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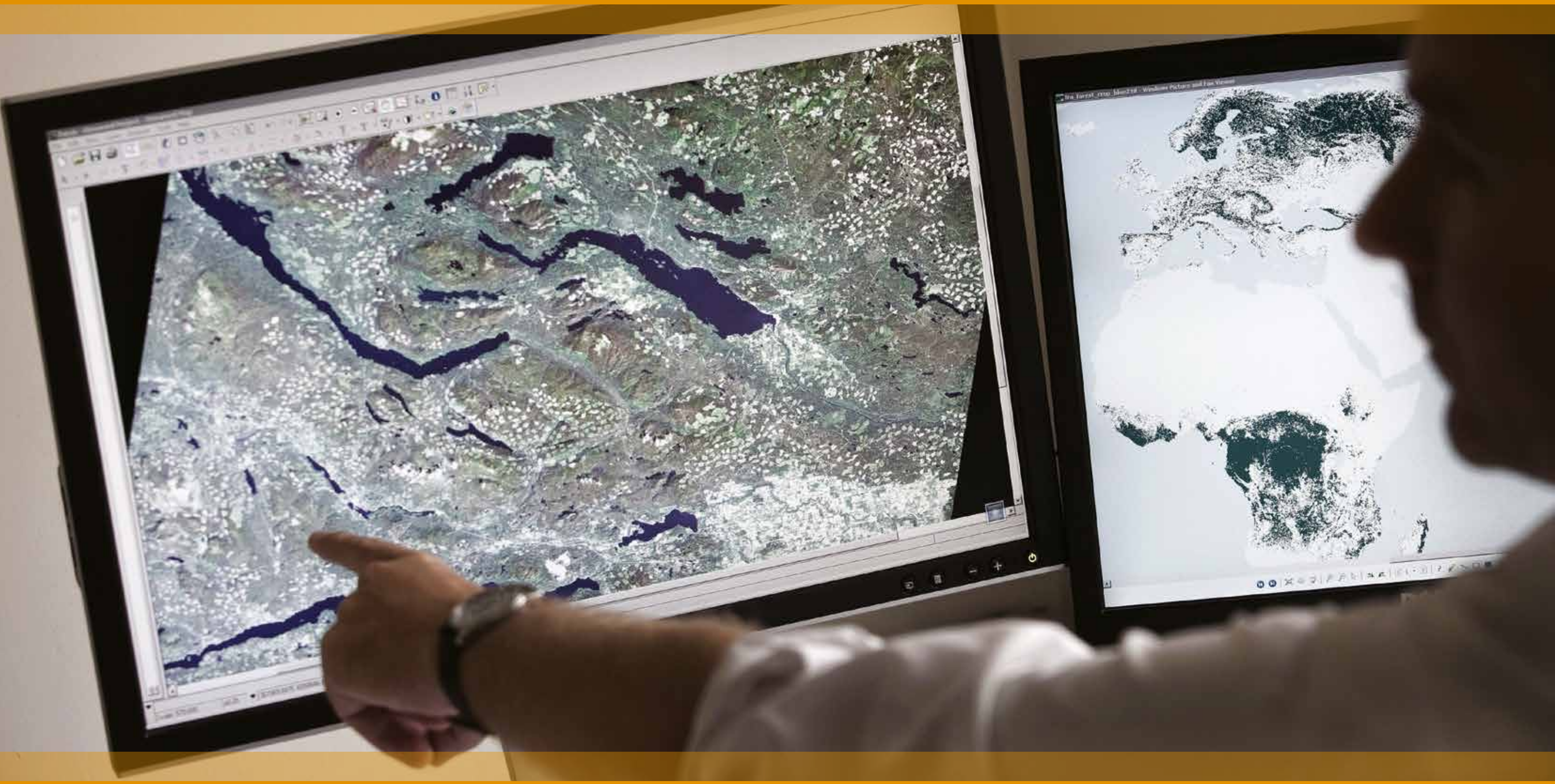

Regional stakeholders workshop on

OPERATIONALIZING THE REGIONAL COLLABORATIVE PLATFORM OF THE WATER SCARCITY INITIATIVE

TO ADDRESS WATER CONSUMPTION, WATER PRODUCTIVITY AND DROUGHT MANAGEMENT IN AGRICULTURE

Proceedings

27-29 October 2015 | Cairo, Egypt

Regional Initiative on Water Scarcity for the Near East and North Africa

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ACRONYMS AND ABBREVIATIONS

ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AfDB	African Development Bank
AOAD	Arab Organization for Agricultural Development
AWC	Arab Water Council
CEDARE	Centre for Environment and Development for the Arab Region and Europe
CIHEAM	International Centre for Advanced Mediterranean Agricultural Studies
DRC	Desert Research Center
DWFI	Daugherty Water for Food Institute
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization of the United Nations
FAO-RNE	FAO Regional Office for Near East and North Africa
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture
IFAD	International Fund for Agriculture Development
IWMI	International Water Management Institute
LAS	League of Arab States
MALR	Ministry of Agriculture and Land Reclamation
MENA	Middle East and North Africa
MSEA	Ministry of State for Environmental Affairs
MWRI	Ministry of Water Resources and Irrigation
NDMC	National Drought Mitigation Center (University of Nebraska)
NENA	Near East and North Africa
NOAA	National Oceanic and Atmospheric Administration
NWRC	National Water Research Center
RICCAR	The Regional Initiative for the Assessment of Climate Change impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCO-IHE	UNESCO - Institute for Water Education
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
USAID	United States Agency for International Development
WB	World Bank
WFP	World Food Program

PREPARATION OF THIS DOCUMENT

These proceedings present the outcome of the regional workshop "Operationalizing the Regional Collaborative Platform to address water consumption, water productivity and drought management in agriculture" held in Cairo, Egypt, from 27 to 29 October 2015. The workshop was organized by the Regional Office for the Near East and North Africa of the Food and Agriculture Organization of the United Nations (FAO RNE) in collaboration with the Robert B. Daugherty Water for Food Institute (DWFI) of the University of Nebraska at Lincoln (UNL), the International Center for Biosaline Agriculture (ICBA), the National Drought Mitigation Center (NDMC) and the United States Agency for International Development (USAID). Financial support for the workshop was provided by FAO-RNE and DWFI. This document was prepared by Ramy Hanna, University of Sussex, with the support of Elodie Perrat, Regional Initiative Associate Officer, under the supervision of Pasquale Steduto, Delivery Manager of the Regional Initiative on Water Scarcity. The workshop was facilitated by Pasquale Steduto, Fawzi Karajeh and Faycel Chenini from FAO RNE and Rachael McDonnell from ICBA.

ABSTRACT

The Regional Collaborative Platform (RCP) is the key mechanism to implement the Regional Collaborative Strategy for evidence-based policy decisions. It is an innovative approach based on selected priority issues. In this respect, the NENA regional stakeholder workshop, *Operationalizing the Regional Collaborative Platform*, addressed three key thematic areas: water consumption and water accounting, crop water productivity and drought management. The workshop was held in Cairo, Egypt, from 27 to 29 October 2015 and brought together about 100 national, regional and international stakeholders involved in agricultural water management and drought management. The workshop was notably attended by Hossam Mughazy, Minister of Water Resources of Egypt, representatives of countries in the region and academics and experts on the subject matter.

This report presents the proceedings of the regional workshop and provides a summary of discussions, by thematic area, covering the three key topics: water consumption, crop water productivity and drought management. Under each theme, an abstract summary of each key expert contribution is presented, followed by summaries of country presentations providing country views on certain topics and activities as well as their future potential inputs to the Regional Platform.

A main objective of the workshop was to develop an operational work plan based on the main recommendations made by each country following the discussions addressing each of the three key topics. The recommendations are made by each country based on their priorities and needs, and constitute the basis for consultations between the relevant institutions at the country level towards the elaboration of a comprehensive national work plan to be implemented through specific actions.

Discussions on day 1 indicated that a proper water accounting system considers water availability (dry and wet years) in allocating water (supply). Countries also highlighted the need to balance supply and demand in a context of water scarcity. In this respect, demand is defined by sector, which can ultimately define the status of water stress. Countries agreed that the way forward for the NENA region on the issue of water accounting includes preparing monthly water accounts; posting data on repositories available to water use planners in order to enable policy planning, towards sustainabile withdrawals and consumption; establishing a monitoring program whereby the required data is provided from remote sensing (RS) projects and publishing lessons learnt from other arid climate countries.

Discussions on crop water productivity recognized that the best way to achieve impact on the ground and meaningful changes is through a collaborative approach, for which the RCP has been established. As such, it was agreed that solutions must be pursued with appropriate government, regional and local agricultural and water management agencies. Products should be verified in the field to allow for feedback, model modifications and improvements. Ground verification data must be collected, analysed and interpreted jointly in order to achieve mutual learning. Training needs that were identified in the discussions included training on quality

control (QC) and data analysis and interpretation. Overall, participants have recognized that the platform should be viewed as a joint venture involving multiple countries. Long-term commitments in this respect include the FAO and USAID ten-year program, which aims to capture knowledge but also bringing satellites and data mining to the ground.

Discussions on drought management identified country needs including an early warning system, baseline surveys and data distribution as well as improving technical know-how and institutional arrangements. Countries confirmed that there is a data gap due to different interests and measurement scales as relevant to each context. In terms of communication and monitoring, there is no real coordination among the agencies responsible for drought information and data. This is another main challenge that needs to be addressed through the RCP.

The workshop proposed that country recommendations be used to further elaborate their national work plans, according to the following steps:

- definition of methodological approach to monitor water consumption, water productivity and proper drought indices;
- identification of agricultural systems to be monitored;
- development of criteria for field validation of remote sensing assessments;
- capacity development for water productivity analysis and response measures, to enhance agricultural water management.

These recommendations will constitute the basis towards the elaboration of comprehensive national work plans.

STRUCTURE OF THE REPORT

This document provides a summary of discussions by thematic area covering the three key topics of water consumption, crop water productivity and drought management. Under each theme, a summary of each key expert contribution is presented, followed by a summary of the country presentations providing country views on certain topics and activities, as well as their future potential inputs to the Regional Platform.

For each session, the main points of discussion and the key messages are presented and summarized. The key conclusions for each thematic area are presented separately for each day.

The report ends by providing the main workshop messages and the way forward for the Regional Collaborative Platform. Lastly, in the appendices, the report provides a list of the presentations made during the workshop, the workshop agenda and a list of the participants.

Introduction

BACKGROUND

Today's agriculture uses about 70 percent of all fresh water withdrawals globally and up to 95 percent in several developing countries. Particularly in the Near East and North Africa Region (NENA), already naturally exposed to chronic water shortage, countries must cope with one of their most striking challenges: the pursuit of food and water security for sustainable social and economic development, under an unprecedented severe escalation of water scarcity. Demographic growth, the tendency to increase food self-sufficiency to reduce vulnerability to import and price volatility, the expansion of urbanization, energy demand and overall socio-economic development, further exacerbated by the negative impacts of climate change and the considerable degradation of water quality, are key factors driving such scarcity.

Furthermore, there is an alarming trend observed over last decades of more frequent, intense and long droughts in the NENA Region. This threatens productivity of the agricultural systems and increases land degradation and desertification, augments severity of sand storms and deteriorates livelihoods. Drought impact might be disruptive if timely and proper mitigation measures at local, national and regional scales are not put in place.

It is therefore of paramount relevance that countries strategically plan their water resources allocation and review their water, food security and energy policies to account for the impact of climate change (particularly its extreme events) and to ensure their alignment with the imperative of making the best use of each single drop of water. Moreover, reducing the risk of drought and other climate-related hazards must be addressed and 'drought management' measures must be incorporated at policy and institutional levels.

To address this challenge, in 2013, FAO launched the "Regional Initiative on Water Scarcity" (WSI) and developed the "Regional Collaborative Strategy on Sustainable Agricultural Water Management in the Near East and North Africa Region". The Regional Collaborative Strategy represents a framework to assist countries in identifying and streamlining policies, governance, investments and practices that can sustainably improve agricultural productivity and food security in the region.

In order to implement the Regional Collaborative Strategy and accelerate the adoption of agricultural water management solutions in the NENA Region, FAO is currently deploying a *Regional Collaborative Platform.*

In order to accelerate delivery of results, the Regional Collaborative Platform leverages other existing regional and international initiatives (including DWFI Global Yield Gap Atlas and UNESCO-IHE Water Accounting), partnerships (such as ICBA, AWC, ICARDA and National

Centres of Excellence) and projects (such as “Using remote sensing in support of solutions to reduce agricultural water productivity gaps” implemented by FAO/Netherlands; “Modelling and monitoring water and agricultural resources for development”, implemented by ICBA, USAID and NASA; and the GEF project “The Regional Coordination on Improved Water Resources and Capacity Building Program” with AWC, NASA, WB and USAID).

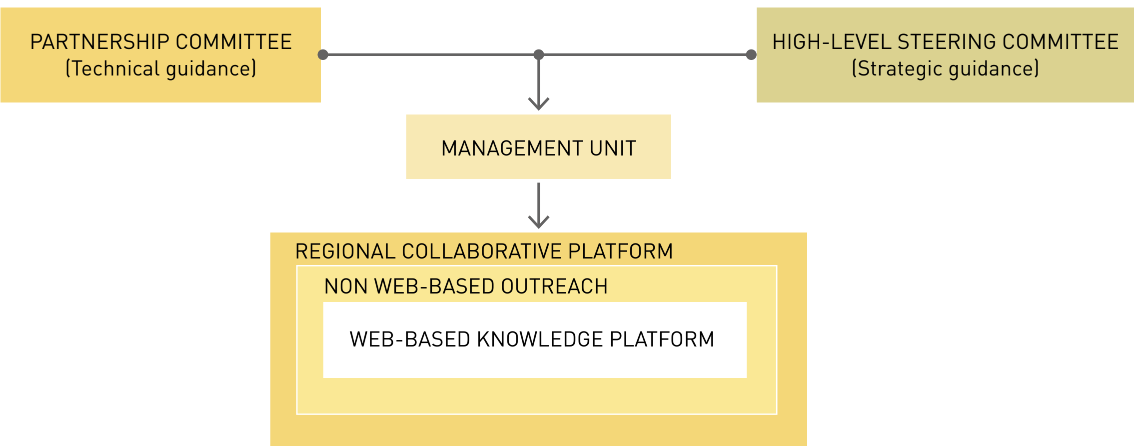
A fundamental feature of the platform is compiling and developing state-of-the-art information and data to provide evidence-based research to support water resources management, policy-making and decision-making processes. The platform is a major step forward in the NENA region for quantitative benchmarking, monitoring and target setting of pertinent output and outcome indicators (including those related to the Sustainable Development Goals).

THE REGIONAL COLLABORATIVE PLATFORM AT A GLANCE

The Regional Collaborative Platform is an important structured mechanism of the Regional Initiative on Water Scarcity for implementing the Regional Collaborative Strategy. The platform promotes collaborative knowledge-generation and communication to strengthen a coalition of stakeholders working together to upgrade capacities and improve the management of scarce water resources for agriculture, irrigation and food security in the NENA region. In this respect, the main objectives of the Regional Collaborative Platform are:

- to provide access to knowledge, innovation, governance and good practices needed to address water scarcity in agriculture;
- to create a forum for professionals and decision-makers for knowledge sharing and exchange and for mutual learning from existing experiences;
- to establish a database/information system on key water parameters;
- to implement a substantive capacity development program on major themes of interest such as drought management, water accounting, water productivity, groundwater governance, etc.

The Regional Initiative on Water Scarcity



Its architecture is conceived to have:

- a web based knowledge platform;
- a non-web based outreach for advance knowledge and sharing of solutions, capacity development and policy fora.

The major initial themes/issues to be addressed by the platform are:

- water consumption, water productivity and water saving in agriculture;
- climate change and drought management;
- groundwater stewardship;
- modernization of irrigation;
- reform of water institution governance (including on-demand water delivery system, decentralization, water user associations, basin and groundwater authorities).

Target Groups:

- public agencies, institutions and policy–makers;
- governmental and non-governmental organizations;
- private sector;
- professionals;
- farming communities.

Governance of the Regional Platform:

- The Regional Collaborative Platform is at the present constituted by a Management Unit (under the responsibility of FAO), a Technical Advisory Committee (in which the partners can participate) and a High-Level Steering Committee (where country representatives are providing mostly strategic guidance).

WORKSHOP OBJECTIVES

In order to operationalize the Regional Collaborative Platform, it is essential to involve the various stakeholders, starting at the conceptualization phase. As such, the workshop was designed to ensure the participation of the two main groups of stakeholders:

- partners and experts from academia, research centres and international institutions, presenting state-of-the-art technologies and methodologies addressing the three key topics;
- country representatives (from the relevant ministries), who will ultimately be the end-users and owner of the platform, developing evidence-based agricultural water management policies and solutions.

In light of this background, the specific workshop objectives were to:

- propose and discuss a work plan for the biennium 2016-17 to operationalize the Regional Collaborative Platform, addressing water consumption (reduction), 'water productivity (increase) and drought management (preparedness) in agriculture;
- deploy remote sensing metrics to satisfy the data and operational requirements for monitoring key water parameters;
- identify subnational agricultural areas or systems in which to monitor key water parameters;

- assign roles and responsibilities to implement the different components of the work plan;
- design an effective institutional arrangement for drought monitoring and early warning and to conduct risk/vulnerability assessments and develop drought preparedness and response plans;
- elaborate on the use of financial resources already mobilized (and to be mobilized) in support of the countries to operationalize the Regional Collaborative Platform;
- recommend an optimal governance arrangement for the Regional Collaborative Platform, including the composition of the technical and steering committees.

The expected results of the workshop were to:

- set standardized methodologies to consolidate, monitor and analyse data across countries in a streamlined manner;
- develop country-level work plans to enhance capacity, covering the following aspects: major objectives, needs, existing multi-disciplinary and partnership schemes, monitoring systems;
- present the status of each country's capacity, including state-of-the-art remote sensing products/utilities and the capacity development required by each country.

STRUCTURE OF THE WORKSHOP

The workshop took place over the course of **three full working days**. The following section summarizes the main topics discussed each day and the key highlights of the sessions.

