upstream to downstream, would be needed to identify changes in potential energy, chemical properties and biological aspects that directly influence the potential use of water for different purposes and the cost of water quality restoration. Another concern towards achieving data democracy in water resources is to account for the uncertainties and bias in the water measurements through WA tools. Apart from addressing technical gaps, without proper communication about the WA process, the whole exercise could prove to be futile. Communication regarding the WA process among the stakeholders and all the related beneficiaries including the general public needs to be strengthened in order to establish WA as a standard procedure for advanced water information systems.

In conclusion, ICID supports the view that WA should form the framework for assessing, sustainably managing and planning of current reserves of water resources in order to secure the scarce natural resource for current

[3]Determinand is defined as a constituent or property of the water that can adversely affect the water's taste, odour, colour, clarity or general appearance. E.g. organic and oxidizable matter; nitrogen; nitrates; phosphorus; suspended matter; colour; temperature; salinity; acidity; phytoplankton; micro-organisms; mineral micro-pollutants in water; metal on bryophytes (moss); pesticides in water; and organic pollutants (except pesticides) in water. (SEEAW, 2012)

and future scenarios. Same as agriculture, other sectors can also benefit from the concept of WA or through a more comprehensive framework.

Way Forward

An integrated analytical planning framework inclusive of technological advances, traditional cropping practices, the involvement of all the stakeholders and sound institutional engagement needs to be implemented for sustainable AWM at various levels. The way forward to bring WA into effect is through raising awareness of the gravity of problems and the concept of WA amongst the various actors and the beneficiaries of the water sector. By proper communication and collaborations, WA can be incorporated in the national agenda for water resources planning and management at various spatial and temporal levels. Policies and practices must be drafted to suit the water requirements of the beneficiaries inclusively and sustainably. And, there should be regular monitoring of the effect of these policies and practices on the water resources and revise them accordingly to changing climate and demography.

Currently many specialized organizations are working on tools which can store global and local data on hydrological and climatic processes in the selected region and possibly future projections through a cloud-based platform and make it available to a wide range of users, especially in data scarce regions of the world. The ongoing work is focusing on providing comprehensive water information, in particular to specific biophysical, social and economic conditions in developing as well as developed countries in order to find sustainable alternative solutions which are also economically beneficial, especially to the rural population. The main idea behind such an approach is to have a low-cost, easily accessible and readily available tool for all users to assess the water-related information. Such a tool would address institutional challenges and would require lower institutional or intellectual capacity and would bridge the knowledge gap with the current systems to provide comprehensive information based on which broad policy measures can be deduced which contribute to SDGs related with the water-energy-food nexus.

As mentioned in this position paper, technically, there are tools available to carry out water accounting and auditing such as WA+, Australian National Water Accounts, and SEEAW among others. The combination of currently available tools can be further researched to assess the quantitative and qualitative aspects of water accounts. Continually, state-of-the-art research is being applied to improve the technology part of the water accounts. However, the adoption of WA into practice worldwide still remains a challenge. To this end, the World Water Council (WWC) members (FAO, IHE-Delft, IWMI, ICID, DWFI, and WWAP) are working to raise the profile of WA for decision making and demonstrate the added value WA can bring in smart planning processes in water management and water governance. The WWC members prepared a White Paper on WA for policy making and it was launched at the 8th World Water Forum in March 2018.

The National Water Accounts of Australia offer an opportunity to test-case WA at the national level as they are planned to be developed with similar principles as are defined for financial accounting. Apart from furnishing the general-purpose water accounting reports, an equal emphasis is being given to the auditing of the water accounts so as to ensure the reliability of the results and have the confidence of the investors and the general public regarding the management and investment strategies implemented. Given the importance of the knowledge of such issues, water accounting is proposed to be included in the curriculum in academia, particularly in water resources related subject areas. WA is planned to increase awareness among the stakeholders and also ensure the consistent use of water terminology for improved multi-disciplinary, collaborative, inter-sectoral, trans-boundary communications (A Possible Water Accounting Vision 2030).

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Annexure 1

Water Accounting Plus (WA+)[4] (www.wateraccounting.org)

Water accounting (WA+), a tool developed by UNESCO-IHE, IWMI, FAO and UNESCO-WWEP, provides water resources related information and the services generated from the net amount of water used (consumptive use) locally, basin-wise or nationally to users such as policy makers, water authorities, managers, and hydrologists to name a few. WA+ relies mostly on satellite-based information of water and land resources rather than detailed hydro-meteorological measurements. Several performance indicators are developed to test the outcomes of WA+ results (Karimi et. al., 2013). The WA+ tool generates 8 sheets which provide the water-related information of the system and consistent standards for reporting on water usage and availability.

- WA+ provides an analytical framework that summarises water resources conditions and management in complex river basins.
- WA+ uses accessible satellite measurements as its main input data source, instead of detailed hydro-meteorological measurements, and global hydrological models which determine the water flow, including groundwater flow, in irrigated river basins.
- The WA+ framework evaluates the impact of interventions such as (i) water re-allocations, (ii) reduced groundwater withdrawals, (iii) deficit irrigation, (iv) modernisation of irrigation, (v) artificial recharge, (vi) water retention and storage, (vii) wastewater treatment, (viii) water productivity improvement, (ix) urban expansion, (x) deforestation, (xi) introduction of biofuel crops, (xii) cropping pattern change, (xiii) altered cultivation practices, etc.
- Accordingly, different management aspects can be assessed using WA+ in order to provide a sustainable water supply for agriculture and control depletion of aquifers.
- **WA+ Input**: Precipitation; and changes in storage of surface water, groundwater and snow packs to arrive at the net inflow
- **WA+ Output**
  - **Resource Base**: Rainfall, ET, storage, outflow, net withdrawals, atmospheric moisture flow
  - **Evapotranspiration**: evaporation from soil and water, transpiration, interception
  - **Agricultural Services**: Yield, consumptive use and water productivity
  - **Utilized Flow**: Withdrawals, consumptive use, return flow, drainage, recharge
  - **Surface Water**: Runoff, drainage, withdrawals, actual flow, marginal flow, return flow, storage changes
  - **Groundwater**: Recharge, withdrawals, return flow, lateral flow
  - **Ecosystem Services**: Recycled rainfall, surface runoff, baseflow, river flow, water yield, erosion, exchanges between land and atmosphere, i.e. greenhouse gases (H20, CO2, CH4, N2O), carbon sequestration, water storage capacity
  - **Sustainability**: Time series of rainfall, soil moisture, land use changes, ET anomalies

