COUNT AND ACCOUNT WATER FOR AGRICULTURAL SUSTAINABILITY AND SUSTAINABLE DEVELOPMENTIN THE NENA REGION

Jiro Ariyama[1], Charles Batchelor[2], Amgad El Mahdi[3,] Robina Wahaj[4,] and Domitille Vallee[5]

ABSTRACT

The Near East and North Africa (NENA) region experiences severe scarcity, and there is a need to understand the fate of water to sustainably manage water. Well-adapted and well-implemented water accounting (WA) provides countries and/or regions that face increasing water scarcity a sound and transparent basis for managing the scarce water resources and inform management to achieve relevant goals and targets. WA differentiates consumptive and non-consumptive water uses in space and time. The latter is a crucial element of monitoring systems, for example, to evaluate and quantify benefits and potential trade-offs that result from policies and practices aimed at improving water efficiency, productivity and sustainability. Well-adapted and well-implemented WA also provides detailed information at different scales and institutional levels needed by potential users. To use water accounting properly for decision making, uncertainty in water accounting should be managed and communicated so that users of outputs know the level of confidence they can have in these outputs.

Better information, facts and evidence from water accounting alone may not deliver a quick fix to the complex challenges in the areas experiencing increasing water scarcity. Meeting these challenges will depend also on: better governance of water resources; investments in infrastructure; adoption of new technologies and better co-operation including data sharing and dialogue between key stakeholders within and across institutions and sectors. In this regard, water auditing can add value to water accounting by placing trends in water supply, demand, accessibility and use in the broader context of governance, institutions, public and private expenditure, legislation and the wider political economy.

This paper highlights the benefits of using water accounting that is multi-scalar, problem-focused and based on active stakeholder engagement in the NENA region. Typical challenges of institutionalising, operationalising and upscaling water accounting and water auditing are also highlighted alongside practical approaches to addressing and overcoming these challenges. The paper also describes the capacity development strategy and innovations that are being piloted in the NENA region. Finally, the paper lists recommended standard features of international standard water accounting systems.

Keywords: water accounting, water auditing, water scarcity, Near East and North Africa, capacity building,

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[1] Food and Agriculture Organization (FAO), Near East and North Africa Office; Email jiro.ariyama@fao.org

[2] FAO, Near East and North Africa Office; Email batchelorch@gmail.com

[3] International Water Management Institute, Middle East and North Africa Office; Email a.elmahdi@cgiar.org

[4] FAO, Pakistan Office; Email Robina.Wahaj@fao.org

[5] FAO, Near East and North Africa Office; Email domitille.vallee@fao.org

1 INTRODUCTION

1.1 Near East and North Africa Context and Challenges

The Near East and North Africa (NENA) is one of the most water scarce regions in the world. Over 60 % of the region's population lives in areas with high or very high surface water stress, compared with a global average of about 35 % (World Bank, 2018). Over 70 % of the region's gross domestic product (GDP) is generated in areas with high to very high surface water stress, compared with a global average of some 22%. Notably, the region's current water challenges go far beyond constraints of water scarcity linked to imbalances between water supply and demand. Additional challenges that have emerged in recent decades include: water quality and lack of water treatment infrastructure; climate change that seems to be influencing rainfall regimes and the frequency and severity of extreme events (e.g. floods and droughts); water-food-energy nexus issue and issues relating to transboundary water.

In most areas of the NENA region, agriculture is the biggest consumer of both surface and ground water. This has prompted a raft of policies and programmes aimed at improving the efficiency and productivity. While these policies and practices have delivered some benefits, it is notable that in many cases they have led to trade off that include increases in net consumptive water use at irrigation scheme and river basin scales (e.g. Molle, 2017). The solution to these problems in areas experiencing increasing water scarcity is relatively simple in conceptual terms: less water must be consumed, and whatever water is available should be used as productively as possible. A water accounting[6] (WA) can provide information to find possible solutions. However, the politics of this solution are far from simple, because choices have to be made regarding who should reduce water use. And the choices made likely have economic, social and food security implications (Molle and Closas, 2017) that require multi-agency participatory approach to be sustainable (Elmahdi and McFarlane 2011).

The NENA region offers many successful examples of policies to improve the governance of water services (World Bank, 2018). Yet institutional and governance constraints, such as low accountability or a lack of financial skills within the sector, still pose a barrier to progress toward improved service delivery. Also, water governance in most countries tends to be uni-sectoral while alignment of plans and policies and information sharing among agencies are required for successful water governance. There is also a tendency to seek engineering solutions rather than more challenging but also more appropriate demand-side solutions or social agreements.