Day 1

The workshop began with a presentation providing the background on the Water Scarcity Initiative and the Regional Collaborative Platform, followed by setting the scene for the objectives and expected results of the workshop. The focus of the day was **the determination of agricultural water consumption (or Evapo-Transpiration) via remote sensing (RS)**. A set of presentations explained the proposed framework for water accounting/budgeting at national and farming system levels using the latest RS products (of proper spatial and temporal resolutions), which will be made available at the country level. In addition, country representatives illustrated the status and outlook on the RS determination of Evapo-Transpiration (ET), given each country context, and provided an assessment of the elements they require in order to be able to develop an operational and effective data acquisition, monitoring and processing system. The sessions concluded with discussion between the country representatives addressing the details of the ET components of the result-oriented work plan to be implemented by each country as follow-up to the workshop.

Day 2

The sessions during the second day focused on determining **Crop Water Productivity (CWP)** using remote sensing (RS). Presentations introduced methods for the determination of cropped areas and crop identification via RS, algorithms for the estimate of crop yield and the use of a water productivity score. A second group of country representatives illustrated the status and outlook of their countries and provided gap assessments. Following the same group work approach adopted during day 1, representatives from each country gathered to resume the discussions and integrate the CWP Monitoring and ground validation protocols into the work plan recommendations.

Day 3

The focus of the third day was **drought management.** In addition to drought monitoring and early warning using RS, indices, vulnerability, risk assessment and preparedness completed the correct framework for drought management. The remaining country representatives presented the status and outlook and gap assessment of their countries. Representatives from each country gathered to finalize the recommendations regarding the essential aspects of their national work plan. To conclude the workshop, each country briefly presented their work plan recommendations.

DAY 1

OPENING CEREMONY

Abdessalam OuldAhmed (FAO) began his opening remarks by describing the water scarcity challenge as a heritage of nature, also driven by factors partially out of our control, including climate change impacts on water resources. He stressed that FAO aims to balance human needs, production and consumption patterns, which have been challenged in recent decades due to unsustainable practices and population growth reaching 600 million in 2050. As such, the current challenges in facing the overuse of natural resources without proper natural resource management, may increase the frequency of droughts and advance desertification.

Of the 19 countries of the NENA region, only five are not considered water scarce (Iran, Iraq, Lebanon, Sudan and Mauritania). In this respect, in 2013, FAO launched a broad process of consultation and dialogue across the region, culminating with the adoption by member countries and by regional and international partners of the *Regional Collaborative Strategy* (RCS) at the Land and Water Days in December 2013). The League of Arab States also endorsed the RCS. The purpose of the RCS is to determine solutions to help countries address the water scarcity and food security challenges in a sustainable way. The RCS is based on following principles:

- evidence and science-based decision-making;
- inclusiveness: ensuring the participation of different stakeholders associated with water policy decision-making;
- positioning farmers at the centre of the implemented policies and programs to promote sustainable water management and knowledge sharing to demonstrate changes on the ground and overcome water scarcity, given that farmers are the ultimate end users and managers of land and water resources.

In addition to the primary focus on water productivity, climate change and drought have been also recognized as major priority areas by several countries in different parts of the world. This is clearly reflected in the Sustainable Development Goals (SDGs), whereby water scarcity is positioned at the centre of at least seven of the 17 SDGs, with particular relevance to SDG 6. Additional targets include increasing water efficiency across all sectors, ensuring sustainable withdrawal levels to reduce water scarcity and combating climate change challenges and uncertainties.

Mr OuldAhmed concluded by stating that the scope of the workshop is aligned with the global development agenda, the SDGs and with FAO strategic objectives. In this respect, a key message of this workshop is the recognition of the importance of partnerships. FAO recognizes the comparative advantages of other partners. As such, the workshop will collectively share the existing capacity and knowledge to identify what could be the right path/policies of action given the challenges imposed by water scarcity.

Christopher Neil (DWFI) indicated that a key objective is to produce more food with less water by increasing water productivity ("more crop per drop"). In this respect, USAID provides support to the "Drought Centre in the MENA region" primarily addressing water management and water accounting. He also stressed the importance of participation and collaboration among different stakeholders in order to achieve the desired impact on the ground (as illustrated by the MOU between the University of Nebraska and the FAO).

John Wilson (USAID) addressed the efforts towards the development of a Regional Drought Management System for the Middle East, indicating the importance of bringing regional partners and stakeholders together to achieve the desired objectives. Key issues in drought management include climate change and its effect on water availability for agriculture, as well as rising temperatures and decreasing rainfall, resulting in more frequent and intense droughts in the MENA and NENA regions. Therefore, it is important to focus on water risk management through a regional drought monitoring and early warning system, as well as in-country capacity development to measure impacts of water scarcity and to develop the national strategies for drought and associated mitigation measures. Other important elements include enhancing capacity by providing training in operating early warning systems; helping each country design a drought monitoring program that fits their country conditions and developing water management capacity through better policies and decision making processes.

Ismahane Elouafi (ICBA) confirmed that the International Centre for Biosaline Agriculture (ICBA) is committed to contributing to drought management and indicated that the frequency of climate change and drought endangers water, food and agriculture and has short and long-term consequences for health and livelihoods. For example, current climate change pressures and drought impacts may result in the migration of millions of people. The United Nations Economic and Social Commission for West Asia 2013 report highlights that there are limited drought risk management plans, policies or strategies to address and coordinate drought response, in addition to a lack of capacity for managing these extreme events. (In sum: no plans, no strategies, no policies and no capabilities.) As such, government responses to emerging crises are more reactive than proactive, leading to loss of livelihoods and to migration. This situation calls for collaboration and integrated efforts that focus more on mitigation and adaptation.

For the next decade, ICBA has committed to contributing to the region's drought management efforts in collaboration with USAID, University of Nebraska and FAO. ICBA has started to develop monitoring and early warning capabilities that will be refined in the process of working with end users. In summary, the importance of this workshop is in bringing the needs of policy-makers (ministers and LAS) to experts in relevant topics and sharing knowledge.

Djamal Djaballah (LAS) stressed the importance of creating an implementation plan for the Arab Water Security strategy, which can serve as a common work plan to address future predictions through negotiation and collaboration with stakeholders, scientists, civil society organizations, etc. It is also important to recognize the relevance of investment in water projects and capacity building as part of the efforts to combat the challenges of climate change. In this respect, LAS welcomes collaboration and a true commitment in terms of funding, technology and capacity building.

Hani Ramadan, Director of the Soils, Water and Environment Research Institute (SWERI) of the Agricultural Research Centre (ARC), under the Ministry of Agriculture and Land Reclamation (MARL). Mr Ramadan added that securing water productivity/availability are major challenges faced by the region and that greater water security would results in greater food security. As such, there is a need to enhance water security by reducing consumption and by converting irrigation systems into better, innovative, technology-based systems, in addition to attempting to overcome the problems of excess water use by certain crops.

Hossam Mughazy (Minister of MWRI). The Minister of Water Resources in Egypt summarized the country's situation by highlighting that the current increase in water demand is primarily due to population growth and improved standards of living, which do not match the limited available water supply. An additional challenge relevant to Egypt's water resources is the deterioration of water quality as a result of different pollution streams. The cost of creating, operating, and maintaining a water system has increased dramatically, making water management increasingly complex and requiring large investment.

In terms of the key water policy issues, water recycling is a policy priority in Egypt. The importance of environmental and socioeconomic factors are recognized as well. Egypt's water resources are limited, with a total budget of 60B M3/year in terms of supply and a total demand of 75B M3/year. The country is attempting to close the gap by recycling water from different sources, in addition to using groundwater and desalinating water.

In this respect, the ministers of water resources/irrigation and agriculture (MWRI, MALR) are collaborating to develop the 2017 National Water Resource Plan. Key priorities of the plan include working on institutional reform and developing a water strategy through 2050. The plan also includes a climate change strategy, as well as groundwater and coastal zone master plans for the 1.5 million feddan agricultural mega project, which mainly relies on groundwater resources. The planned mega project aims to apply water accounting and advanced, solar-powered water technologies.

Overall, there is a need to change the way of thinking about water resources by creating an enabling environment for better water management, taking into consideration the nexus of environment, water and food security. This approach outlines the importance of working together to share knowledge, experience and alternatives, solutions and policies to cope with current challenges.

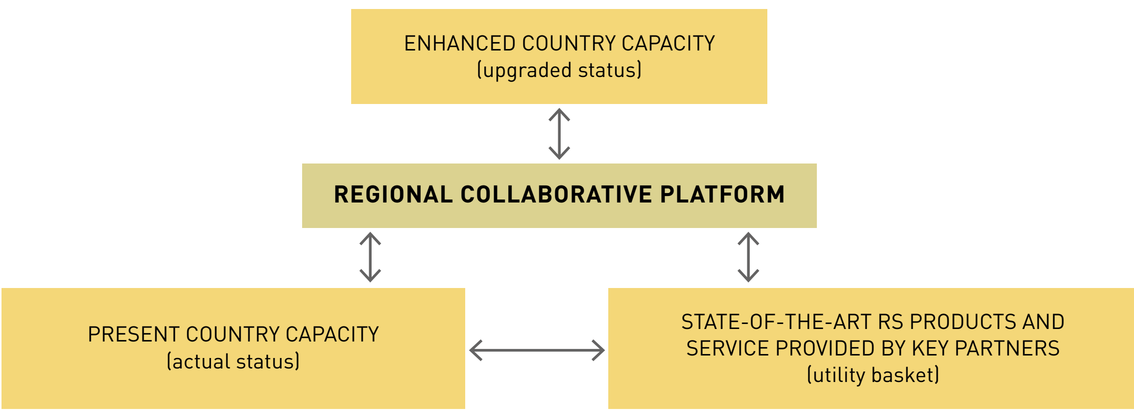
SETTING THE SCENE: INTRODUCING THE WORKSHOP OBJECTIVES AND ITS EXPECTED RESULTS

Dr. Pasquale Steduto (FAO) explained that, since the new strategic framework was put in place by FAO, three regional delivery mechanisms have been established to provide focus across the region. The Water Scarcity Initiative (WSI) is one of those initiatives. The initiative provides focused support for countries to cope with water scarcity - one of the region's worst challenges. In 2013, FAO RNE began a consultation process with major stakeholders and conducted an gap analysis of the region. The dialogue led to the creation of a strategy of regional collaboration (the Regional Collaborative Strategy) addressing all dimensions of the responses to water scarcity, as well as a results-based approach to be able to deliver on the commitments and established targets. An essential aspect of the WSI is the partnership with major stakeholders already working in the region and matching their capabilities with projects where they can have the greatest impact, given the thematic focus.

The Regional Collaborative Platform (RCP) is the key mechanism for implementing the Regional Collaborative Strategy for evidence-based policy decisions. It is in an innovative approach based on selected priority issues. The RCP is oriented toward the sustainability of water management and the enhancement of country capacity. It focuses on a broad spatial scale and aims to set the premises for a transformational (i.e. fundamental) change. Figure 1 illustrate schematically the pathway for country capacity enhancement.

Overall, the RCP comprises non-web based outreach and a web-based knowledge platform. Its governance structure includes a Partnership Committee, for technical guidance, and a High-level Steering Committee, for strategic guidance. The implementation approach is focused and selective, prioritizing key problems (solutions oriented), and seeks to leverage existing knowledge and technology, with strong stakeholder engagement.

Figure 1. **Result pathway**



Workshop Objectives and Expected Results

Given this background, the design of the workshop took into consideration two key aspects; (i) the need to share the state-of-the-art tools and methodologies for the three targeted topics, and (ii) the identification of country needs and key priorities for national and regional work plans. Accordingly, a main outcome of the workshop was to develop and share an operational work plan - a short outline of what the countries "commit" to do and how they will work collaboratively to operationalize the RCP, based on all the scientific content received during the workshop. The workshop was participatory and relied to a large extent on focused discussions on specific topics and outcome discussions of the break out groups. The workshop also aimed to facilitate the exchange between experts from academia and country representatives as an approach to analyse needs for capacity enhancement, identify systems to be monitored (national/sub-national), explore potential resources to support the work plan, and establish multi-disciplinary and partnership teams. As such, the key elements of the workshop design included:

- **standardized methodologies,** approaches and protocols to address water consumption, water productivity and drought management as a common basis among the countries, and
- **country-level work plans** to enhance capacity in water accounting/water consumption, water productivity and drought management (based on remote sensing metrics).

Accordingly, each day of the workshop addressed one topic in depth (water accounting, crop water productivity and drought management), as follows: Day 1 focused on developing a strategic plan covering the water accounting issues of quota allocation, abstraction limits and withdrawal regulations. Day 2 focused on how to ensure that water use benefits are maximized and water productivity is assessed. Day 3 focused on drought monitoring and early warning systems (assessing supply variability), a focus that responds to the increase in frequency, intensity and length of droughts in the region.

Summary of Discussions

The facilitator, Fawzi Karajeh (FAO RNE), highlighted that the workshop is unique and not traditional as it offered the opportunity for country representatives to think about how to move from a traditional water management approach towards a more advanced, technology-based approach, to better enhance water resources management.

The Kingdom of Saudi Arabia representative emphasized that water quality and quantity are correlated and must be considered together in order to address water productivity and, thus, the sustainability of the resource. Water quality should indeed be accounted for in the water balance, as quality is essential to deciding which crops are selected. To address the sustainability of water, the quality aspect must also be considered (use of brackish water, for instance). Thus, water quality and quantity must be considered together for crop production.

Egypt's Ministry of Environment (MOE) representative emphasized the importance of the issues of climate change impacts and water management in response to water scarcity, especially given the importance of climate change adaptation as a main concern of the developing countries that participated in the COP21 conference. A suggestion was therefore made to add one more objective to this initiative: "Capacity building on how to cope with climate change challenges". This was considered especially important as most of the NENA countries are rainfed. It was also noted that Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ), the Economic and Social Commission for Western Asia (ESCWA) and FAO initiated the RICCAR project, as an opportunity for countries to look at their needs in order to move from traditional water management to more accurate and improved water management technology (such as RS) to improve the management and sustainability of water resources.

The International Centre for Advanced Mediterranean Agricultural Studies (CIHEAM) emphasized that the focus should be directed not only at farm level but, rather, at all levels, and that farm allocation should be part of the productivity equation and should be reflected in the work plan for this platform. It was also mentioned that there is a need to better understand where farmers use and from where they withdraw water, including rivers, groundwater and other sources. Overall, the important linkages between the institutional and farm levels must be taken into consideration across different scales.

The issue of cooperation was also addressed as an added value of the platform. Such cooperation should be based on country requirements and needs and be realized through the engagement of all possible stakeholders and regional partners. As such, there is a strong commitment from the Arab Water Council (AWC) to support the platform through the different projects it is implementing. The AWC also highlighted the importance of collaboration and cooperation between all related regional initiatives and programs, especially the WSI and the World Bank-AWC Regional Program (implemented in partnership with USAID and NASA), Regional Cooperation on Improved Water Resources Management and Capacity Building. The AWC noted that the program has already achieved remarkable results and efficient outcomes in the same field and those results can be considered a main input for the platform. It was also indicated that the participation of the World Meteorological Organization and Arab Meteorological Services would be very relevant in this initiative where meteorological data is of high importance, especially to predict drought.

The AWC also mentioned water governance at the country level (necessary for an enabling environment for achieving results) as an additional element that must be considered. Governance is particularly relevant in the agriculture sector. As such, it is important to determine whether the countries' environmental and socio-economic dimensions are strong enough to improve the water institutions and enable the achievement of results in each country. As such, governance elements should be reflected in each country's work plan.

A final comment was made concerning the future sustainability of the WSI: how to make the initiative sustainable, how to guarantee its continuity, how to manage the different levels of preparedness of the countries and how to deal with possible conflicting interests between countries, etc. It was clarified that FAO has been given the mandate from 2012 to generate the delivery mechanism, as the Water Scarcity Initiative, on long term and will remain the focus of FAO in the region over several biennia. In addition, work is ongoing with various stakeholders in order to create long-term vision and focus. One of the drivers of this initiative is to enable countries to have their institutional support to continue to work on the initiative into the future on a sustainable path.

SESSION I

WATER CONSUMPTION (EVAPOTRANSPIRATION – ET)

1.1 Consumptive and non-consumptive water use: getting the right framework for sustainable water resources management

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Abstract

Unsustainable water use – over-drafted aquifers, drying rivers, disappearing lakes and wetlands – is a problem across the world. Competition for water and unsustainable rates of use are evident from California to the North China Plain. In particular, the Near East and North Africa (NENA) Region, which includes many of the most water short countries in the world, faces severe intensification of water scarcity due to numerous drivers: demographic growth, policies to increase food self-sufficiency and to reduce import vulnerability and price volatility, urbanization, high energy demands and the overall advance of socio-economic development. Furthermore, the anticipated impact of climate change will compound these already difficult and complex challenges. Developing strategies for sustainable water resources management under water scarcity is therefore of paramount importance.

The apparent solution is simple: water use must be reduced, and whatever water is available should first be allocated to the most important uses. The politics of this simple solution, though, are far from simple: Who should reduce use (which country/region/sector/farmer? Which users are most important? What are the economic, social and food-security implications of reducing water use?

Scientists, planners and policy-makers look at scenario analyses of future water demands, including alternative criteria for optimal water resources allocation among sectors. Food, water, environmental and energy security policies are formulated in the attempt to address the questions related to more sustainable water resources management.

In the case of the NENA Region, irrigated agriculture is the single largest user of fresh water resources, accounting for 85 percent of total water withdrawal. Consequently, even a small percentage of water savings in irrigation would be of enormous benefit for other sectors and for the environment at large. Therefore, the irrigated agriculture sector has a vested interest and shared responsibility in identifying the best options for sustainable future water resources management.

Interestingly, the majority of the proposals and interventions for irrigated agriculture in response to water scarcity focus on improving the efficiency and productivity of water use through modern or hi-tech irrigation. The underlying assumption is that increasing efficiency and productivity of on-farm irrigation leads to a corresponding reduction in demand, and saves of water resources. The water ‘saved’ is then assumed to be available for other users.