National Water Accounts – Australia[5] (http://www.bom.gov.au/water/nwa/about.shtml)

The standard prescribed by AWAS assists in an integrated and coherent water accounts for all the river basins in Australia. A general-purpose water accounting report (GPWAR) is generated inclusive of the contextual statement, accounts, information regarding water assets and liabilities, net water assets, changes in water assets and liabilities and statement of water flow across the basins including rights and claims to water resources. The report is further reviewed by qualified practitioners to assess the compliance of standards laid out by the AWAS (Australian Bureau of Meteorology, 2017).

[4] https://www.hydrol-earth-syst-sci.net/17/2459/2013/hess-17-2459-2013.pdf
[5] http://www.bom.gov.au/water/standards/wasb/wasbawas.shtml

- Provides water accounts as a combination of the science of hydrology and financial accounting models for a specific financial year developed by water industry experts, financial accountants, and financial accounting standard setters
- Comprehensive annual water information report on major urban and rural water supply systems [customized to Australian conditions] including water rights and water entitlements
- Characteristics of National water accounts data: best available data; standardized information; nationally consistent; easily available to all the sectors and highlights data gaps.
- Provides detailed accounts of water resources management (volumes of water storage, flow, usage, traded, extracted and managed) for 10 major regions in Australia
- Informs water resources planning, water market activity, investment decisions, environmental management decisions, policymaking and community dialogue to ensure water security
- Metering System to account for volumes of water usage
- The water information reports are based on the Australian Water Accounting Standards.
- Water accounting is a systematic process of identifying, recognising, quantifying, reporting, and assuring information about water, the rights or other claims to that water and the obligations against that water.
- Data required: Climate data; Metered data – flows, transfers; Modelled data – runoff, groundwater movement; Licence data
- Water accounting statements for water assets and water liabilities – Assets and liabilities; stocks and flows

The water information report includes information on:

- Changes in water inflows, outflows and storages
- Existing water access entitlements
- Water management plans applied to govern water access
- Water allocated for use during the reporting period
- Total traded water entitlement
- Amount of water abstraction for use
- Amount of water made available to the environment

Output/Outcomes:
Safety: Cyclone warning; Flood warning; Marine weather warning; Heatwave warnings etc.
Sustainability: El Nino and La Nina; Water resource assessment and account; Sea temperature and currents; Climate monitoring etc.
Well-being: Temperature and wind; Rainfall and sunshine; UV protection; Coral bleaching etc.
Prosperity: Aviation forecasts; Disaster mitigation; Commercial weather services; Information infrastructure etc.

System for Environmental-Economic Accounting for Water - SEEAW[6] (SEEAW, 2012)

Adopted as a provisional international standard developed by the United Nations Statistical Commission (UNSC), SEEA-Water provides the experts with uniform definitions, concepts, classifications and accounts for water resources. SEEAW provides an integral cross-sectoral perspective on water-related issues since it establishes a direct link between water, environment and economic accounts. It focuses more on the flows in the rivers, canals and other utilities, however, it does not consider the biophysical processes in the river basins generating renewable water resources ("SEEAW", 2017).

- SEEA-Water relates the water resource system with the economy. The methods used for evaluation of the water resources are similar as in economic analyses and the accounts are measured in physical and monetary units.

[6] https://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf

- SEEAW accounts provide information on the water-economy-environment interactions such as the contribution of water to the economy, flows between the economy and the environment such as abstractions and emissions and so forth.
- The modular structure of SEEAW (different categories) allows the users to prioritize the modules according to their concerns and data availability and hence provides a problem-oriented approach to design policies
- SEEAW addresses the spatial and temporal characteristics of water in their accounts
- Due to extensive data requirement and other issues, further researches are being conducted to standardize quality accounts and valuation of water resources.
- The social aspect of water resources and the impact of disasters have not been included in the SEEAW yet

The SEEAW Framework comprises the five categories of accounts described below (SEEAW 2012):

Category 1: ***Physical supply and use tables and emission accounts*** (physical supply and use tables provide information on the volumes of water exchanged between the environment and the economy and within the economy; emission accounts quantifies the pollutants added to or removed from the water)

Category 2: ***Hybrid and economic accounts*** (describes in monetary terms the use and supply of water-related products, the costs associated with these products, the income generated, the investments in O&M of hydraulic infrastructure etc.)

Category 3: ***Asset accounts*** (measure stocks at the beginning and the end of the accounting period and subsequently records the changes in the stocks that occur during the period due to natural causes)

Category 4: ***Quality accounts*** (describes the stock of water in terms of its quality)

Category 5: ***Valuation of water resources*** (describes background concepts in the economic valuation of water, different techniques, their strengths and weaknesses as well as their relevance to particular policy questions)