Water auditing[7] can shed light on the relationship between the WA outputs and governance, social, political and economic contexts to support successful use of WA for decision making. However, it would be naïve to believe that improvements to water governance or policy development will follow automatically and seamlessly from water accounting and auditing (WA&A). People who implement and/or use outputs of WA&A need to be aware that collection, evaluation, analysis and interpretation of biophysical, economic, and societal information that is central to

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[6] **Water accounting** refers to the systematic study of the hydrological cycle and the current status and future trends in both water supply and demand. Beyond the simple accounting of volumes and flows, it also focuses on issues relating to accessibility, uncertainty and governance of water. Therefore, Water Accounting is a critical tool to support any initiative aiming at addressing the challenges of water scarcity. (FAO, 2017)

[7] **Water auditing** goes a step further than water accounting by placing trends in water supply, demand, accessibility and use in the broader context of governance, institutions, public and private expenditure, laws, and the wider political economy of water in specified domains. (FAO, 2017)

WA&A is subject to uncertainty and professional biases and behavioural irrationality (Batchelor et al, 2017).

WA&A may face limited availability and accessibility to quality water-related data. Many projects and programmes have sought to upgrade existing data acquisition and management systems by investing in equipment and need-based capacity development. Nevertheless, funds are not always available to cover the recurrent operating costs on these systems. The increasing availability of relevant remotely sensed (r/s) data has helped overcome the challenges of ground-based data acquisition systems. However, good quality ground-based information is still needed to validate and/or calibrate outputs produced from r/s data.

1.2 NENA Regional Water Accounting Initiatives

WA has been used in the NENA region at the pilot scale during the last two decades. For example, WA case studies have been carried out in Jordan using the WA+ and SEEAW frameworks (SEEAW, 2012). Also between 2009 and 2012, as part of MASSCOTE approach for irrigation system modernization, WA at the irrigation scheme level was carried out in a number of countries including Syria, Jordan, Iran, Tunisia, Egypt, Morocco, Lebanon (CiHEAM and FAO, 2013). In most cases, these case studies were supported by necessary technical capacity development programmes. To date, there has been limited progress towards the institutionalisation of sector-wide national or basin level WA systems. However, progress has been made towards the establishment of a WA unit in the Planning Section of Egypt's Ministry of Water Resources and Irrigation. This activity is being supported by the EU STARS Project and FAO projects funded by Swedish International Development Cooperation Agency (Sida) and other agencies.

It is notable also that FAO is implementing the same Sida-funded Project[8] across eight NENA countries including Egypt. It supports the countries to adapt and institutionalise an international standard and scientifically-sound WA system, based on advances in space technology and ground measurements.

2 BASIC CONCEPTS, TERMINOLOGY &FRAMEWORKS

2.1 What Is Water Accounting?

It is being recognized increasingly that well-designed and well-implemented WA is fundamental to effective water management as well as irrigation modernization (FAO, 2007)[9]. At it's simplest, WA consists of methods, tools, and practices to assess and monitor volumes of water available and used consumptively and non-consumptively throughout a water system (After Escriva-Bou, 2016). It can be applied to water management at all scales, from large river basins to local irrigation or urban water utilities.

The origins of WA are debatable. In the 80s, the French government's demand for green accounts led to the first effort to propose a physical and financial WA framework (Collective, 1986). Both Spain and France piloted the approach in the 90s but did not develop it further (Margat, 1999). The UN Economic and Social division

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[8] Regional Project "implementing the 2030 agenda for water efficiency/productivity and sustainability in the NENA region" under the Near East and North Africa Water scarcity initiative led by FAO. This project is funded by Sida.

[9] FAO (2007, 2013) developed approaches and methodologies to modernize irrigation systems, which include water accounting addressing multiple water uses within the canal command areas. The whole

built on that framework to develop SEEAW that was published in 2012. However, a seminal publication by Seckler (1996) influenced many early WA efforts. Amongst other interesting observations, this publication stated: "The fundamental problem with the concept of water use efficiency based on supply, that is, diversion to a project, is that it considers inefficient both the evaporative loss of water and the drainage water. This is invalid for that part of the drainage water which can be reused. To overcome this confusion in the concept of water use efficiency, knowledgeable people now distinguish between “real” water savings and “paper” water savings—or, as they say in California, between “wet” and “dry” water savings".