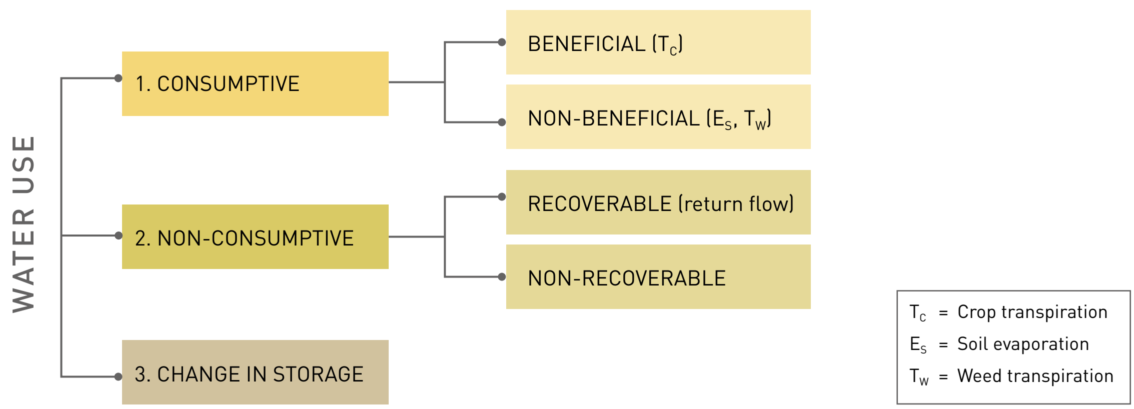
This sequence of assumptions – that less water is consumed, that demand is reduced and that savings can be re-allocated – has induced countries to invest hundreds of millions of dollars in converting traditional irrigation systems (e.g. surface or furrow, with field application efficiency of the order of 50 percent) into modern irrigation systems (e.g. localized, with application efficiency of the order of 85 percent). Many benefits have been derived: increased yield, diversified cropping patterns, reduced pumping costs, savings in fertilizer application and labor costs, reduced groundwater pollution, etc. Yet, while each of these benefits increases the profitability of irrigation, the most commonly assumed 'headline' benefit, saving water, has nowhere been observed. In fact, water scarcity and overuse have worsened.

This unintended result is largely the consequence of failing to apply a robust water accounting framework such as that proposed by Willardson *et al.* (1994), supported by the International Commission on Irrigation and Drainage (ICID) and re-emphasized by Perry (2011). This is the type of framework referred to in this presentation.

To determine whether irrigation water will be saved through any modernization investment, technical intervention, or new management practice, it is necessary to know where all the water is going *before* the change, and where all the water will go *after* the change. In any irrigated system, some water is '*consumed*' through evapotranspiration. We use the term '*consumed*' because when water evaporates into the open atmosphere (change of phase from liquid to vapour) it is no longer available to the system under consideration. The '*consumed fraction*' of water can be further distinguished as '*beneficial*' (i.e. consumed for the intended purpose, for instance to obtain crop yield) or '*non-beneficial*' (i.e. consumed for purposes other than the intended purposes, for instance evaporated from bare soil or transpired by weeds).

The remaining water is the '*non-consumed fraction*'. It remains in liquid phase and either percolates underground or runs off the field. This '*non-consumed fraction*' may be either '*recoverable*' (i.e. it can be captured and reused, for instance by pumping from an aquifer or by users downstream) or '*non-recoverable*' (i.e. it is lost to further use, for instance it ends up in deep aquifers that, economically, are not exploitable; or in very saline groundwater; or it flows to the sea). The distinction and quantification of these various water 'fractions' represent the basis for a correct water accounting framework (see Box).

BOX 1. **Water accounting framework**



Let's take the case of a farmer pumping groundwater and irrigating by traditional methods with a field application efficiency of 40 percent. This means that if 40 units of water were required to be *consumed* by the crop, 100 units of water need to be applied to the field (40/0.4). The 60 extra units applied either percolate back to the groundwater (perhaps with a degraded quality), run off the field or evaporate as *non-beneficial* consumption. If the same farmer adopts a localized irrigation method (e.g., drip) with an application efficiency of 80 percent, the water to be applied to satisfy the 40 units of water to be *consumed* by the crop decreases to 50 units (40/0.8).

The common assumption is that if we incentivize the farmer to convert the traditional method (with 40 percent efficiency) to localized irrigation (with 80 percent efficiency), the farmer will 'save' about 50 units of water (100-50). However, the complete accounting framework described here leads to important additional questions: Where did the extra 60 units of water required for the traditional system go? Was *non-beneficial* consumption significant? How much of the *non-consumed fraction* was *recoverable* and used subsequently by others? Often, losses from 'inefficient' irrigation are a major source of groundwater recharge. Similarly, runoff from one farm or area may be the source of water for downstream.

The only changes that lead to genuine savings of water for reallocation to other uses are reductions in (i) *non-beneficial* consumption and (ii) *non-recoverable* fractions. Worldwide observations (e.g. Berbel *et al.*, 2015) show that the most common impacts of the introduction of hi-tech irrigation are the expansion of the locally irrigated area, a substantial increase in the *consumed fraction* and reduced availability of water for other uses – precisely the opposite of the 'water saving' objectives used to justify the investment (Perry *et al.*, 2009).

From the farmer's perspective, the productivity and the profitability of high-tech irrigation make the new systems more attractive. Consequently these irrigation systems will increase the demand for water and the intensify competition for the scarce resource. Again, the impact is most likely to be negative in terms of sustainable resource use. For an analysis of water productivity, the reader is referred to Steduto *et al.* (2007) and Molden *et al.* (2010).

In conclusion, the evidence shows that the adoption of hi-tech irrigation tends to *increase* water consumption and *increase* the demand for water. Consumption must therefore be managed by limiting the overall irrigated area or controlling the quantity of water allocated to the irrigation sector. Sequencing is critical. That is,: (i) define and enforce a sustainable limit on water consumption and (ii) exploit hi-tech irrigation to make the most beneficial and profitable use of each single drop of water *within* this limit (FAO, 2014).

Berbel, J., Gutiérrez-Matin C., Rodríguez-Díaz A. J., Camacho E., Montesinos P., 2015. Literature review on Rebound effect of water saving measures and analysis of a Spanish case study. Water Res. Manage., 29, 663-678.

FAO, 2014. *Regional Initiative on Water Scarcity*, http://www.fao.org/fileadmin/user_upload/rne/docs/WSI-Pamphlet-en.pdf

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M.A., Kijne, J., 2010. Improving agricultural water productivity: Between optimism and caution. Agric. Water Manage. 97(4), 528-535.

Perry C., 2011. Accounting for water use: Terminology and implications for saving water and increasing production. Agric. Water Manage. 98, 1840–1846.

Perry, C., Steduto, P., Allen, R.G., Burt, C.M., 2009. Increasing productivity in irrigated agriculture: agronomic constraints and hydrological realities. Agric. Water Manage. 96, 1517–1524.

Steduto, P., Hsiao, T.C., Fereres, E., 2007. On the conservative behaviour of biomass water productivity. Irrigation Science 25, 189–207.

Willardson, L.S., Allen, R.G., Frederiksen, H., 1994. Eliminating irrigation efficiencies. In: USCID 13th Technical Conference, Denver, Colorado, 19–22 October, 15 pp.

Discussion

The above topic raised the question of the elements impacting the efficiency of non-consumptive water use. Elements of answer were gleaned from ICARDA studies that demonstrate that it is possible to save up to 30 percent of non-beneficial water through management (demonstrated in an example from China about plastic mulching). For non-consumptive water, savings could range between 40 and 70 percent, varying according to the system efficiency. However, if management is not effective, even drip irrigation will be inefficient, as the potential of the technology will not be exploited. The example provided showed that there is no advantage to changing traditional irrigation systems to drip irrigation if this change is not coupled with effective management.

Conclusions/Key messages

- Water saving refers to water that would otherwise no longer be available to the system under consideration (spatial-scale issue).
- We need a water accounting framework to clearly determine whether we are saving water or not.
- It is assumed that the use of efficient, high-tech irrigation systems (e.g. drip irrigation) saves water, but in reality such systems only re-allocated water at basin level.
- The NENA Region, and the world in general, is heavily dependent on unsustainable water consumption.
- Possible responses include: supply management (better storage and conveyance efficiency, integrated surface and groundwater management, grey water management, rain water harvesting, protection of water resources, wastewater treatment and reuse, desalination); demand management (land use, market-based instruments, increase of water productivity, reduction of food loss, intersectoral allocation, raising public awareness, etc.)

1.2 National Water accounting: setting the limits of consumptive water use in the agricultural sector

Wim Bastiaanssen[1,2], Rutger Hofste[2,3] and Tim Hessels[1,2]

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Abstract

Water Accounting Plus (WA+) meets the request from governments and donor agencies to better quantitatively describe the overall water resources conditions in river basins. Simple water accounts have been made for the Near East and North Africa region, and a more

extended version for the Nile basin. The water consumption of rainfed crops in North Africa has been computed from remotely sensed rainfall and crop evapotranspiration (see Figure 2).

Available water resources (after commitment to environmental flow requirements and navigation) can be computed to appraise how much water can be withdrawn from reservoirs, lakes, rivers and aquifers for use in agriculture without jeopardizing the total supply-demand balance. The current levels of utilized water, calculated by blue water withdrawals, were first computed along with non-utilized outflow due to storm flow. The cap of agricultural water consumption in the Nile basin can be determined from the current rainfed farming (green water: 133 km^3/yr. for cropland and 54 km^3/yr. for timber in 2010), irrigation farming (green water: 13.0 km^3/yr., blue water: 29.0 km^3/yr. in 2010), changes in water storage (117 km^3/yr. in 2010) and utilizable outflows (32 km^3/yr.). Utilizable outflow exceeded blue water consumption. This suggests that more land could be irrigated in the Nile basin, provided longer-term storage changes are negligible. The changes in stocks should be inspected across a longer period of time. While, in certain cases, groundwater is taken out of stock and the cap on consumptive use for agriculture should be reduced; in other cases, there is a possibility to further utilize blue water and thus expand the irrigated area.

The difference between water demand and blue water consumption provides an indication of whether there is a shortage of water resources. This is essential for reflecting the overall sufficiency (i.e. timing and amount) of water withdrawals. Crop water stress can be determined from remote sensing using the difference between potential and actual ET (i.e. ET deficit). This is a very good measure to determine the crop response to water (Figure 3).

Should the quota for agriculture needs to be reduced, crop types and their accumulation of consumptive use across a season should be evaluated. Either farmers continue to grow the same crop against a lower consumptive use (mulching, use of cropping calendar, drought tolerant varieties), or they move to another crop with a lower consumptive use. Remotely sensed water accounts provide time series of water consumption in cropland and the crop water stress.

Figure 2. **Annual Rainfed ET for MEWINA in mm/year 2012 Mercator**

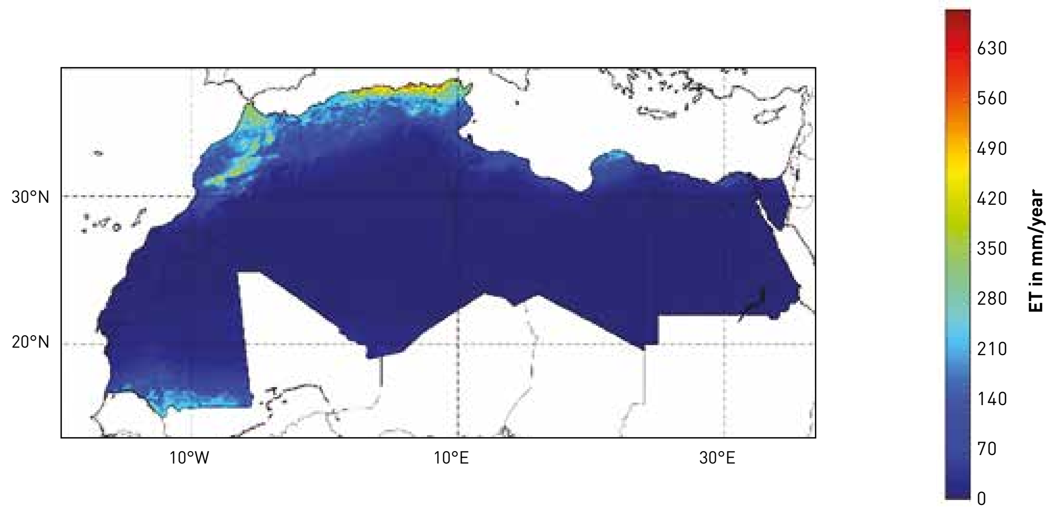
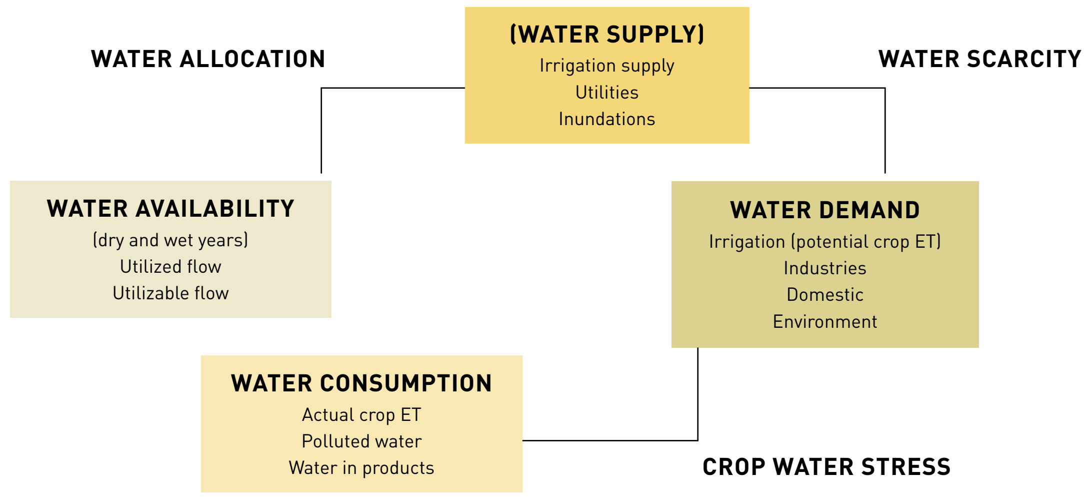


Figure 3. **Proper Accounting**



These time series can be explored to determine whether farming systems can continue in the business as usual scenario or should seriously invest in improving resource efficiency. Increasing water productivity is a general first step to safeguard food security while producing crops at a lower rate of consumptive use. Hence, water productivity can save water, but water accounting is necessary to control the total volume of water consumed in the agricultural sector.

WA+ helps to assess the extent of environmental problems and where investments in water resources are meaningful. Satellite measurements are an important input into WA+. Reporting systems must be standardized in order to make global reporting feasible. Strategic information will no longer be made available to a small group of national decision makers only. Transparency and the right to access information are essential building blocks of data democracy.

Concluding remarks

Technically speaking, it is possible to start preparing monthly water accounts for the entire NENA region. The data will be posted on a repository and will be available for all planners in the agricultural water use sector. This will enable better national agricultural policy planning, including maximum sustainable withdrawals and consumption. The implication might be a reduction of the cap and farming communities receiving ET quota, which highlights the need for a monitoring program to be established.

Discussion

The above topic generated a series of questions about whether water accounting is heavily based on modelling, and how to bring it to a policy-making level with a high level of uncertainty. Additional questions arose regarding how to validate the pixel numbers of the countries lacking good data sets and how to influence the decision making processes taking into consideration the different uncertainties. FAO representatives indicated that in order to overcome the problem of scale, it is important to zoom in to a small pixel.

The discussions also highlighted that the water market approach in Australia is a successful experience in water system management as it is based on water accounting. The Australian "water farmer market" is based on the notion that if the farmer saves water he can sell it. Nevertheless, it should be noted that water accounting in Australia is completely different from water accounting in the NENA region, especially in terms of models. However, the system, which was developed about 50 years ago, may be a good example for setting up a proper methodology. The issue of scaling down this global water accounting model to the field scale can be addressed using the proposed methodology, as the outputs are presented in tables, charts and maps, and these can be zoomed in (with 30m resolution), providing good detail and good enough field data.

For countries such as the Kingdom of Saudi Arabia, water accounting measures are much more important as a parameter than financial accounting. In countries such as Egypt, accurate accounting is challenging, especially in presence of transboundary water resources.

It is also important to understand how water accounting takes into consideration underground water resources. We need to insist on undertaking water accounting to establish national water resource plans. A satisfactory system for water accounting should be able to measure every drop in the system.

Conclusions/Key messages

NENA should take advantage of the fact that much of the data is free, mapped, interpreted and ready to use. A full assessment of water accounting can only be conducted with a platform of stakeholders. The maps can be prepared in a centralized way but the information needs to be verified on the ground, and this can only be done through partners working in the field within the region.

1.3 Evapotranspiration and water resources reporting: country status and outlook, country representatives

EGYPT: Advanced irrigation scheduling model utilizing remote sensing and low cost field monitoring network

Mohamed Rami Mahmoud, National Water Research Center

Egypt's agricultural land suffers from severe fragmentation (with plots of a quarter of a feddan). This has negative consequences for water and land productivity. Taking into consideration that there is a two-week delay in water delivery from Aswan Dam, an accurate daily accounting takes place at *mesqa* level where the measurement is at 600 points. In addition, Egypt has developed an existing low cost telemetry system to monitor the water level in canals. However, the information on flow is still missing, and an improved monitoring mechanism is needed. Remote sensing (RS) is used to determine wheat growth area, using Landsat 8 images with data loggers made in Egypt (cost:1 800 EGP), in addition to WEAP modeling. For other problems related to urbanization over arable lands, a global ET model is used. However, data is not accurate (METRIC provided better results than SIBAL) and the Ministry of Water Resources and Irrigation (MWRI) still needs additional time to generate reliable data.

At present, Egypt has 500 000 feddans under the operation system. The proposal is to cover two million feddans. A major challenge in this regard is that it is very costly to monitor water levels/discharge in irrigation canals. In this respect, the use of Landsat was very costly and up to two months were required to validate the work. However, it provided free and available data, at high definition and in a quite short time span. For example, in relation to rice cultivation (a high water consumptive crop) many farms violated the regulations, and the government is trying to take action by identifying the farmers who did so through monitoring. The system will be used on groundwater, but it is not yet applied on groundwater resources of state owned wells.

LEBANON: Use of remote sensing to investigate striking challenges in water resources (WR) in Lebanon

Amin Shaban, National Council for Scientific Research

Surface and subsurface water resources in Lebanon are available and can be considered abundant. They include:

1. surface water resources (2900mm^3):
   - 12 perennial watercourses;
   - > 2000 springs (>50l/sec);
   - snow (which covers 25 percent of Lebanon);
   - several lakes and ponds (artificial and man-made);
2. groundwater resources (1750mm^3):
   - three carbonate aquifers (extending over two-thirds of Lebanon);
   - tremendous water-bearing karstic galleries and conduits.

Lebanon is already undertaking water accounting and ET measurements nationwide. The entire country has been mapped using the Alexi algorithm (3 km resolution). However, the resolution is not satisfactory. For this reason, Lebanon has undertaken a second study in a pilot area covering ten percent of the country ET mapping at greater resolution. In terms of the application of remote sensing, ET is mapped and the whole country is covered (using ALEXI at 3 km); in Central Bekaa (1 300 km^2 representing ten percent of the land area of the country). In addition, Landsat 8 with field verification is to be applied to map ET. Once calibrated, the data can be extended to the entire country. At this time, however, reliable field data is still missing.

The country has confirmed its interest in joining the Regional Collaborative Platform (RCP); the priority being to validate the high-resolution data which has been already captured. Should the validation process provide good results, Lebanon will move ahead in the RCP. Another relevant aspect to Lebanon's water accounting development is the lack of data regarding water consumption and the need to develop an inventory of climatic variability through future projects.

TUNISIA: Evapotranspiration

Nabil Sghaier, National Center of Cartography and Remote Sensing (CNCT)

CNCT mission:

1. National mapping:
   - topographic maps, nautical charts, thematic maps and urban maps;
   - ensure archiving, editing and marketing of maps;
   - aerial photography;
   - gravimetric network.
2. Remote sensing (RS):
   - domain activities: agriculture, natural resources evaluation, urbanization, environment, spatial planning;
   - research and development;
   - provide services for public, private, national and international organizations.

Ongoing programs/projects in RS of ET (and/or related parameters):

- research (post-doctoral, graduate students, etc.);
- design of cereal crop insurance product;
- projects are coordinated by the Ministry of Agriculture, Department of Financing, Investment and Professional Organizations (DGFIOP);
- partners: National Institute of Field Crops (INGC) and CNCT;
- funded by Agence Française pour le développement (AFD).

Summary of elements still needed in order to have a complete, operational RS of ET program in Tunisia and the role of the Regional Collaborative Platform:

- role of FAO in consolidating the National Multidisciplinary and Interministerial Team (NMDT) to address sustainable agricultural water resources management;
- institutional capacity building,
- developing knowledge and skills (for technicians) in the following areas:
  - implementation of ET estimation at field level for selected crops;
  - estimation of ET via RS (in Tunisia, a spatial resolution of 100 m -1 ha- would be effective).
- With FAO funding, the NMDT coordinator can organize a workshop targeting ET in the coming days.

IRAN: Water consumption (Evapotranspiration - ET)

Bahram Taheri, Ministry of Energy

Iran has a water budget of 400 cubic km and is ranked as water scarce with 1 300m^3/year/capita. It is estimated that 93 percent of the country's water resources are allocated to the agriculture sector. Iran emphasizes the importance of regional collaboration given its shared boundaries with several countries, which in turn gives rise to several transboundary issues. The country has developed a strong pool of data and an impressive system for data measurement; however, the country has not developed a reliable water accounting system. The Ministries of Energy, the Environment and Agriculture produce a considerable amount of data through meteorological and agricultural stations, and data is shared amongst these different institutions. Nevertheless, the same data is interpreted in different ways by these different ministries and experts, which leads to many inconsistencies.

The infrastructure to validate remote sensing (RS) data on the ground is available, and the Iranian RS Center provides RS maps, including ET. ET data has been published for more than 15 years with a good level of detail. However, just having data is not enough to face the challenge of water accounting. The available data is also differentiated into meteorological and agrometeorological data; however, it faces many constraints in terms of data validation despite the growing use of images. Ongoing projects include a collaboration between the Ministry of the Environment and the German Space Agency using datasets from MODIS and LANDSAT in a pilot area (covering 2.5 percent of the country's total surface area).

Overall, Iran has strong technical capacity to estimate water productivity (WP) in the country, but a number of shortcomings should be overcome:

- The reliability of data is not up to standard and data collection is not always optimized. As a result, the government spends a considerable amount of money on data collection where it is not strictly necessary.
- Data collectors and extension officers require training in data collection in order to increase data quality and for the surveys to be more efficient and cost-effective.
- Remote sensing data is underutilized. RS is currently used only in a project in central Iran covering only 2.5 percent of the cultivated land.
- There is a need to broaden the scope of the water management approach to better respond to disaster response and to assist decision makers in the formulation of development plans.

Iran aims to develop a multi-partnership programme based on a nexus approach, addressing important themes such as food security, water optimization, environmental protection, etc. The programme should start with pilot activities and should have a regional scope, in order to strengthen regional coordination and collaboration (nexus approach). In this context, remote sensing can greatly help to address the problem of lack of harmonization of data at the regional level and help to optimize ground truth campaigns. A strong training component should also be included. The programme should involve a number of national and international partners, such as the Iranian Ministry of Foreign Affairs and FAO, as a facilitator.

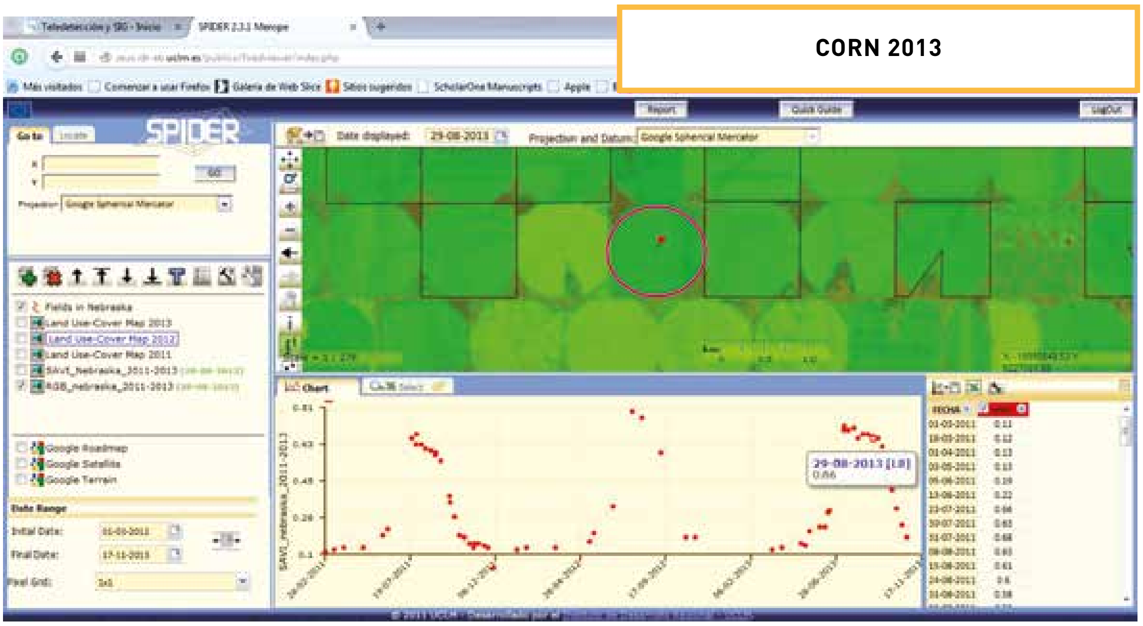
1.4 Remote sensing methods for operational ET determinations in the NENA region

Christopher Neale, Director of Research, Water for Food Institute, University Nebraska
Isidro Campos, Post-Doctoral Scholar, Water for Food Institute, University of Nebraska

Abstract

Remote sensing methods for estimating evapotranspiration (ET) of crops and natural vegetation have become robust and operational over the last two decades. The two main approaches presently used with success over agricultural areas are the reflectance based (basal) crop coefficient method (Neale *et al.*, 1989; Calera *et al.*, 2005, Campos *et al.*, 2010) and the energy balance method (Norman *et al.*, 1995; Bastiaanssen *et al.*, 1998; Chavez *et al.*, 2005, Allen *et al.*, 2007, Anderson *et al.*, 2011). An example of how multi-temporal satellite imagery can be used for obtaining the soil adjusted vegetation index (SAVI), related to the basal crop coefficient, is shown in Figure 4.

Figure 4. **SAVI (related to basal crop coefficient) for one pixel in a centre pivot irrigated field in Nebraska (Corn, soybean, corn rotation through the 2011 – 2013 seasons)**



Multiple satellite platforms are now available for remote sensing applications, providing multi-temporal data inputs for this type of reflectance based crop coefficient applications and decreasing the gaps in the sequence resulting from cloud cover (see Table 1).

Table 1. **Medium to high spatial resolution satellite sensors available for ET estimates**

Operational EO satellites with medium to high spatial resolution			
Satellite/Sensor	**Time Resolution**	**Image size**	**Spatial resolution**
Landsat 8 LDCM	16 days	185 km x 185 km	30-100 m
Landsat 7 ETM+	16 days	185 km x 185 km	30-60 m
DMC constellation	Up to daily revisit	Up to 600 x 600 km	Up to 20 m
Sentinel-2	15 days	290 km x 290 km	10 m
IRS-AWIFS-P6	6 days	740 x 740 km	56 m
IRS LISS III-1C	24 days	142 km x 142 km	23 m
IRS LISS III-1D	25 days	148 km x 148 km	23 m
CBERS CCD	26 days	113 km x 113 km	20 m
SPOT 5	Up to daily revisit	60 km x 60 km	10 m
FORMOSAT	Up to daily revisit	24 km x 24 km	8 m
Rapid eye	Up to daily revisit	25 km x 25 km	5 m
IKONOS	3 days	13 km x 13 km	4 m
QUICKBIRD	1-5 days	16.5 km x 16.5 km	2.44 m

Recently, a hybrid methodology that combines both water and energy balance approaches was proposed by Neale *et al.*, 2012 (Figure 5) and programmed in a software interface called SETMI that works in ArcGIS (Geli and Neale, 2012). This model can be applied to pixels or grids/zones at subfield scales. Spatial information on soil water holding capacity is needed for the fields being modelled. In Figure 6, daily ET values estimated with the soil-water balance portion of the model, using updated reflectance based crop coefficients for corn and soybean, are compared to measured ET with eddy covariance energy balance flux towers in irrigated corn and soybean fields at Mead, Nebraska, showing good agreement.

Satellite-based remote sensing approaches have been used to estimate seasonal evapotranspiration of irrigated crops and irrigation water demand, water balance of large irrigated areas, water accounting in watersheds and basins, continental scale evapotranspiration for early warning of drought, soil water content and crop monitoring, among others.

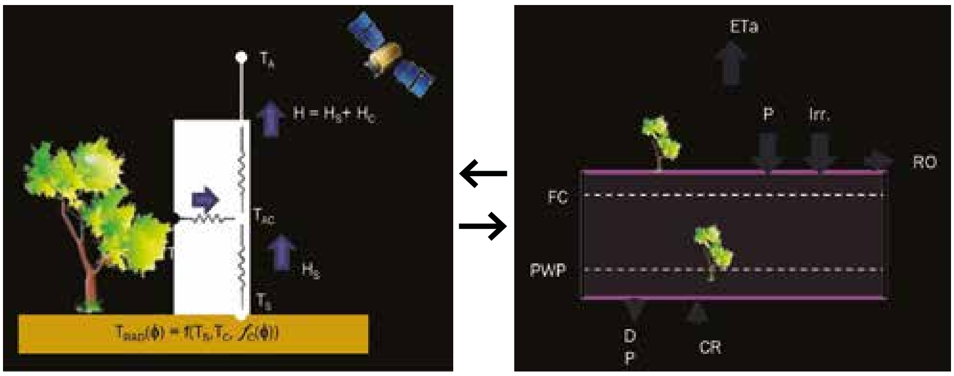
For the NENA water productivity estimates (crop ET and yield), we propose using a downscaled ET from the ALEXI-DisALEXI approach (described in the Hain, Anderson and Neale abstract, contained herein) over selected agricultural regions in the different countries. The areas should be selected in consultation with the country government water resource agencies and regional and local water management agencies participating in the project. Ground truth fluxes from eddy covariance towers and reference evapotranspiration from automated weather stations will be needed to verify the ET products being generated through this approach.

Figure 5. **The hybrid ET model (Schematic of the hybrid ET methodology combining the energy balance with the water balance approach, supported with satellite remote sensing inputs.)**

THE HYBRID ET MODEL[1]

Diagnostic SVAT Scheme The Two-Source Energy Balance Model (TSEB)[2,3]

Prognostic Modified FAO-56[4] **water balance of the root zone**



$ET_a = K_c . ET_0$

$K_c = K_{cbrf} . K_a + K_e$

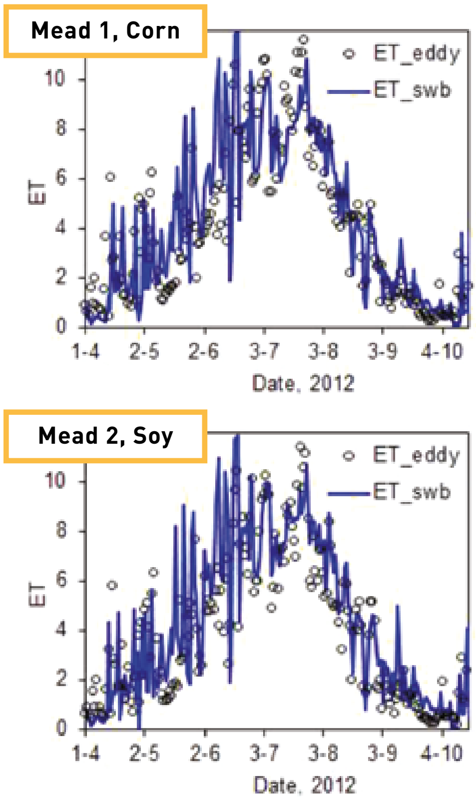
Series Resistance Formulation
LE = Rn – G – H

Modified with reflectance - based basal crop coefficient (Kcbrf)[5]

1 Neale *et al.* (2012), Soil water content estimation using a remote sensing based hybrid evapotranspiration modeling approach. Advances in Water Resources.
2 Norman and Kustas (1995)
3 Li, *et al.* (2005)
4 Allen *et al.* (1998)
5 Neale *et al.* (1989)

Figure 6. **Model Evaluation at Mead, NE experimental fields (Comparison of estimated ET using the soil-water balance model supported with remotely sensed inputs, and measured ET using eddy covariance for two irrigated fields in Mead. Nebraska.)**

MODEL EVALUATION AT MEAD, NE EXPERIMENTAL FIELDS RS-Soil water balance



Field data analyzed:

- ET measurements in Mead 1 (irrigated corn and Mead 2 (irrigated soybeans) during the 2012 growing season
- Available data:
  - Eddy covariance ET, H, Rn and G fluxes
  - Irrigation applied
  - Temporal evolution of reflectance based Kcb

Model evaluation:

- General good agreement with RMSE<1 mm/day for both crops in both seasons
- Low levels of water stress in spite of the irrigation applied

Allen, R. G, M. Tasumi and R. Trezza. 2007. Satellite-Based Energy Balance for Mapping Evapotranspiration with Internalized Calibration „METRIC...—Model. *Journal of Irrigation and Drainage Engineering*, Vol. 133, No. 4, August 1, 2007.

M. C. Anderson, W. P. Kustas, J. M. Norman, C. R. Hain, J. R. Mecikalski, L. Schultz, M. P. González-Dugo, C. Cammalleri, G. d'Urso, A. Pimstein, and F. Gao. 2011. Mapping daily evapotranspiration at field to continental scales using geostationary and polar orbiting satellite imagery. Hydrol. Earth Syst. Sci., 15, 223–239, 2011

Bastiaansen, W.G.M., M. Menenti, R. A. Feddes and A.A. M. Holtslag. 1998. A remote sensing surface energy balance algorithm for land (SEBAL): 1. Formulation. J. Hydrology, 212-213, p. 198 – 212.

Calera, A.; A. M. Jochum; A. Cuesta, A. Montoro and P. Lopez. 2005. Irrigation management from space: Towards user-friendly products. Journal of Irrigation and Drainage Systems, Vol. 19, No 3-4, p337-353

Campos I; C. M. U. Neale; A. Calera; C. Balbontin; J. G. Piqueras. 2010. Assessing satellite-based basal crop coefficients for irrigated grapes (Vitis vinifera L) Agricultural Water Management 98 1 45-54

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Discussion

Christopher Neale presented different types of ET monitoring through remote sensing:

- Kcb methodology FAO-56;
- energy balance (Sebal, Metric, SSebop methods – one layer solutions, and Alexi, DisAlexi – two layer solutions);
- hybrid methods combining energy and water balance (SETMI).

This topic led to discussions about the efficient to use of microwave sensing to estimate ET, and shed light on two issues:

- passive microwave: the size of the footprint is twelve km;
- very shallow penetration depth: measuring water content just a few centimetres below the surface is not efficient.

It was clarified, however, that there are outcome products such as soil water maps and precipitations maps which could be very useful if coupled with the ET estimates to add additional intelligence to the system and identify if the water has been incorporated or infiltrated or has run off and is part of the whole water balance accounting. Active and passive microwave are more useful on the precipitation side of the equation.