2.2 Water Accounting Vs Financial Accounting

Financial accounting is often used as a metaphor for WA. The principles on which financial accounting is based are common to any type of accounts: financial accounting is the application of a set of definitions and rules to incomes, expenditures, and other transactions so as to describe, for a given period of time, the financial flows, including increases and decreases in savings, profits and losses for a financial entity (Perry, 2007). It is notable that most of us are familiar with some terms used in financial accounting such as expenditure, income, surplus, deficit, profit and loss. Furthermore, the temporal frame of reference must be appropriate: sales in one season may be much higher or lower than sales in another, so that accounts must either be qualified as unrepresentative of a whole year or must include the whole year.

Elmahdi (2018) reported WA concepts were developed using the water balance and financial accounting principles. There are ***similarities*** between water and financial accountings. Both types of accounting

- Provide quantitative and qualitative information about the system, domain or entity being reported on;
- Provide 'cash flows' (in WA terms, 'water flows') and 'accrual' accounting reports (where changes are recognised when a claim to water or obligation to deliver is recorded, not when the actual flow occurs);
- Can use double-entry accounting to ensure reliability.
- However, there are also ***clear differences*** between the two:
- Users include multiple stakeholders for making and evaluating decisions about water;
- The primary unit is water volume (L/KL/ML/BCM), rather than monetary currency;
- Water report systems, domains or entities can be geographic regions or water systems as well as organizations;
- There is greater variation in the accuracy of water data, particularly where data modelling and estimation are necessary for quantification;
- Water flows, fluxes and changes of state are all subject to the laws of physics.

Box 1. Water use fractions

(1) ***Consumed fraction*** comprising of:

- (a) ***Beneficial consumption*** e.g. evapotranspiration from an irrigated or rainfed crop (but not the soil).
- (b) ***Non-beneficial consumption***e.g. evaporation from bare soil, weeds, roads and reservoirs.

(2) ***Non-consumed fraction*** comprising of:

- (a) ***Recoverable fraction***: e.g. deep percolation of excessive irrigation or rainfall to an aquifer without adversely affecting the water quality of this aquifer or treated urban wastewater.
- (b) ***Non-recoverable fraction***: e.g. water flowing into a saline sink or heavily polluted aquifer.

2.3 Water Use Fractions

In general, when water is diverted and used, a fraction of the used water is no longer available for reuse either locally or downstream (e.g. the fraction evaporated into the atmosphere). This fraction of water use is often referred to as the *consumed faction* (see Box 1). This consumed fraction can be further subdivided into water use or *water* pathways that are beneficial or non-beneficial.

The fraction of water that is not consumed is referred to as the non-consumed fraction. By definition, this fraction returns to, for example a river or canal either locally or downstream. This non-consumed fraction can be further sub-divided into recoverable or non-recoverable fractions. For example, water percolating to groundwater is likely recoverable if the aquifer is not highly saline and non-recoverable if the aquifer is highly saline or polluted. Further subdivisions are possible. However, the more sub-divisions there are, the more difficult or time consuming it is to use fractional analysis. Hence the recommendation in this paper is, as a general rule, to only use the four water fractions defined in Box 1.

One of the objectives and merits of fractional analysis is that it draws attention to the importance of return flows (usually non-consumptive recoverable fraction) and the fundamental differences between water use pathways that are consumptive and non-consumptive (in space and time). Fractional analysis also draws attention to the inter-connectedness of hydrological systems and, particularly, the fact that increasing consumptive water use in one part of a catchment or basin can reduce water availability for other users in the basin.

Important attributes of the fractional approach to WA include: 1) It can be adopted for analysis of the water use of rainfed and irrigated farming systems and 2) It can be adopted for analysis of any water-using sector – not just agriculture (Perry et al, 2009). However, to be effective, fractional analysis must be based upon sound physical data, rigid consistent analysis of the water volumes involved and their disposition in time and space (Frederiksen and Allen, 2011). Also, stakeholders should have a good understanding of the methodology and the outputs that are generated (Frederiksen and Allen, 2011).

A practical alternative to considering multiple water use fractions is to quantify and communicate two water use fractions, namely, *gross* and *net* water use. The gross water use is the volume of water used for a specific purpose, and the net water use is the sum of volumes of water that are consumed (e.g. as evapotranspiration) and water that is non-recoverable for one reason or another (Figure 1).The difference between gross and net water use are the return flows (i.e. the volumes of water that returns to rivers, streams, or aquifers and is available for reuse).