In terms of understanding why farmers tend to over-irrigate, it was indicated that the next step for DWFI is to work with the Nebraska system’s extension irrigation engineer to identify the high-end users and visit the farmers to understand what the rationale is. The next step will be to conduct an economic analysis, which is very important to see if farmers optimize their economic return.

Conclusions/ Key messages

- RS models are fairly accurate;
- near real time applications are possible;
- models are continuously being improved;
- data fusion can fill gaps;
- in the project, Alexi will be used to measure ET;
- ET will be used also for drought monitoring;
- Disaggregate ET using DisAlexi and Sebal 3.0.

1.5 & 1.6 Operational estimation of ET using the ALEXI and DisALEXI modelling frameworks[1]/ Demonstration of the High-Resolution ALEXI ET product for the NENA region[1,2]

[1] Chris Hain, NOAA Center for Satellite Application & Research – University of Maryland

[2] Martha Anderson, USAID

Abstract

As our world's water resources come under increasing tension due to dual stressors of climate change and population growth, accurate knowledge of water consumption through evapotranspiration (ET) over a range of spatial scales will be critical in developing adaptation strategies. Prognostic land-surface models require accurate *a priori* information about global precipitation patterns, soil moisture storage capacity, groundwater tables and artificial controls on water supply (such as irrigation, dams and diversions, inter-basin water transfers and others) to reliably link rainfall to evaporative fluxes. In contrast, diagnostic estimates of ET can be generated, with no prior knowledge of the surface moisture state, by energy balance models using thermal-infrared (TIR) remote sensing of land-surface temperature (LST) as a boundary condition. The LST inputs carry valuable proxy information regarding soil moisture and its effect on soil surface evaporation and canopy stresses limiting transpiration. In this project, we propose a high-resolution 375-m ET dataset over the NENA region be generated with the TIR-based Atmosphere-Land-Exchange Inverse (ALEXI) model. ALEXI is based on the two-source energy balance (TSEB) land surface representation, which partitions fluxes and surface temperature between nominal soil and canopy components within the modelling scene. The dataset will be generated with a recently developed technique, which exploits day-night observations of LST from polar orbiting sensors such as MODIS and VIIRS to estimate the morning rise in LST needed as a crucial forcing factor to the ALEXI system. This method has been evaluated against geostationary observations of LST and has been shown to reasonably match high temporal resolutions of mid-morning rise in LST, with errors generally in the 5 to 10 percent range. The use of polar sensors circumvents the significant resources needed to generate global datasets of morning LST rise (needed by ALEXI) from the current suite of geostationary sensors which are each operated by their own parent organizations, which have varying constraints on data sharing. Furthermore, geostationary sensors are limited to a range of around 60N to 60S due to constraints on view angle, while polar sensors provide full global coverage.

With the launch of the Suomi NPP platform, high resolution (375-m), twice daily observations of land surface temperature became available from the Visible Infrared Imaging Radiometer Suite (VIIRS). These LST observations serve as the primary input to ALEXI to retrieve evapotranspiration (along with other surface energy flux components) and provide a significant upgrade over other polar orbiting sensors (such as MODIS and AVHRR) in terms of spatial resolution, scanning geometry and radiometric accuracy. The proposed system will provide near-real-time satellite retrievals of evapotranspiration over the NENA region which will be used as the primary input and boundary condition to the DisALEXI flux disaggregation system. This, when used in concert with 30-m LST from Landsat, can provide estimates of

water use on the field scale. The proposed system will be a joint effort between the University of Maryland, the Daugherty Water for Food Institute at the University of Nebraska, the USDA Hydrology and Remote Sensing Lab, the International Center for Biosaline Agriculture and USAID. Steps involved in the application are:

- Completing ALEXI with polar orbiting sensors such as Visible and Infrared Scanner (day/night difference measurement of the temperature at 375 m resolution);
- LAI and green vegetation fraction for deriving a composite LAI daily;
- The model with the microwave land surface temperature has been run several times at 375 m resolution. So far, the comparison of microwaves and thermal is quite good. The only area where they diverge is over cloudy regions. Data from microwave sensors can be used to fill in data when the thermal data provide cloud contaminated results.
- This application fills out the portfolio of Alexi and DisAlexi systems to become almost a whole sky/whole day modelling system. With data fusion you can start to reconcile a lot of the different spatial resolutions.

This system is quite operational now. The core code is built and most of the processing is automated.

The evaluation still needs to be done after pouring it in a parallel system. At the moment it serves as a prototype, but it can be directly applied to the type of processing that NOOA is proposing. The system will be finalized in a few months.

Discussions

Lessons learned and needs identified

Satellite imagery is continuously used to monitor ET at the global, regional and landscape scales. High capability computer codes are used to remotely measure ET at a high time resolution (up to daily level), and ET data is used to derive drought indicators such as the evaporative stress index (ESI). ESI can also be used to estimate staple crop production at the country level. New sensors can help to improve the quality of the results and increase the accuracy of the measurements.

The presentations suggest using Alexi at 375 m for this regional platform. It will be challenging to identify drought component ET anomalies at this resolution. As a result, the output of the operation at 375 m will be constrained at the viewer's area. One can focus on VIIRS and try to sharpen MODIS to get to the same resolution.

The computational overhead required to run this system is challenging but training can be provided. The issue is not so much that it is difficult to run, it is the time required for training. For the moment trainings take place within the ALEXI team, targeting about ten people to run the system.

Conclusions/ Key messages:

- We can't manage what we can't measure.
- It is important to monitor changes in water use with changing climate, land-use and population

- We need to Improve hydrologic monitoring (flood, drought, runoff) to better cope with extremes
- We need to Improve accounting of current water use and crop water productivity (crop per drop)
- We need crop stress detection and yield estimation

1.7 Operational work plan – Discussion sessions

In terms of the country level operational work plans for water consumption and water accounting, countries have identified their needs as follows:

JORDAN

At the regional level:

- Build the capacity of government ministries and institutions in the field of managing water consumption in agriculture as a key measure to cope with water scarcity in the region. This can be achieved through training, study tours, workshops and awareness campaigns.
- Promte regional cooperation and knowledge exchange with international agencies in the field of remote sensing and introduce up-to-date tools and technology to help calculate the crop water requirement, water consumption and water productivity. Bilateral cooperation could be also fruitful if there are common issues to be focused on.

At the country level:

- Form a national team with representatives from the relevant governmental institutions to coordinate the roles and responsibilities of each institution in the field of water consumption and in following up on results and outcomes. The relevant institutions are: Ministry of Water and Irrigation, Ministry of Agriculture, Ministry of Environment, Jordan Meteorological Department, National Centre for Agricultural Research and Extension and Royal Jordanian Geographic Center.
- Develop a training plan covering the above-mentioned topics targeting the staff of the relevant departments and units in each ministry/institution.
- Determine the tools, equipment, programs, knowledge and capacities required to use advanced technology to measure crop water requirements, water consumption and water productivity in agriculture and be able to build scenarios to cope with drought waves.

MOROCCO

Strengthening capacity in water accounting:

- strengthening the existing capacities of the partners to control and handle the project products;
- implementation of project tools.

End user:

- define and analyse needs;
- involvement in implementation and validation.

TUNISIA

Water Consumption (ET):

- use of ALEXI energy balance model to obtain daily surface ET at 375 m resolution from the VIIRS satellite instrument;
- use of the ET product for drought early warning estimates and water accounting in watersheds;
- for field scale water productivity, use of DisALEXI and SEBAL to disaggregate ET;
- capacity building on different tools and models and operation of the ground flux station;
- modification of institutional arrangements.

IRAN

Operational steps include:

- the Ministry of Environment, Ministry of Energy and Ministry of Agiculture will engage the participation of other stakeholders in the country working on issues related to the key themes of the regional platform;
- regular meetings will be held to discuss priorities and develop an action plan, involving international agencies working in Iran;
- need for internal coordination on activities that overlap and on issues where there could be gaps;
- MoFA could be a good partner to strengthen regional cooperation and collaboration. FAO can serve as the umbrella of this regional effort and drive deeper and broader cooperation.
- moving toward regional cooperation - how to harmonize and unify methodologies among data centres and standardize methods at the regional level;
- FAO should place more emphasis on strengthening regional cooperation.

EGYPT

Water Consumption/ET:

- need for a new application of remote sensing;
- providing water consumption measurements on a daily basis;
- increasing capacity of MARL and MWRI and other institutions, as needed.

Priority areas identified by Egyptian participants:

- new remote sensing application at the macro level;
- water saving;
- water accounting;
- drought and water scarcity evaluation on a large scale;
- maximize water productivity per each drop (economic productivity);
- integration of water productivity aspects in a comprehensive proposal by the end of the three days;
- the importance of a monitoring and tracking system;
- there is disagreement with regard to the measurement of groundwater using remote sensing (some approaches are still experimental)
- the Water for Food Institute in Nebraska will provide water consumption data on a daily basis;

- groundwater needs to be monitored through water accounting;
- there are elements that could be taken into consideration, such as what would be the perspective regarding the environment and the use of remote sensing in rangeland;
- there is a need for good management practices in rangelands;
- land degradation and desertification are also important issues;
- there is a need to increase capacity of MALAR and MWRI staff on the use of remote sensing.

WEST BANK AND GAZA STRIP

Water accounting (lead Palestinian Water Authority):

- Remote sensing data on evapotranspiration needs to be monitored:
  - identification of best technique/system for ET calculation;
  - capacity development (human and equipment), within the related ministries (mainly MoA), in remote sensing, data analysis and ground validation;
- Rainfall is currently monitored on a daily basis by the Meteorological Department (MoT) using only rain gauges. Need to develop technique to monitor rainfall through remote sensing.
- Need for monitoring of surface water run-off, which is of importance in terms of the implications floods have for groundwater recharge. Surface water run-off is not monitored at the moment. Needs to be monitored both on the ground and through remote sensing.

LEBANON

Water accounting:

- capacity building on data management and accuracy analysis;
- renovation of tools and equipment (for physical measurement of agro-meteorological, hydro-meteorological and water related conditions).
- modelling: management and forecasting (scenarios);
- Lebanon has many water problems at all levels. Work should be done on:
  - updating legislation (including the water code) and law enforcement;
  - supply assessment and monitoring;
  - demand assessment, monitoring and optimization;
  - improvement of water quality (including reuse of treated wastewater);
  - enhancement of research on relevant topics in evapotranspiration and hydrology;
  - capacity building.

1.8 Conclusions, Day 1

Water productivity is part of the solution of the water crisis, but higher water productivity does not imply that the water budgets are positive. Water accounting and water productivity should be considered jointly to address the challenge of unsustainable use of water and to ensure that water is shared by different users.

There is a need to distinguish between blue water (water that is usually managed by people) and green water (water that is not managed by people and is used for soil, moisture, etc.), and to take into account the fact that both are linked from a river basin perspective and cannot be physically disconnected. It is therefore important to address both when undertaking water accounting exercises.

Linking water resources to land use is very important to better understand how water is consumed in agriculture, forests, wetlands, etc. Computational worksheets were developed to calculate the water budget per type of land use, with the energy balance. Accounting is performed by pixel.

A main challenge is that, despite the availability of data, the data is not shared nor is it reliable or complete. In this respect, remote sensing is important and more than 70 satellites are used for water assessments, in order not to rely just on one sensor. As such, much of the data is free and serves to interpret water availability across sectors. Six key data sets are available: DEM; land use; precipitation; ET; net radiation and biomass production. Water levels and groundwater recharge are still under development. Currently, work is carried out on an ensemble of models for ET layers. These maps will need to be validated locally.

A proper water accounting system considers: **availability** (dry and wet years) to allocate water (supply); the **supply – demand balance**, which defines scarcity and **demand**, which is defined by sector. This ultimately will define the crop water stress.

The way forward for the NENA countries:
- prepare monthly water accounts;
- post data on a repository available for water use planners to enable policy planning, including maximum sustainable withdrawals and consumption;
- establish a monitoring program (required data are to be provided from RS projects); publish lessons learnt from other arid climate countries.

DAY 2

SESSION II

CROP WATER PRODUCTIVITY (CWP)

2.1 Crop water productivity: briefing on concepts, definitions and goals

Andrew Noble, International Center for Agricultural Research in the Dry Area (ICARDA)

Abstract

Significant scientific progress has been achieved in remote sensing, which has enabled researchers, land managers, farm advisers and farmers to make more informed decisions and manage their systems. This is especially relevant to the entire area of enhancing water productivity (WP), within both irrigated and rainfed systems, through remotely sensed data. A key indicator of water use efficiency is water productivity (WP), which in its most simplistic terms is the ratio of the net/gross return (i.e. biomass, yield, income, environmental benefits, etc.) per unit of water consumed (i.e. evaporation, transpiration, quality of water, etc.). From a management perspective, the objective is to increase net return per unit of water consumed. Within cropping systems, whether irrigated or rainfed, increasing net output per unit of water consumed is contingent on how the evaporation (E) component is effectively managed with respect to evapotranspiration (ET).

In arid regions that dominate most of North Africa and the Near East soil evaporation is the largest contributor to ET that results in relatively low water productivity. Addressing this component of ET through a range of interventions (i.e. zero tillage, surface mulching, reducing the wetted area, changing crops etc.) will reduce the E component and have positive impacts on WP. The transpiration (T) component in the ratio is a fixed term that can only be changed through the manipulation of the physiological attributes of crops. Water productivity is an integrating element that has scale implications and goes beyond a simple ratio.

Water productivity requires a systemic approach, and consultations around it should not be constrained to water experts, physiologists and scientists at large, recognizing that WP is an integrating element that goes beyond a simple ratio. A number of key drivers influence productivity and are not accounted for in our calculations, such as the environmental and social benefits (i.e. employment). Factors such these should be taken into consideration when assessing water productivity. It should be also recognized that scale matters when addressing WP, as examining productivity from a farm or a basin/allocation perspective influences how

we understand the notion. In order to influence ET, a key element of productivity, E should be managed (where the gains can be achieved), and T should be considered as fixed, unless the physiological attributes of the crops are changed.

Discussion

The issue of WP raised several points of discussion, indicating that from a conservation standpoint, the social component of water productivity is important and is not linear, in contrast to its economic dimension. As such, it is sometimes challenging to clearly distinguish between the two parameters: (a) addressing water conservation only (by changing existing crops for less water consumptive crops), or (b) examining water productivity and its economic benefits. For this reason, it is important to clearly decide on the goal and targets of adopting water savings as a key parameter in national strategies (i.e. future outlook at food security). This will define how WP is perceived in national contexts and whether it is defined based on the economic value of water or on its social dimensions. For example, in Australia WP has been driven by an economic perspective, and the country has assigned an economic value to water, which resulted in significant behavioural change.

The discussion also raised issues regarding how water productivity can be maximized to ensure the maximum benefit. In this respect, a main challenge in the NENA region is that water productivity has not been maximized yet, especially at farm level. For this reason, it is important to consider water productivity variability, gap and other factors beyond the national goals and targets.

Other perspectives on how to define a WP strategy included social considerations (how many farmers /how much labour is working with the water in the region) as well as the political dimensions of food security, which is often a political decision that requires the people working in the field (social benefit) to be part of the equation.

Conclusions/Key messages

- water productivity is an integrating element that goes beyond a simple ratio;
- water productivity requires a system approach;
- it is important to take into consideration the social component of water productivity along with its economic aspects;
- scale matters;
- transpiration is fixed, unless we change the physiological attributes of crops;
- E in ET is where gains can be made through management.

2.2 Crop productivity assessment through remote sensing: radiation-driven and water-driven algorithms

Christopher M. U. Neale, Director of Research, Water for Food Institute, University Nebraska, Lincoln, NE

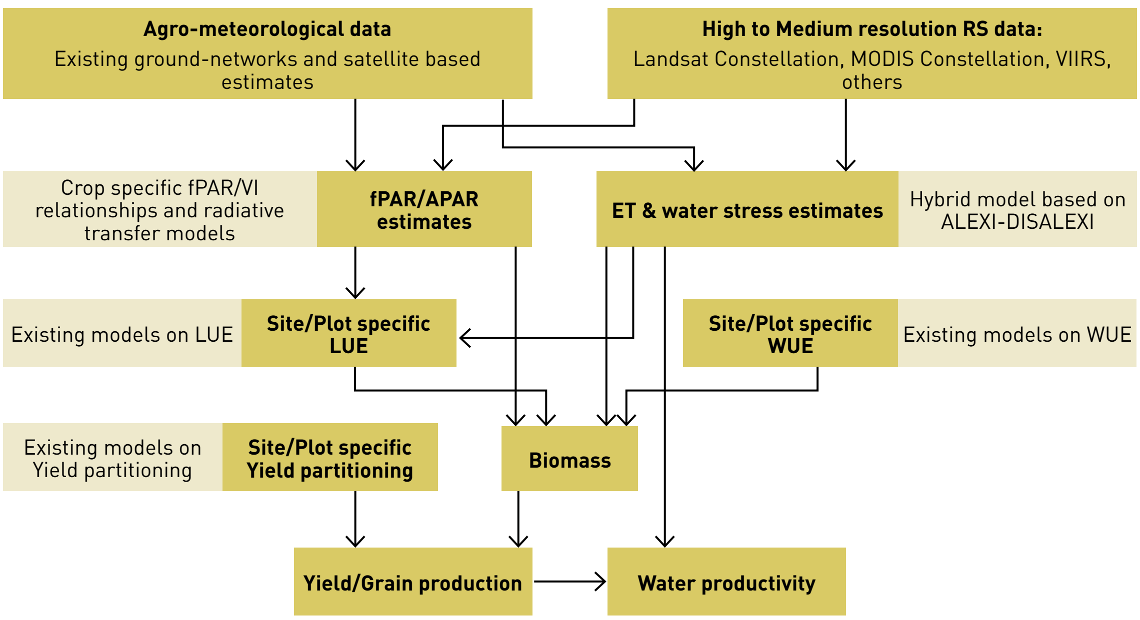
Isidro Campos, Post-Doctoral Scholar, Water for Food Institute, University of Nebraska

Abstract

Satellite based remote sensing has been extensively used for crop monitoring and yield forecasting for over 40 years, since the beginning of the Landsat program in the early 1970's. Multiple methodologies for crop yield estimation have been developed and published during this period. These include: (1) simple regression models relating vegetation indices to biomass production and yield; (2) crop growth models coupled with the assimilation of remotely sensed variables such as leaf area index, biomass and evapotranspiration; and (3) biomass production and partitioning models based on remote sensing of absorbed photosynthetically active radiation (APAR).

With the goal of estimating crop yield and water productivity using remotely sensed inputs, we propose the methodology summarized in the diagram of Figure 7. In this approach, biomass production is estimated using both the water use efficiency (WUE) and light use efficiency (LUE) routes to determine the most limiting factor: water stress or light limitation on photosynthesis. Yield is estimated through a yield-partitioning factor sometimes referred to as the harvest index. This approach requires the adequate estimation of both WUE and LUE and the yield partitioning factors, so previous knowledge on these crop specific factors is needed.

Figure 7. **Schematic of a remote sensing based approach to estimate crop biomass and yield and water productivity**



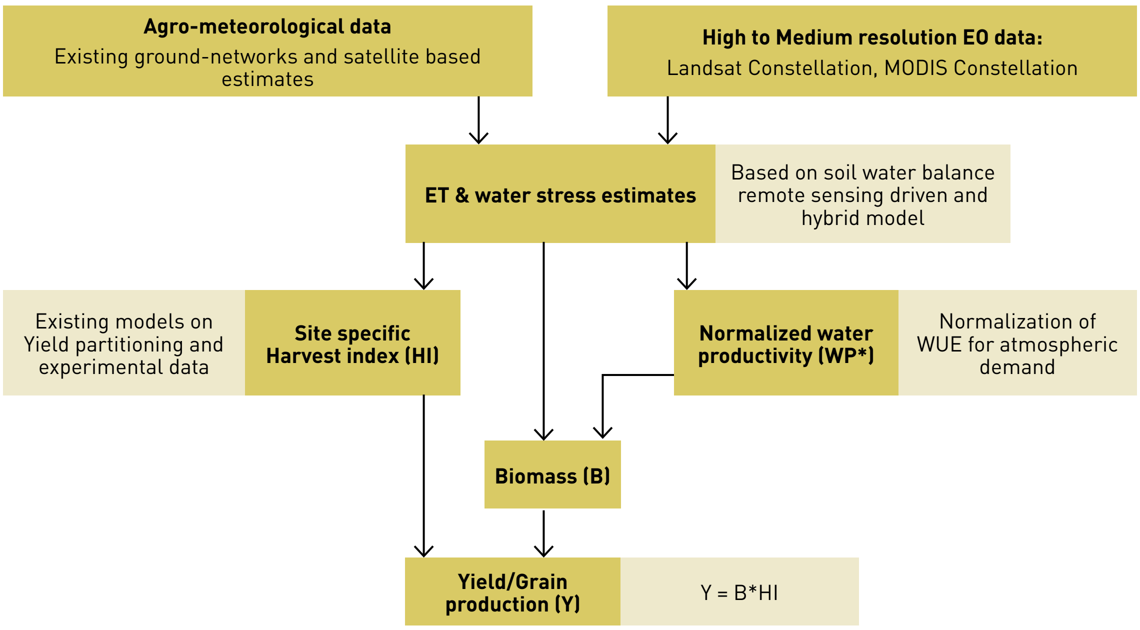
Remote sensing methods for estimating evapotranspiration (ET) of crops and natural vegetation were described in another abstract by Neale and Campos in this same volume. Two methods can be used to estimate ET and, thus, transpiration for biomass production: (1) the simpler reflectance based (basal) crop coefficient method (Neale *et al.*, 1989; Calera *et al.*, 2005 and Campos *et al.*, 2010) coupled with a water balance model or (2) the energy balance method coupled with a water balance model, such as the hybrid approach by Neale *et al.* (2012) in the SETMI model described in Geli and Neale, (2012).

Considering that the driving force for biomass production could vary depending on the location, environmental conditions and the crop phenology, an integrated analysis of biomass production based on both WUE and LUE approaches should be considered. Ideally, LUE and WUE approaches should provide similar estimates under non-limiting conditions, i.e. non-limiting radiation and water availability. Thus both approaches can be integrated by using assimilation procedures. Under limiting conditions, the most restrictive approach could provide better estimates of biomass.

Most irrigated agricultural regions are arid or semi-arid and, generally, light conditions are not restrictive. Thus, water stress could become the limiting factor if irrigation water management is deficient. In these cases a simplified approach for estimating biomass and crop yield could be used, as depicted in Figure 8 below.

The theoretical approach to biomass production at canopy scale and its relationship to plant transpiration or the normalized transpiration coefficient (Kt) was given by Steduto *et al.*, 2007.

Figure 8. **Simplified approach to estimate biomass and yield from remote sensing**

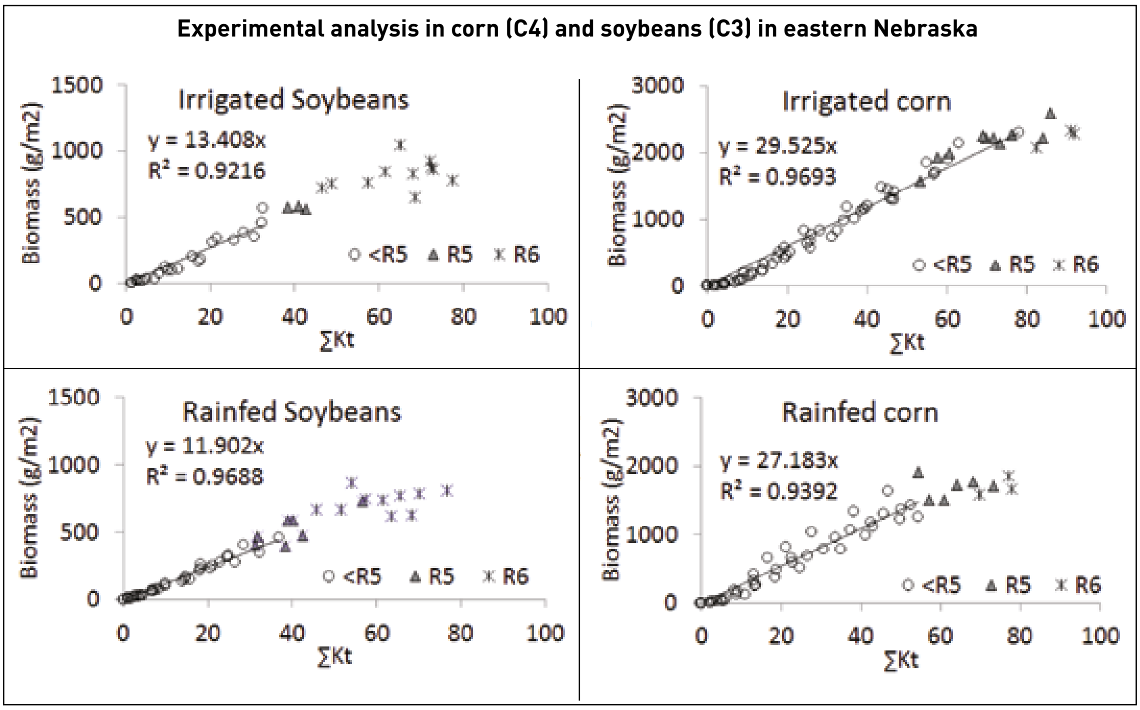


The relationship between Kt and the basal crop coefficient was further discussed by Raes *et al.,* 2012. We use the well-established relationship between the remotely sensed soil adjusted vegetation index (SAVI) and basal crop coefficient, integrated over the season as the ∑Kt term. In eastern Nebraska, a strong relationship has evolved for corn and soybeans (Figure 9) in irrigated and rainfed conditions, demonstrating the potential of this method to monitor crops under light water stress conditions.

In addition to testing the biomass relationships for other C4 and C3 crops, further research is needed to establish a seasonal harvest index to adjust the theoretical values described in the FAO 66 manual for several crops (Steduto *et al.*, 2012).

Figure 9. **Relationship between biomass and the normalized transpiration parameter Kt for irrigated corn and soybean fields in eastern Nebraska**

ANALYZING THE RELATIONSHIP BETWEEN SAVI (CROP TRANSPIRATION) & CROP PRODUCTION



Calera, A.; A. M. Jochum; A. Cuesta, A. Montoro and P. Lopez. 2005. Irrigation management from space: Towards user-friendly products. Journal of Irrigation and Drainage Systems, Vol. 19, No. 3-4, p. 337-353

Campos I; C. M. U. Neale; A. Calera; C. Balbontin; J. G. Piqueras. 2010. Assessing satellite-based basal crop coefficients for irrigated grapes (Vitis vinifera L) Agricultural Water Management 98 1 45-54

Geli, H. M. E. and C.M.U. Neale, (2012), Spatial evapotranspiration modeling (SETMI), Proc. IAHS 352, Remote Sensing and Hydrology (September 2010), ISSN 0144-7815

Neale, C. M. U., Bausch, W., Heermann, D., 1989. Development of reflectance based crop coefficients for corn. *Trans. of ASAE,* 32(6), 1891-1899

Neale, C. M.U., H. M.E. Geli, W. P. Kustas, J. G. Alfieri, P. H. Gowda, S. R. Evett, J.H. Prueger, L. E. Hipps, W. P. Dulaney, J. L. Chávez, A. N. French, T. A. Howell. 2012. Soil water content estimation using a remote sensing based hybrid evapotranspiration modeling approach. Advances in Water Resources, Volume 50, December 2012, Pages 152-161, ISSN 0309-1708, 10.1016/j.advwatres.2012.10.008.

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Discussion

For NENA countries, down-scaled ET values from ALEXI over the irrigated areas are proposed at biomass and ET. Wheat is a strategic crop for the region, and assessing biomass production using RS can be easily applied to wheat, using the same methodology that was applied on corn.

For biomass production, the driving force could vary depending on the location, environmental conditions and crop phenology, an therefore integrated analysis of biomass production should be based on both WUE and LUE approaches. Ideally, LUE and WUE approaches should provide similar estimates under non-limiting conditions, that is, non-limiting radiation and water availability. Thus, both approaches can be integrated by using assimilation procedures. Under limiting conditions, the most restrictive approach could provide the better approach.

Conclusions/Key messages:

- The use of remote sensing to estimate crop biomass appears straightforward for corn and soybeans. It needs to be further examined for multiple crops.
- Remote sensing allows for spatial estimates of biomass and yield.
- With concurrent estimates of ET, crop water productivity can be estimated spatially.
- For the NENA region, downscaled values of ET and biomass should be used.

2.3 Monitoring cropland areas using remote sensing

Murali Krishna Gumma, International Crops Research Institute for the Semi-Arid Tropic, RS-GIS Unit - Resilient Dryland Systems (ICRISAT)

Abstract

Monitoring agricultural areas and land use changes and identifying stress prone areas (drought/heat stress/submergence) is important for sustainable food production and rural livelihoods. Net agriculture area in most areas is varying quite frequently due to climate change. Reliable data on area and extent of agricultural lands is not available in most countries. There is discrepancy in statistics provided by national agencies such as State Irrigation Department, State Agriculture Department and census departments. Irrigation projects of the provincial and state irrigation departments cover large areas using major reservoirs. However, the irrigation projects do not meet the demand of the state, or even of the command areas. Consequently,

tail-enders grow dry crops. Agricultural practices and investments vary by season due to the different challenges faced, such as drought, heat, or flooding, and the different resources required, such as varietal choice, water source, inputs and crop establishment methods. Thus, spatial and temporal information on the seasonal extent of croplands is an important input to decision-making related to increased agricultural productivity and the sustainable use of limited natural resources.

Remote sensing based approaches have successfully demonstrated an alternative, quick and independent estimation of croplands, cropping intensity and changes in the country. Several studies have reported the use of multi-spectral and multi-temporal data to map irrigated areas, land use, land cover and crop type along with seasonal croplands using MODIS time-series data. We developed a spectral matching technique and decision tree algorithms to obtain information on different rice cropping systems. The usefulness of seasonal temporal imagery helps in determining the frequency of stresses such as drought and submergence. This helps in identifying such areas and disseminating suitable varieties to the farmers.

The results demonstrated that the methods we applied for analysing and interpreting different satellite imagery can accurately capture seasonal changes in the extent and area of croplands, agriculture land use changes and identifying stress prone areas.

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Discussion

The presentation raised the questions of how to separate and identify the irrigated areas from rainfed areas, as well as how to separate these from groundwater resources, and how these differences appear in the statistics. The differentiation between rainfed and irrigated areas is based on two elements: the cropping intensity (low: rainfed, high: irrigated) and the planting dates, which are different. It was also clarified that data and statistics are available and have been developed at district and subdistrict levels.

Other issues addressed the knowledge based approach, which can be automated. Such is the case of ALEXI, in which the time response is indicated (dynamic of mapping) to get the ET data of a specific date. In terms of crops, the system uses dynamic mapping and releasing the information. As for groundwater resources, it is only a matter of time before groundwater data will be obtained. The approach is ready to be used. For example, in South Asia much of the ground water data is best captured during the middle of the season in order to get a clear picture of water levels.

Conclusions/key messages

- map cropland areas/types/systems for Asia and Africa at 250 m already exist;
- an automated cropland classification algorithm (ACCA) is developed, integrating segmentation and knowledge-based decision trees;
- remote sensing derived statistics are compared to conventional statistics.

2.4 Crop water productivity: country status and outlook, country representatives

ALGERIA: Un million d'hectare supplémentaire 2015–19

Larbi Kious, Ministry of Agriculture and Rural Development

The presentation explored the economics of water resources as a way of saving water, raising the interesting question of whether water economics can be applied to water quantity and quality. Algeria has a program to improve productivity of irrigated land and another program for food security, both mainly financed by the Algerian Government with support from some donors. These programs recognize that: a) drought is increasing in Algeria with impacts to human health and the environment and b) more water is needed for public use and agriculture.

JORDAN: Remote sensing and water management

Awni Kloub, Ministry of Water and Irrigation (MoWI)

In Jordan, the Ministry of Water and Irrigation is the government body responsible for remote sensing (RS). Jordan is implementing the Remote Sensing Project to improve the country's capability and build the Ministry's capacity in this area. Currently, RS is been applied for a number of areas including water consumption, identification of irrigated areas, natural resource management and water resource management for agriculture. The Jordan Meteorological Department is responsible for data collection, including satellite data. Data and images are processed by the Meteorological Department and other government departments such as the Jordan Department of Geography.

For Jordan, the expected outcomes of the workshop include: a) experience exchange; b) capacity building; c) helping countries to access software and hardware and d) more research.

SAUDI ARABIA: Agriculture and irrigation at the Ministry of Agriculture

Saleh Alluhaydan, Ministry of Agriculture

In Saudi Arabia, the Ministry of Agriculture is the government body responsible for remote sensing. The country is shifting its policies from food self-sufficiency towards water security as agriculture uses 83 percent of the water available in the country. Options include reducing cropped areas to save water, thus increasing water availability. The country has two important strategies: the National Agricultural Strategy and the National Water Strategy. However, each strategy is governed by a different ministry. Key projects in the country include the "National project on the rational use of irrigation water" which included the use of RS, and a project with FAO to develop irrigation water management and improve water use efficiency.

MOROCCO: Moroccan water strategy

Berhili Elhassan, Ministry of Water Resources and Irrigation (MWRI)

In Morocco, the Ministry of Energy, Mining, Water and the Environment is the government body responsible for remote sensing. The country has been investing in the mobilization of surface water by constructing a number of dams. The mobilized water is supplying large-scale irrigation projects in the country as well as hydropower generation. Morocco's Water Strategy 2030 aims to save water in irrigation areas, and the country has also enacted a Water Act to better manage its water resources. Key challenges include: a) limited potential for new sources of water; b) water pollution and c) climate change.

MAURITANIA: Adaptation to Climate Change in Mauritania

Mohamed Seydna Aly Saghiri, Ministry of Agriculture (MoA)

For Mauritania, major water resources in the country include the Senegal River and the existing groundwater resources. Agricultural water is mainly used for pasture as well as for wheat and rice cultivation. Due to recent droughts, the country has been suffering from water shortage, and the government started shifting its policies to replace rice crops with wheat or crops that consume less water. The drought has also brought attention to transboundary issues with Senegal over the use of water from the Senegal River. At present, the government is investing in modernizing irrigation in order to decrease the pressure on water. Overall, remote sensing development in Mauritania is not well developed and is not being used for water resources planning in the country.

IRAN: Crop water productivity in Iran

N. Riazi, Ministry of Jihad-e Agricultural

In Iran, agriculture uses around 88.6 percent of the available water resources, and water productivity is around 1.05kg/m^3. Groundwater is major water resource in Iran, representing approximately 83 percent of available resources. The country has revival plan including 15 projects. However, renewable water resources are continuously being reduced, increasing the pressure on groundwater. Major problems facing the increase of cropping area in the country include: a) water scarcity; b) soil salinity and c) water logging and low fertility. Iran also has an Integrated Soil and Water Management Policy in place that deals with water allocation and aims to increase crop water productivity and agricultural production.

Water price is difficult to estimate considering legal and cultural aspects. The latter is a key factor in Iran, where traditional systems are deeply rooted and land inheritance is very common. National expertise in data accounting exists, but the country lacks of a system able to harmonize different types of data and to create a network for accessing, processing and disseminating data efficiently. Although water accounting is a key decision-making tool for the region, there are no consolidated standards for collecting data and for water accounting calculation (e.g. cost-benefit analysis and time-series intervals). One of the reasons for this is that water accounting is difficult to achieve, and therefore an integrated water management plan is very important, especially at watershed level.

Whatever methodology is implemented, the socio-economic aspects need to be considered. In Iran, for example, there are about 98 000 wells, many of which are illegal. The government knows this, but it would be difficult now to take drastic measures in that regard without seriously affecting the welfare of a good part of the population.

Iran is considering piloting the integrated programme and the nexus approach in the Urmia province, and extending the methodology and the approach throughout the region.