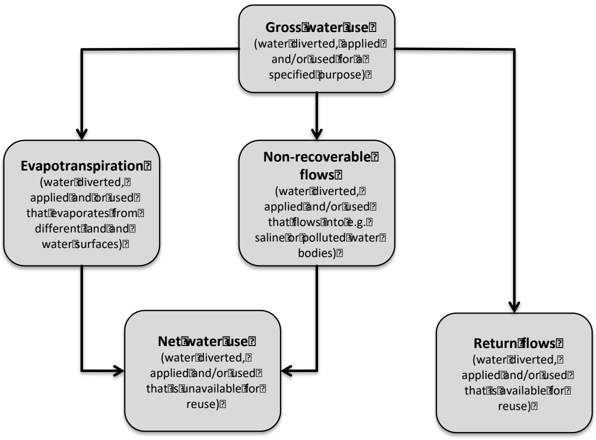

Figure 1: Gross and net water use fractions (After Escriva-Bou et al, 2016).

At one level, fractional analysis is relatively simple especially when used to analyze the water use pathways that are off-stream and involve one type of water use. However even in simple cases, quantifying water use fractions can be problematic due to limited data availability. It is important to note also that the relative magnitude of water use fractions is influenced by many factors that are highly variable in space and time. Another point to recall is that return flows may be reused again once or multiple times either locally (e.g. by the original water user) or by downstream water users.

2.4 Schematics and Perceptual Models for WA

Identifying, classifying and quantifying flows in a specified domain of interest (e.g. a river basin, and aquifer or an irrigation scheme) for WA can be a daunting task given inherent levels of complexity in pristine and heavily engineered systems. One option here is to develop a preliminary perceptual model or schematic of an area of interest using existing information and knowledge (e.g. reports, easily-accessible data, and experience of specialists who know the area well). This can be supplemented by field visits and, for example, time series and spatial analysis of relevant secondary data.

The aim of the perceptual model is to produce a graphical representation of, for example, the dominant biophysical and societal processes that influence water flows, fluxes, pathways and stocks (in space and time). The main benefits of developing perceptual models in the early stages of a WA process include: 1) It helps ensure that WA takes account of and/or builds on existing knowledge and practices; 2) It provides information of the quality and accessibility of secondary data; 3) It encourages those involved to think carefully about the underlying causes of water-related problems in the domain of interest and possible opportunities for addressing these problems; 4) It provides a good basis for identifying methods and/or additional equipment that may be used or needed for estimating the flow rates and quality return flows. In most cases, a small group of specialists and key stakeholders will develop or update the perceptual models. As a result, the models will reflect the perceptions, knowledge and experience of this group. However, the perceptual models can also be shared, discussed and modified following a broader consultative process (e.g. during stakeholder dialogue). Figure 2is a perceptual schematic of the Nahr El Kalb River

river basin in Lebanon. This schematic was used by the Sida Project WA team as basis for classifying the main water fluxes, uses and pathways according to whether or not they are consumptive (beneficial or non-beneficial) or non-consumptive (recoverable or non-recoverable.

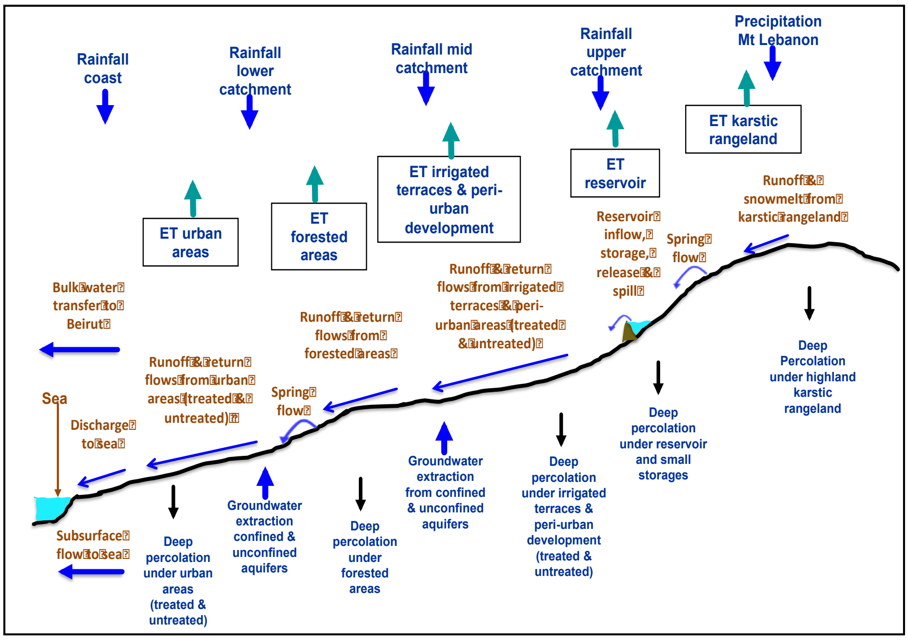

Figure 2. Perceptual schematic of predominant water flows, stocks, pathways and uses along a East-West transect of the Nahr El Kalb river basin Lebanon.

2.4 Water Accounting and Auditing (WA&A)

As a general rule, water accounting and auditing processes are mutually supportive and best designed and implemented in parallel with a high degree of stakeholder engagement (see Figure 3). Three different approaches have been recommended for designing and implementing water auditing, namely: governance assessment, political economy analysis and some combination of both. Guidelines for these approaches/analyses can be found online (e.g. UNDP 2009 and 2013, World Bank, 2011, and Rao, 2014). However, a crucial first step is to identify the needs, priorities and the institutional levels at which water auditing will be of most value to key stakeholders. Only then should a decision be made on the most appropriate water auditing approach. Consideration should also be given to potential synergies between water accounting and water auditing. Mutual support and integration of interdisciplinary biophysical and societal analysis will be easier and more productive if the same or similar spatial and temporal scales and granularities are used when collecting, processing and analysing information and making recommendations. Finally, water auditing may generate findings and outputs that are politically, culturally or professionally sensitive. In such cases, this should be considered when planning the water auditing process. If the sensitive findings are expected, permission should be obtained from key stakeholders before any findings or outputs are shared.

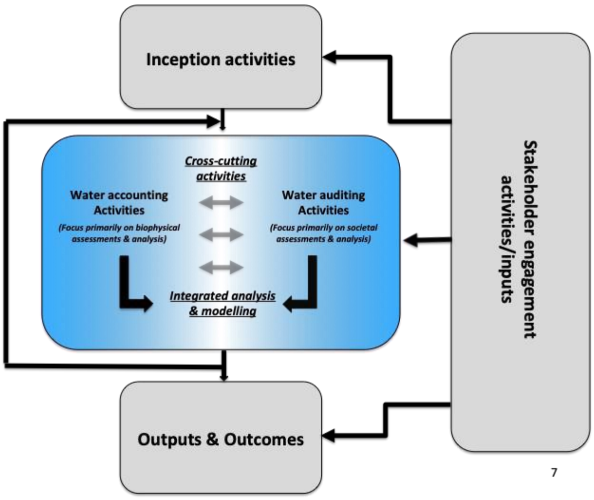

Figure 3: Overall approach to water accounting and auditing (FAO, 2017)

2.5 Efficiency, Productivity and Sustainability Terms

Generically, 'water efficiency' is a dimensionless ratio that can be calculated at any scale and used for different classes of water supply and use. In the agricultural sector, it is referred to as irrigation efficiency (IE) and used to assess and monitor system losses that can be classified as consumptive non-beneficial (e.g. evaporation from a canal) and non-consumptive recoverable/non-recoverable (e.g. seepage from unlined canals to a usable or unusable aquifer) fractions. At the national, basin and large irrigation scheme scales, there are good reasons for improving IE. For example, higher IE leads to less energy for pumping water. Lower levels of water abstraction or diversion for irrigation can also reduce impact on the availability for other water users and uses of the same water source (e.g. a reservoir or an aquifer). This in turn can reduce the risks of overexploitation of the water source, damage to aquatic ecosystems, and unequal access to water among farmers (e.g. at the tail-end of the supply system). However, these benefits may be negated where downstream water users have grown dependent on return flows (e.g. deep percolation, leakage from supply systems), or where increased IEleads to expansion in the irrigated area, an increase in cropping intensity, and, thus, a major increase of consumptive water use at the national, basin and large irrigation scheme scales.