The water accounting tool, together with other software facilities, should be included in a decision support system (DSS), which should provide easy-to-use access to data, methods and standards related to a number of water issues (drought, water accounting, etc.). The lack of a proper water accounting system has also affected the government's ability to resolve water sharing issues between provinces that share water basins.

2.5 Demonstration of SEBAL3.0 for field scale crop water productivity analysis

Wim Bastiaanssen, UNESCO, Institute for Water Education (UNESCO-IHE)

Abstract

The presentation was centred on a quick demonstration of the use of SEBAL for estimating water consumption in MENA region. The key steps in ET estimation over large areas consisted of: downloading Landsat 7 and 8 images, use of ERDAS model, reading DEM, calculating latitude and longitude for each pixel, estimating incoming solar radiation for each pixel for the day of the image (solar radiation outside atmosphere is also determined), calculating reflectance, NDVI and land surface temperature, calculating vegetation parameters and ET outputs and biomass for C3/C4 crops. The SEBAL 3.0 under ERDAS includes also descriptive statistics for all generated parameters. A SEBAL code on python was also developed and building readiness for sharing it with a wider audience is ongoing.

Discussion

To estimate crop biomass production. SEBAL includes a formalism for estimating fPAR together with surface temperature and actual ET difference to potential. There is a need to measure biomass production on a weekly basis (make time series) and start to accumulate data across the entire cropping season. Crop yield is the result of the biomass production throughout the growing season.

Different approaches to calculate biomass include light use efficiency. The example shown is also based on light use efficiency. So we calculate how much radiation is absorbed by the chlorophyll: We compute the absorbed photosynthetic active radiation, the light use efficiency from the transpiration fluxes (carbon has to go through the same stomata as the water vapour). Once we know the opening of the stomata, we can calculate the water and light use efficiency. When the stomata are fully open, light use efficiency is maximum. But as soon as there is a shortage of water, or the temperature is too high, the stomata close, and that is what we calculate.

Conclusions/key messages

Lessons learned and needs identified:

- Actual ET can be estimated over large areas using open source satellite measurements and computer programs.
- Water productivity scores are derived from the surface energy balance models in order to evaluate practices at the basin level and field scales.
- The outputs of the modelling are validated using a wide range of ground truthing measurements of ET and related biophysical parameters.
- DWFI and UNESCO-IHE are focusing on using the RS based ET modelling for drought monitoring and crop water productivity indices in the Regional Collaborative Program.

2.6 Ground validation of crop water productivity: developing a protocol

Christopher Neale, DWFI

Abstract

The presentation addressed estimating actual ET at the basin and field scales. The actual options for ground truthing ET measurements are: weather stations, lysimeters, flux towers, stream data and others. These field data instruments are used for validating various biophysical and dynamical models. Regarding the estimation of yield and biophysical parameters, surface energy balance modelling enables performing yield gap analysis and crop type classification (e.g. CropScape platform) as well as generating digital soil survey information systems. Recently, other new ground truthing measurements, such as near real time monitoring of soil moisture using capacitance sensors, enables empirical accounting of water consumption (e.g. ICBA work within MENA Network of Water Centres of Excellence).

One of the major models for local ET estimation is SEBAL that can be used for creating ET time series over production basins. Consequently, performance indicators of irrigated efficiency are generated along with field water balance and water productivity scores.

The Water for Food Institute collaborates with USDA, NOAA, ICBA, NDMC at UNL, Center for Advanced Land Management Information Technologies (CALMIT) at UNL, UNESCO-IHE, USAID and FAO on issues related to drought monitoring at global and regional levels. The scaling up of daily ET products such as water balance, drought early warning systems and other operational products (mainly crop-water productivity indices) could be supported through this Regional Collaborative Platform.

Discussion

In many parts of the world, due to over-production and the lack of incorporation of nutrients and organic matter, soils have been degraded resulting in the low yield that we are seeing in this region.

In terms of water productivity, the scale and time frame of the Alexi and DisAlexi energy balance modelling covers the whole region for the long term. Downscaling would be initially for specific cooperation with the countries. This is because DisAlexi can be a piece of the puzzle and can be transferred only to people who can be trained to use it at country scale. DisAlexi could be used for downscaling at smaller regions, however collaboration with local organizations is needed, followed by scaling up the modelling by the locals in accordance with their context and specific conditions.

The Visible and Infrared Scanner (VIRS) product will be available for free for different countries for_at least five years. The VIRS program has a 15-20 years approval at NOAA. It is on a platform called MPP and will be launched in GPSS1 in a year or two and then in GPS2. The United States has committed to financially to support the land-satellite mission long term. Thus, there is no fear that Landsat will disappear in the next 15 to 20 years. VIRS was launched in 2013 and in March we will begin a 15 year lifespan. To start with, there is a guarantee in place for a minimum of five years with the goal to reach 15 years for ET for the whole region. As for crop productivity, there is still a need to elaborate the plans for further development.

Conclusions/Key messages

For the development of the Regional Collaboration Platform, the following elements need to be taken into consideration:

- The Platform is a joint venture involving multiple countries.
- Ground verification data needs to be collected, analysed and interpreted jointly so that the learning is mutual.
- Training can be provided on Quality Control (QC) and data analysis and interpretation.
- Joint publications can be produced.
- Solutions need to be pursued with appropriate government, regional and local agricultural and water management agencies.
- A collaborative approach is the best way to achieve impact on the ground and meaningful change.
- Products must be verified in the field to allow for feedback, model modifications and improvements.

2.7 Operational work plan – Discussion sessions

In terms of the country level operational work plans on crop water productivity (CWP), countries have identified their needs as follows:

JORDAN

At the regional level:

- It is necessary to build the capacity of the governmental ministries and institutions in the field of water productivity as a key measure to cope with water scarcity in the region. This can be achieved through training, study tours, workshops and awareness campaigns.
- Regional cooperation and knowledge exchange with the international agencies in the field of drought early warning systems and remote sensing should be promoted and up-to-date tools and technology should be introduced to help calculate crop water productivity. Bilateral cooperation on common issues could be also fruitful.

At the country level:

- To form a national team representing the relevant governmental institutions (Ministry of Water and Irrigation, Ministry of Agriculture, Ministry of Environment, Jordan Meteorological Department and National Centre for Agricultural Research and Extension, Royal Jordanian Geographic Center). This team will be responsible for coordinating the roles and responsibilities of the relevant institutions in the field of water productivity and follow up on results and outcomes.
- Develop a training plan covering the topic of agricultural water productivity for the staff of the relevant departments and units in each ministry/institution.

MOROCCO

Project data and products:

- inventory of existing products;
- accessibility and sharing;
- harmonization and standardization.

Validation of models/products:

- implementation of a validation method (common protocol); determine the data/products to validate;
- determine the instructions to apply.

Production scale:

- determine the perimeter: local, national, regional (to be defined at the beginning of the project);
- determine the resolution: spatial, temporal, availability, long term, etc.

TUNISIA

Crop water productivity:

- estimation of wheat biomass and yield in the irrigated area of Bous Salem (northern Tunisia);
- crop mapping of the irrigated area of Bous Salem (northern Tunisia);
- capacity building.

IRAN

Operational steps include:

- Representatives of MoEn, MoE and MoA will engage the participation of other stakeholders in the country that are working on issues related to the key themes of the regional platform.
- Regular meeting will be scheduled to discuss priorities and develop an action plan involving international agencies working in Iran.
- There is a need to integrate activities that overlap and determine where there are gaps.
- MoFA could be a good partner to strengthen regional cooperation and collaboration. FAO can be the umbrella of this regional effort and drive cooperation deeper and further.
- Moving toward regional cooperation. Determine how to harmonize and unify methodologies of the data centres and how to standardize methods at regional level.
- FAO should place more emphasis on strengthening regional cooperation.

EGYPT

Crop water productivity:

- focus on crop rotation, considering the water demands;
- maximizing water productivity for each drop (crop per drop);
- importance of having a cropping system: assessing overall productivity and consumption;
- full farming system: taking into account multiple years;
- since water productivity is difficult to validate and measure in a short time - as least two years are required;
- we must consider land productivity and water productivity simultaneously;
- standardization of modelling in crop water productivity.
- economic water productivity seen as a cropping system (intercropping system) over multiple years;
- food farming system over multiple years and looking at local productivity for the whole system;

WEST BANK GAZA STRIP

Crop water productivity:

No systematic work is being done on water productivity at the moment, but it would be useful to do such work in order to maximize productivity per cubic meter of water, increase the efficiency of water use and save water. To enable this:

- Human resources capacity must be developed in the area of software and equipment.
- There is interest in piloting a remote sensing operational product to calculate crop water productivity in a local context.

LEBANON

Crop water productivity:

- research enhancement on ET per crop (crop coefficient);
- smart irrigation technology (LARI early warning system);
- crop quality:
    - Research on crop water requirements needs to be promoted and updated. (Data and research is based on concepts of the 1960s.)
    - Promote local action at watershed level. Local communities are often more active than the national government.
    - Increase crop quality by increasing crop water production.
    - Reduce different types of land degradation: soil erosion, forest fires, landslides, overgrazing, polluting, etc.
    - Enhance relevant research.
    - Build capacity.

2.8 Conclusions, Day 2

Day 2 addressed key topics including the basic concepts, definitions and goals of crop water productivity (CWP), as well as balance models used to analyse the scale of crop water productivity, in addition to developing a protocol for ground validation of CWP. Key conclusions from Day 2 covering these topics can be summarized as follows:

- Water productivity is an integrating element that goes beyond a simple ratio.
- Water productivity requires a system approach in which scale is taken into account.
- It is important to take into consideration the social component of water productivity along with the economic aspects.
- Transpiration is fixed, unless we change the physiological attributes of crops.
- E in ET is where gains can be made through management.
- Actual ET can be estimated over large areas using open source satellite measurements and computer programs.
- Water productivity scores are derived from surface energy balance models in order to evaluate practices at the basin level and at field scales.
- DWFI and UNESCO-IHE are focusing on using RS-based ET modelling for drought monitoring and to determine crop water productivity indices in the present Regional Collaborative Platform.
- Ground verification data needs to be collected, analysed and interpreted jointly so that the learning is mutual.
- Training can be provided on data analysis and interpretation.
- Solutions should be pursued with appropriate government, regional and local agricultural and water management agencies.
- A collaborative approach is the best way to obtain impact on the ground and meaningful change.
- Products should be verified in the field to allow for feedback, model modifications and improvements.

DAY 3

SESSION III
DROUGHT MANAGEMENT

Climate change increases the intensity and frequency of drought. The region is already witnessing the impacts of droughts over the last decade, including mass migration, loss of crop production systems and loss of livestock. This raises the question of how the MENA region can begin to plan and prepare for current and future drought scenarios. In this regard, there is a need to build on international experience. For instance, the best indexes for any type of drought management can be found at the University of Nebraska's NDMC, which has been implementing, monitoring vulnerability analysis and mitigation planning for decades and transferring this experience to different countries on a global scale. Such experiences may be useful in further developing drought management tools and techniques at the regional level.

3.1 Drought management: setting the framework right - overview of drought indicators and their application in the context of a drought early warning and information system

Mark Svoboda, NOAA/NIDIS Drought Risk Management Research Center, University of Nebraska-Lincoln

Abstract

An integral part of drought risk management is monitoring and early warning. Specifically, there are three essential pieces to any drought plan: 1) monitoring and early warning; 2) vulnerability and risk assessment; and 3) mitigation and response actions. In order to "trigger" action within a given drought plan, whether it be going into or coming out of a drought, thresholds of various indicators and indices are used. The National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, USA, has been a strong advocate for a proactive drought risk management approach since its creation over 20 years ago. Recent efforts have brought together the NDMC and partners around the globe, including the National Integrated Drought Information System (NIDIS), World Meteorological Organization (WMO), Group on Earth Observations (GEO), Global Water Partnership (GWP) and many others, to establish and coordinate on a global drought early warning and information system (GDEWIS).

A GDEWIS will allow for early drought detection, which can lead to an improved and coordinated response as drought develops. The use of decision support tools, which tap into

various indicators, helps trigger action within a drought plan. As such, a GDEWIS becomes a critical foundational pillar of a drought plan. There is a common misperception that a GDEWIS only focuses on forecasting. *It is important to note that a GDEWIS consists of both monitoring and forecast tools and products.* Access to timely data is critically important as this information needs to be distilled and disseminated to decision-makers via a variety of "value added" derivative products and information, including information regarding drought impacts.

Although there is no universal definition for drought, drought can be described as meteorological, agricultural or hydrological in nature. There are indicators and indices that address each of these types of drought. Just as there is no catch-all definition for drought, *there is no single indicator that captures all types of droughts*. In other words, there is no "one size fits all" when it comes to how to best monitor and depict drought. Different indicators tell different stories and can help us monitor and track the magnitude (a function of intensity, or severity, and duration) and spatial extent of drought.

Drought *indicators* can be loosely defined as variables or parameters that are used to describe drought conditions. Examples include precipitation, temperature, streamflow, groundwater and reservoir levels, snowpack, soil moisture and even drought indices themselves. *Indices*, on the other hand, typically are computed numerical representations of a drought's severity or intensity using climatic, hydrologic, modelled or remotely sensed inputs. *Triggers* are specific values, or thresholds, of an indicator/evidence that can be used to initiate and/or terminate each level of a drought plan along with each level's associated management responses. Ideally, these triggers are linked back to a drought plan and can be used to coordinate who is accountable for what management actions and when the actions should be implemented. Drought indicators and indices help to simplify complex relationships on the landscape and can serve as good communication tools. They help track intensity; duration and spatial extent of droughts and can provide a historical reference of drought occurrence, which can be used in planning applications.

Many options exist in terms of indicators and indices, and there are several considerations one should weigh in choosing an ideal set of indicators and indices. First and foremost, the user must understand that the indicators used must match the reality of the local conditions. In order to ensure that they match, it is vitally important that the indicators be matched to impacts at the local level. This increases the reliability of the indicator(s) in those areas where local data, or impact information, is lacking. This is especially true of modelled or remotely sensed indicators, which are vital for augmenting data for data void areas. The appropriate indicators must detect drought in a timely manner and take into account various spatial and temporal sensitivities when it comes to local, regional and seasonal differences in any given area. Are the data and indicators available in a routine and stable manner and do they have an adequate and sufficient historical data? All of these factors play a role in determining the ease of implementation and operational stability, both going into and out of drought. In addition, the user can choose any number of individual indicators, multiple indicators or composite/hybrid indicators, which blend indicators (typically using a weighted approach) as a means of capturing the challenging and multiple facets and impacts that droughts present.

A newly created *Handbook of Drought Indicators and Indices* will be launched in late 2015 or early 2016 by the WMO and GWP, under the auspices of the Integrated Drought Management Programme (IDMPP). The purpose of the handbook is to identify some of the most commonly used physically based drought indicators and indices that are being applied around the world in support of risk based drought management policies and preparedness plans. It is intended to serve as a potential starting point to determine which indicators and indices are available and being put into practice. The indicators and indices chosen are aimed at the physical nature of drought and do not cover overlapping issues such as climate change, vulnerability assessment, risk, aridity, desertification or water scarcity, all of which play a role in how drought should be monitored and addressed. A "traffic light" (green, yellow, red) approach was applied to assign an "ease of use" classification with green being the easiest to apply and red being the most difficult. It is also important to note that just because an indicator or index is green doesn't mean it is the best indicator or index for any given application. The indictors and indices were grouped and classified as being related to temperature and/or precipitation, soil moisture, hydrological conditions, satellite and vegetation and composite, modelled or experimental. A summary of each indicator is provided as well, which touches on the characteristics, strengths, weaknesses and input parameters needed and potential applications, along with the relevant resources and references. Once published, the handbook will be available at: http://www.droughtmanagement.info/.

In summary, the following critical observations have been noted: 1) Typically, no single indicator or index is used alone in determining drought magnitude or in determining appropriate risk management actions. 2) Instead, different thresholds (triggers) from different combinations of inputs are typically the best way to approach drought monitoring. 3) Decision-making based on quantitative triggers is supported favourably, especially when tied back to a drought plan. In the end, monitoring is the foundation of risk management planning. Perhaps no other hazard requires such diligent monitoring in order to detect and respond, as drought. Simply stated, one can't manage what is not monitored.

Discussion

These issues led to discussion about the global drought portal and questions regarding extent to which the portal is already satisfying the demand for drought monitoring in the NENA region. It was clarified by FAO-RNE that the drought portal (www.drought.gov) mainly focuses on a few available global drought indices and seasonal indicators (more core scale). The portal is a part of just one of the three pillars (drought monitoring) of the platform, which is currently being developed predominantly from an integrated drought management standpoint. FAO-RNE also indicated that it is working to identify the elements that are missing in the portal in relation to the expected outcomes.

In terms of the Integrated Drought Management Program (IDMP), and the relevance of having the GWP as a partner in this endeavour, IDMP indicated that is urging countries to develop drought management plans and encourages groups such as FAO, UNCCD and WMO to assist the countries in that regard. Moving forward, the outcomes of this workshop discussion for the NENA region will enable the establishment of a regional platform that will be the first of its kind.

Egypt commented further on the relationship between drought and desertification control, and the importance of accounting for drought when developing National Adaptation Plan within the United Nations Convention to Combat Desertification (UNCCD). Drought and desertification are closely related, and the common thread between climate change, desertification and water scarcity is human influence. It should be also noted that the NDMC guidebook only focuses on drought, excluding other aspects, and the indicators only address the physical aspects of drought. Including additional elements and indicators covering the different aspects of desertification and drought is very important and should not been neglected.

Conclusions/Key messages

- Typically, no single indicator or index is used to determine appropriate actions.
- Instead, different thresholds from different combinations of inputs are used to approach monitoring and as triggers, using a variety of indices and indicators.
- Decision-making (or "triggers") based on quantitative values are supported favourably and are better understood.

3.2 Drought monitoring and early warning in the MENA region: the ICBA contribution to the Regional Collaborative Platform

Rachael McDonnell, ICBA
John Wilson, USAID

Abstract

Drought is a worldwide threat to food and water security and is a constant presence in the Middle East and North Africa (MENA) region. In this naturally arid area, rainfed and irrigated agriculture are both affected by drought, particularly in areas of declining water resources and increasing salinity. These impacts unfortunately have affected many in the MENA over the last decades during extreme events in 1958-62, 1998-2000 and 2007-2010 (Hazell *et al.*, 2001a; Food and Agriculture Organization (FAO), 2008; Shaban, 2009).