IE neatly distinguishes the irrigation engineering/management efficiency from the farmer/agronomic efficiency (van Halsema and Vincent, 2012). However, it should be noted that IE estimates are less comparable than sometimes implied because they are scale dependent, both in time and space. This hampers comparison of IE values, across scales, time frames and localities (Van Halsema and Vincent, 2012). Here, IE for a specified domain, is defined as a ratio:

$$IE = QBC / QTWA$$

where QBC is the volume of water beneficially consumed as evapotranspiration, or possibly as leaching to prevent salinization, and QTWA is the total volume of water applied.

Increasing the water productivity (WP) of irrigated agriculture is viewed as an important element of development goals because WP improvements have the potential to increase production per unit of water consumed. This enables a more efficient use of water resources, and this is particularly important where these resources are limited.

Water productivity for a specified domain can be defined and derived as:

WP = Y Actual / Q Consumed

Where Y Actual is the actual crop yield and Q Consumed is the volume of consumed water (evapotranspired) to produce this yield. A significant advantage of this WP parameter is that any absolute increase in water consumption (rather than application) equates unequivocally with an absolute increase in water depletion from a specified domain. This forces explicit consideration of any increase or decrease in water consumption (van Halsema and Vincent, 2012). In contrast, considerable confusion and questionable interpretations occur when the definition and value of the denominator in the above equation is replaced by total water use (or total water applied).

Water resources sustainability is often assessed based on the difference between estimates of renewable water resources available in a specified domain and the total water used by different sectors in the same domain. In many cases, little or no distinction is made on differences between the consumptive and non-consumptive water uses. These omissions put into question the value of these relatively simplistic estimates as metrics of sustainability. Another concern with water resources sustainability metrics is the fact that they often use historic data. Given threats of climate change, it is uncertain whether historic data predict well the current of future rainfall variability. Similarly, trends in pollution, in some cases induced or exacerbated by unsustainable ground and surface water utilisation, are inherently difficult to assess and monitor. It is notable also that the challenge of improving efficiency, productivity and sustainability is complicated by the fact that sustainability beyond farm scale is not necessarily a high priority for farmers. For example, farmers may prioritize reducing risk, reducing labour requirements and/or maximizing returns on investments (Wichelns, 2014). More positively, WA&A provide a sound basis for identifying and monitoring robust sustainability metrics in a different biophysical and societal context.

3. CHALLENGES OF OPERATIONALISING AND INSTITUTIONALISING WATER ACCOUNTING

Typically, operationalising and institutionalising WA is a challenging process that requires time and effort from all stakeholders with a clear champion for the process and implementation (Elmahdi et al, 2017). This section lists lessons learned to date by projects and programmes that have been working with national governments in the NENA region:

Implementation strategy: WA is being implemented in the Sida-funded project in a series of iterative and adaptive cycles that start with rapid WA using mostly secondary data in relatively small pilot areas aimed at building capacity and demonstrating the added value of WA. Subsequent cycles upscale and focus increasingly on priority issues and/or opportunities and adoption of more advanced WA methods and tools on a need basis.

Human and financial resources: Typically, government departments in the NENA region have limited human capacity and financial resources to institutionalise comprehensive WA systems that operate at multiple scales and institutional levels. As a result, problem and/or opportunity focused WA has been recommended that concentrates resources on acquiring and analysing data related to priority issues or needs and scales of most interest.

Team building: Typically water-related government departments are well-endowed with engineers. Engineers are needed in WA teams, but effective WA requires specialist knowledge and experience in, for example, hydrology/hydrogeology, meteorology, agronomy, informatics, cyber technology, GIS and remotes sensing, economics, stakeholder engagement, communication etc.

Capacity development strategy: In the past, WA capacity development has focused mainly on advanced WA methods. However there is also a need for formal and on-the-job capacity development in the basics of WA concepts. It is recommended that all WA trainees and potential users of WA outputs receive capacity development in WA basics before moving to capacity development in advanced WA (such as WA using remote sensing and modelling).

Managing uncertainty: Outputs from WA can have high levels of uncertainties. The level increases when the input data are "uncertain" (gaps in data sets, badly functioning monitoring instruments etc.). Some of this uncertainty areessentially irreducible. Reducible uncertainty is best addressed by cycles of targeted learning aimed at improving the confidence in WA outputs (see Figure 4). Uncertainty also increases when the scale of the WA does not match the scale of the needed information (e.g., Basin scale WA may not provide good information farm water management) hence setting WA's scale correctly at the earlier stage is crucial.

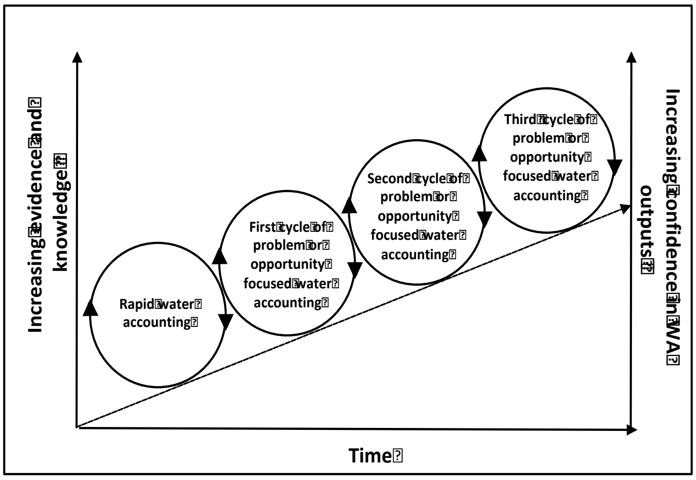

Figure 4. WA cycles of learning and adaptation.

Data accessibility and gaps: In some respects, data accessibility has improved in NENA region. For example, more remotely sensed and terrestrial data are now available from open-access web sites. However, there is still unwillingness amongst key stakeholders to share data in the NENA region where data is treated as treasure and provide level of job security. Unwillingness to share data is difficult to address, however it can be facilitated in the process of water auditing. Hydrometric networks are sometimes poorly maintained. There are many opportunities for improving hydrometric networks using, for example, new (and cheaper) web-based based sensors and communication systems.

Advanced water accounting: Many countries in the NENA region would like to operationalise advanced WA systems. This is understandable but not necessarily advisable if, for example, the institutional arrangements are not in place, if lines of funding have not been approved and/or if good quality data are not available for calibrating and validating models and algorithms that are part of the advanced system. In the Sida-funded project, the rapid WA mostly relying on the secondary data without developing advanced WA system was selected as the first cycle of WA in most countries.

Pollution/water quality: To date, WA projects and programmes in the NENA region have focused on volumes and flows of water. However ongoing WA pilots are finding that pollution and water quality, In particular salinity, is a huge issue that, in most cases, requires as much attention as flows, fluxes and storage of water. It is also interesting to note that return flows are in many cases health risks and appear to play a major role in the dispersion and transport of a wide range of pollutants. Wastewater and drainage reuse offer an opportunity to reduce the risk provided applied water is treated at the required level.

Beliefs and misconception: As in other regions of the world, decision-making based on intuition and repetition of earlier decisions is common among the NENA region's water and irrigation sectors. A key challenge is therefore to shift to decision making that is informed by facts and evidence produced from WA&A processes.

Whole system water accounting: To date, WA pilots in the NENA region have focused mainly on the water diverted and used in crop production systems and the magnitude and location of return flows. The main reason is that crop production systems are the main consumptive water user. More attention could be given to WA from the field to the fork given that considerable volumes of water can be used consumptively and/or non-consumptively during post-harvest activities or as non-beneficial consumptive water use in the form of post-harvest losses.

4. DESIRABLE ATTRIBUTES OF WATER ACCOUNTING SYSTEM

Some WA systems are standardised to the point that one size fits all. However, most WA systems can be tailored to meet the priority demands and needs of a country or a region. Arguably an international standard WA system should**:**

- Be based on standardised WA procedures, principles, concepts and terminology;
- Be tailored to the availability of relevant remotely-sensed and terrestrial information;
- Be tailored to the needs, priorities and scales of most interest to potential users of WA outputs;
- Take a multi-scalar approach or nested structure that typically involves analysis and modelling at multiple scales or institutional levels;
- Take explicit account of uncertainty and ensure that levels of uncertainty in outputs are communicated along with relevant outputs;
- Communicate outputs in forms and formats that meet the needs of decision makers
- Make good use of secondary information and open-access database;
- Make good use of advances in informatics and cyber-technologies e.g. interactive visualisations and dashboards, web-based applications etc.;
- Make good use of advances in data acquisition methods/tools and have dynamic links to databases, web-based environmental sensors etc.;

5. CONCLUSION

Well-designed and well-implemented water accounting systems can and should be used when developing and evaluating strategies for achieving water sustainability. However, a key point is that a water accounting system is much more than a set of models or algorithms. Typically a water accounting system requires: systems and/or platforms for acquiring and managing data and information; a range of methods and tools for processing, analyzing and interpreting data; a team of specialists with relevant knowledge and experience in various field; the active engagement of key stakeholders who may share data and/or use water accounting outputs; and, an enabling institutional environment. To make a good use of the water accounting outputs, water auditing that analyze the social and institutional perspectives is recommended. Water auditing identifies barriers to improved water accounting and/or implementation of policies or interventions aimed at addressing water scarcity. In conclusion, mutually-supportive water accounting and auditing has the potential to underpin a smooth transition to more water-sustainable societies.

6. REFERENCES

CiHEAM-MAI and FAO. 2013. Daniel Renault, Daniele Zaccaria, Robina Wahaj, Mohammed Bazza. Modernization of irrigation system management: SYNTHESIS of MASSCOTE APPLICATIONS in 7 systems of NENA REGION

Collectif, 1986, Les comptes du patrimoine naturel (INSEE. les collections de l'INSEE 137-138 C. n° 535-536. Déc. 552 p. Paris). Chap. 5. J.Margat, le compte des eaux continentales.

Elmahdi, A., and McFarlane, D. 2011. Integrated multi-agency framework MAF for delivering sustainable water resource management. Journal of Water Resources Management.

Elmahdi, A., Parr,E., Walters, C., and Vranes, M.,2017. Australian Country paper: Institutional Reform in Irrigation Sector For Sustainable Agricultural Water Management; ICID.

Elmahdi, A. 2018. EU Water Sector Technical Assistance and Reforms Support (EU Water STARS) report. Water Accounting Frameworks, from challenge and gap analysis to WAU Plan and Implementation.

Escriva-Bou, A., McCann, H., Hanak, E., Lund, J. &Gray, B. 2016. Accounting for California's water. California, USA, PPIC Water Policy Centre.

FAO. 2007. Modernizing irrigation management – the MASSCOTE approach, by D. Renault, T. Facon, T. & R. Wahaj. FAO 2007. IDP 63 207 pages

FAO. 2013. Multiple uses of water services in large irrigation systems: Auditing and planning modernization The MASSMUS Approach. FAO 2013. IDP 67 199 pages

FAO. 2017. Water accounting and auditing sourcebook. FAO Water Report 43 (Revised Edition): www.fao.org/3/a-i5923e.pdf

Margat, J, Babillot, P. 1999. National water comptability in France:an instrument for analysing and managing. LA HOUILLE BLANCHE/N° 3/4-1999.https://www.shf-lhb.org/articles/lhb/pdf/1999/03/lhb1999038.pdf

Molle, F. 2017. Conflicting policies: agricultural intensification vs. water conservation in Morocco. G-EAU Working Paper/Rapport de Recherche No.1. Montpellier, France. http://www.g-eau.net/

Molle, F. and Closas, A. 2017. Groundwater Governance: A Synthesis. Groundwater governance in the Arab World - Project report No. 6. IWMI.

Rao,S. 2014. Problem-driven iterative approaches and wider governance reformhttp://gsdrc.org/docs/open/HDQ1099.pdf

Seckler, D. 1996. The new era of water resources management. Research Report 1. Colombo, Sri Lanka: International Irrigation Management Institute (IIMI).

UNDP. 2009. Planning a governance assessment: A guide to approaches, costs and benefits. http://www.undp.org/content/rbas/en/home/presscenter/events/2012/November/regional_governance_week/_jcr_content/centerparsys/download_8/file.res/Planning%20a%20governance%20assessment.pdf

UNDP. 2013. User's Guide on Assessing Water Governance. http://www.watergovernance.org/documents/WGF/Reports/20058-UNDP-Assessing-water_web.pdf

UNDESA. 2012. SEEA-Water System of Environmental-Economic Accounting for Water. https://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf

Wichelns, D. 2014. Do estimates of water productivity enhance understanding of farm-level water management? Water, 6: 778–795.

World Bank. 2011. How-to Notes: Political Economy Assessments at Sector and Project Levels. http://capacity4dev.ec.europa.eu/political-economy/document/how-notes-political-economy-assessments-sector-and-project-levels

van Halsema,G.E. and Vincent,L. 2012. Efficiency and productivity terms for water management: A matter of contextual relativism versus general absolutism. Agricultural Water Management 108, 9– 15.

World Bank. 2018. Beyond Scarcity: Water Security in the Middle East and North Africa. MENA Development Series. World Bank, Washington, DC