The impacts associated with drought result not only from numerous climatic factors but also from a wide range of societal factors that define the level of societal resilience (WMO/GWP, 2014). The severe drought in Palestine, Jordan and Lebanon during the winter of 2013-14 resulted from rains less than 35 percent of the long-term average values during the winter.

THE NEED FOR A PARADIGM SHIFT

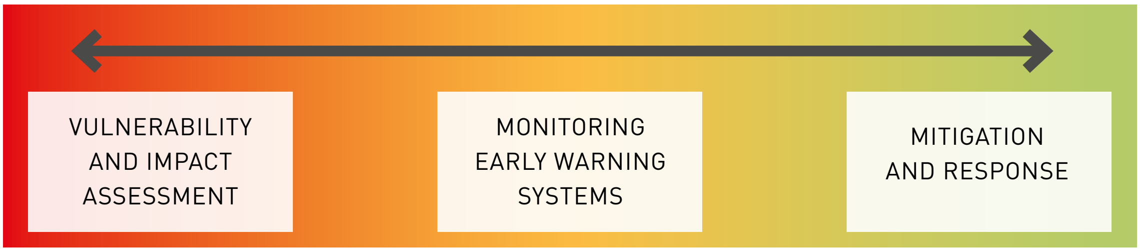
At the high-level Meeting on National Drought Policy in March 2013, Michel Jarraud, the Secretary General of the World Meteorological Organization, stated: "In many parts of the world, the approach to droughts is generally reactive and tends to focus on crisis management. Both at the national and regional scale, responses are known to be often untimely, poorly coordinated and lacking the necessary integration. As a result, the economic, social and environmental impacts of droughts have increased significantly in many regions of the world. We simply cannot afford to continue in a piecemeal mode, driven by crisis."

Dams held less than 50 percent of their usual volumes going into the summer dry season and rainfed agriculture was affected with slow growth or dieback.

Unfortunately, future climate predictions show that droughts will increase in intensity and frequency (Evan, 2009; Evans, 2011; Törnro and Menzel, 2013; IPCC, 2014), yet there has been a dearth of analyses on the likely impacts on food production and water resources, particularly in the most vulnerable communities. Climate change adaptation strategies have highlighted the growing threats from extreme climate events, but offer little detail on the measures and practices needed to adapt to these events at either at the community or national strategic levels.

Developing the MENA-RDMS: A number of recent strategic assessments have highlighted the need to improve methods for characterizing and managing drought risks in the MENA region (Hazell *et al.*, 2001; United Nations Department of Economic and Social Affairs (UNDESA)/ United Nations Economic and Social Commission for West Asia (UNESCWA), 2013). The UNDESA/UBNESCWA report described typical government interventions in the region as reactive and ad hoc, often initiated in response to crises when drought has led to growing and noticeable losses of life and livelihoods and to migration. This is usually the stage when international organizations become involved and the media can play an important role in garnering support. There is a need to make a paradigm shift from responding to crisis to a risk management approach that emphasizes early warning systems and development of drought policies focusing on preparedness and mitigation measures.

Figure 10. **Three pillars of MENA-RDMS**



Under USAID funding and additional support from FAO, the International Center for Biosaline Agriculture (ICBA) and the University of Nebraska-Lincoln will work with local stakeholders to develop a risk based approached to drought management – the MENA-RDMS. This activity is part of USAID's four-year Middle East Water Security Initiative, and FAO's 10-year Water Scarcity Initiative.

The MENA-RDMS will support improving nations' coping capacity or resilience to drought. The key elements of a risk based drought management policy will include three essential pillars, as illustrated in Figure 10, and these form the structure of the activities over the next three years.

The initial work will focus on a needs assessment of the key countries and detailed studies on the impacts and vulnerabilities of past events. In tandem, new drought monitoring maps will be published and shared with in-country partners to assess accuracy and representativeness. In the future, each of the key countries will be supported in developing their own drought monitoring systems which will provide indicators and warnings needed to implement their revised mitigation and risk response plans.

These interventions focus on the collaboration with ICBA, FAO and other partners in laying out a participative approach for the development of a Drought Management System, which would enable MENA to take steps and mitigate drought impacts. This will complement other initiatives such as the Water Security Initiative funded by USAID (three-year initiative).

The presentations focused on the development of the MENA Regional Drought Management System.

This project combines the expertise of the International Center for Biosaline Agriculture (ICBA), the Food and Agricultural Organization (RNE), the National Drought Mitigation Center (NDMC), CALMIT at the University of Nebraska-Lincoln, the Daugherty Water for Food Institute (DWFI) at the University of Nebraska and international and regional partner organizations to deliver new insights, management plans and drought resilience strategies at national and local levels that will reduce drought impacts on the food supply and on the quantity and safety of the water supply in vulnerable communities.

Discussion

The discussion identified that the drought platform should be a system primarily serving member countries and should be developed in cooperation between different countries, as national input is indispensable for the success of this platform (John Wilson) Rachael McDonnell further addressed the socio-economic impacts of droughts and discussed the countries that have developed appropriate drought strategies. An explanation of how the system is expected to develop was also provided, identifying the elements that need to be included in regional drought monitoring.

The MoE representative (Egypt) raised a question regarding the targeted beneficiaries of the forecasting/predicting system and discussed the need to ensure it is useful to policy makers and the communities. This entails determining the target users of the forecasting/predicting system, as well as the possibility to simplify the modeling for the end user. As such, it was confirmed that the End-users are the target of the program, therefore careful measures need to be taken into consideration to identify who they are, and what they need. End-users may indeed include water basin managers, farmers' unions, as well as policy-makers from different ministries such as water, agriculture and planning, amongst others.

An additional question was raised regarding whether data from the IPCC scenarios could be integrated into this system to provide policy-makers with information allowing them to design long-term strategies and whether these could be integrated into the program. In response, it was clarified that IPCC focuses on Asia and Africa but does not look at the MENA region. As such, all the models produced for the last IPCC report were adopted by ICBA and the MENA data were used in the analysis for this Region. ICBA is also planning to make the models available through the knowledge hub once the data is downscaled.

FAO noted that drought preparedness requires a long planning process, which must be initiated at an early stage. A good example is Brazil, which worked for 20 years to establish a planning process that defines the triggers to be activated in response to drought, properly supported by the government. As such, a key question to address is whether the existing systems in the different countries are operational (that is, they have the triggers in place) or if they are still being set up across the NENA region.

It was concluded that drought preparedness systems do exist in the region, but countries differ in their level of preparedness, as shown in the country presentations.

Conclusions/key messages

The pillars of drought management include monitoring and early warning system, vulnerability impact, mitigation and response. Apart from working on drought monitoring, ICBA will continue to work on climate change, as climate change will exacerbate droughts.

Also important to note is that the Regional Drought Management System (RDMS) tackles both regional scale and country scale (Morocco, Tunisia, Lebanon, Jordan) which requires the implementation of different activities including: engaging stakeholders, developing operational Drought Monitoring and Early Warning Systems (DMEWS), conducting vulnerability and impact assessment and providing operational support at the country level. It is also important to establish a link with NASA for seasonal forecasting and for predicting MENA seasonal water deficits using NASA data and models.

The RDMS for the Middle East and North Africa (MENA RDMS) focuses on drought risk management through the development of monitoring and early warning systems, as well as preparedness and mitigation measures. The RDMS will serve the region by addressing the following areas of action:

- establishing a regional drought monitoring and early warning system with their associated information delivery systems;
- providing assessment of drought vulnerabilities and impacts;
- developing actions and measures to mitigate and respond to drought impacts;
- enhancing the importance of drought monitoring based on lessons from cases such as the Levant (2008 and 2014 droughts);
- supporting the limited local strategies and processes for monitoring and managing drought in MENA;
- reviewing existing drought management plans in the MENA countries.

3.3 Drought management: country status and outlook - country representatives

MOROCCO: Drought monitoring in Morocco and case study

N. Bijaber, Royal Centre for Remote Sensing

In Morocco, drought is frequent and covers large areas, making it complex and difficult to study without global observations. SPI, daylight LST, NDVI and ET are mapped using Climate

Hazards Group InfraRed Precipitation (CHIRPS), MODIS and FEWSNEI, whereas CDI is mapped and delivered monthly through a dissemination platform (Web). An evaluation process has started aiming for spatial resolution and CDI periodicity to be improved. Furthermore, a network of evaluators for validation will be activated and reinforced and the end users implicated. Future plans aim for spatial resolution to be improved from 5 km, and for the evaluators' network to be increased.

In response to a question raised by FAO as to whether there is any established governmental planning process with appropriate triggers that enables action in drought situations, it was clarified that Morocco (MoA) has a national plan to fight drought, however it is a reactive, rather than a proactive, plan.

Specific data inputs were selected according to several criteria, including:
- data access, reliability, and long-term availability;
- variables that are commonly accepted and used by the global community for agricultural drought monitoring, that can be combined into a customized CDI;
- future satellite missions planned to sustain specific data input.

JORDAN

M. Saba, National Center for Agricultural Research and Extension (NCARE)

In Jordan, the national strategy and action plan for drought management were established in 2007. Several other national strategies also include a drought component. Establishing a centre for drought prediction and early warning in the country was a recommendation of the plan to combat desertification. The normalized difference vegetation index (NDVI) is calculated on a 16 day basis and compared with the long-term mean to define the correlation. In addition, an atlas of 339 maps is produced providing monthly data covering a 30 year dataset drawn from 48 stations in Jordan and neighbouring countries. Accordingly, Jordan is stressing the importance of sharing data and results as well as integrating information with neighbouring and non-neighbouring states. Jordan is also engaged in a project implemented by the Ministry of Irrigation, funded by the World Bank, to calculate ET using SEBAL.

LEBANON

Ihab Joma, Lebanese Agricultural Research Institute (LARI)

In Lebanon there is no common definition of drought, which is a crucial issue. If we consider water supply, we must examine the impact of drought as well as its impacts for people. A proposed approach is to separate the different drought indices depending on the type of the drought to be monitored, that is, meteorological, hydrological or agricultural. Following this step, it should be decided how the indices will be weighted. This is a very important question that must be addressed within the current drought management context in the country.

TUNISIA: Mechanisms of managing drought in Tunisia

Nabil Sghaier, National Center of Cartography and Remote Sensing (CNCT)

Tunisia has many peculiarities from the climatic and environmental standpoint which need to be considered for proper drought management. There is a detailed governance structure and action plan for dealing with different drought scenarios. The presentation highlighted the different aspects related to drought management, including the following:

- agricultural drought insurance;
- the role of the banking sector;
- the role of legislation;
- relationship between different actors;
- forest fires and drought;
- pollution;
- project performance during drought periods;
- available equipment and tools to combat drought;
- capacity development;
- hydraulic works;
- awareness campaigns on drought management targeting the public at large;
- research programs.

IRAN: Drought management in Iran: Pilot project - Local community participation in sustainable agriculture for saving the Lake Urmia basin ecosystem

Masoud Bagherzadeh Karimi – Ministry of Foreign Affairs (MoFA)

Iran sees a need to strengthen both regional and national drought management systems and to increase and intensify the regional network of institutions and expertise. In particular, it is essential to establish an efficient early warning system for the whole region, able to take full advantage of the remote sensing capabilities. National capacity building activities to acquire and interpret satellite-based data would be key for enabling the environment and building the expertise required to ensure the effectiveness and sustainability of the early warning system.

The following points were mentioned:

- In Iran there is a project funded by UNDP titled "Contribution to water saving in the ecosystems by modelling local community engagement in sustainable agricultural practices". The main approach of this project is creating synergies between the government and the local associations and communities. By implementing this project, Iran clearly recognizes that local communities must participate in water saving actions.
- Iran plans to increase its agricultural land by 300 000 hectares under irrigation around Lake Urmia. In this process, Iranians have been transferring water from the lake to the land, resulting in the critical diminution of the lake and the occurrence of sand storms around the lake. Plans are in place to restore the lake by 2025.
- The nexus approach is not new; several partners are working on it. Food security cannot be addressed alone. It should be addressed together with the environment, water and energy security. Water must be taken into account along with food-energy productivity (kilo calories).
- At the national level, intergovernmental collaborative network needs to be strengthened and national drought monitoring indicators should be defined among the various stakeholders.
- At the regional level, a more substantial effort needs to be made to bring together all the national, regional and international stakeholders and to establish an institutional network

for developing a regional early warning, drought management and monitoring system. In this context, FAO would play a relevant role because of its technical expertise, its capacity to contact and involve national and regional agencies and its ability to mobilize technical and financial resources at the international level.
- In order to embark on this endeavour, rounds of consultations with a number of organizations (e.g. FAO, UNESCO, WMO, the Regional Centre for Drought Management and others) would be needed to kick-start the dialogue and develop a comprehensive plan of action.

EGYPT: Drought in Egypt

Al Hakim, DRC/EEAA (environmental agency)

In Egypt, many areas receive no rainfall for months, or even years, due to extremely random storm patterns (in about 75 percent of the whole territory).

The coefficient of drought variation in the Mediterranean region, which is the ratio of the net radiation left on the surface to the product of the annual rainfall at the evaporation temperature, attains its highest value in the desert areas, where it usually exceeds 3. In Europe, the coefficient is in the order of 1.5 (Accad – UNESCO 1988).

In terms of drought management, the Government of Egypt (Ministry of Water Resources and Irrigation) has formulated strategies to face water scarcity and drought through 2017 and 2050. The government is also developing well-defined laws and regulations for controlling groundwater consumption. These laws are necessary to avoid further depletion and pollution. The strategies recognize that the use of water saving devices on all wells is quite important, both in the developed aquifers and, in particular, in the coastal aquifers. The strategy also recognizes the need to use different techniques for runoff water and for rainwater harvesting in the rainy seasons. A growing demand is geared towards regional, sub-regional and local technical agencies responsible for water services, which are urgently needed to ensure policy cohesion and public support.

3.4 Vulnerability and risk assessment

Cody Knutson, Research Associate Professor, Planning and Social Science Leader, National Drought Mitigation Center, School of Natural Resources, University of Nebraska-Lincoln, USA

Abstract

Drought is often perceived to be largely a natural or physical event. In reality, drought, like other natural hazards, has both natural and social components. As described by Wilhite *et al.* (2005), the risk associated with drought in any region is a product of both the region's exposure to the event and the vulnerability of society and the environment. That is, the threat of harm from drought is based on a combination of the frequency, duration and severity of drought events experienced and the susceptibility of people, activities, and the environment to the negative effects associated with drought. Some regions, people, and activities are more likely to be at risk for a variety of reasons. Exposure to drought varies regionally and there is little, if anything, we can do to reduce the recurrence, frequency, or incidence of precipitation

shortfalls. However, measures can be taken to reduce vulnerability to drought events. An assessment of drought impacts and underlying vulnerabilities will help policy and decision-makers identify who and what are vulnerable to drought and why, in order to identify and target appropriate and effective drought risk management options.

The World Meteorological Organization and Global Water Partnership are leading an Integrated Drought Management Programme (IDMP) which has published national drought management policy guidelines, which include information on how to conduct a drought risk assessment (WMO/GWP, 2014). This assessment includes six tasks: 1) assemble a drought risk assessment team, 2) conduct a drought impact assessment, 3) rank the drought impacts, 4) conduct a vulnerability assessment, 5) identify potential drought mitigation and response strategies and 5) select strategies to be implemented. At the national level, a risk assessment team and sectoral working groups are often assembled to carry out the assessment. The team is comprised of sectoral experts and other relevant stakeholders who have knowledge regarding drought and its effects within sectors of interest. In some cases, consultants or other researchers may also carry out studies to investigate drought risk.

One of the first tasks of this team is to conduct a drought impact assessment. This may be an assessment of drought impacts experienced during a drought of record, a recent drought and/or drought conditions that are likely to be experienced in the future. The initial goal would be to identify as many drought impacts as possible (e.g. economic, environmental, and social impacts) from relevant sectors (such as agriculture, water resources, public health, wildlife, energy and tourism/recreation). An increasingly popular tool for archiving and investigating drought impacts are searchable, drought impact databases. For example, the National Drought Mitigation Center (NDMC) in the United States has developed the Drought Impact Reporter (http://droughtreporter.unl.edu). This database is updated daily with reports of drought impacts from news media, government and other sources from around the country. It serves as an archival system that allows individuals to better understand the occurrence of drought impacts affecting different sectors and regions. With a good understanding of the full range of experienced/potential drought impacts that may affect a region, priority impacts can be determined to help target areas, people or activities that are especially at risk. The selection of criteria is often helpful to prioritize drought impacts, such as the amount of financial loss, whether it's a growing problem and/or a national/public priority, whether it affects especially vulnerable populations, etc. The result of this analysis is a list of high priority drought impacts that should be the focus of further study.

The next task is to investigate why these impacts are occurring to identify underlying causes that can be addressed through the implementation of targeted drought mitigation and response strategies. As stated by Ribot *et al.* (1996), "vulnerability analysis bridges the gap between impact assessment and policy formulation by directing policy attention to the underlying causes of vulnerability rather than to its result, the negative impacts, which follow triggering events such as drought". There are a range of strategies that have been implemented in conducting vulnerability assessments, such as: workshops and/or interviews, scenario building exercises, a logical framework approach, systems modelling and other quantitative analysis. Assessments were often more qualitative in the past, while new methodologies are increasingly quantitative in nature and/or use a hybrid of qualitative and quantitative approaches (see the CWCB, 2013; Islam *et al.*, 2009; Andreu *et al.*, 2007; and World Bank, 2006 for a range of approaches).

Again, identifying priority drought impacts and investigating why they are occurring allows for more informed decision-making and the selection of appropriate and effective drought mitigation and response actions. Tools such as the United Nations Framework Convention on Climate Change Database on Local Coping Strategies (http://maindb.unfccc.int/public/adaptation) and the NDMC's U.S. Drought Management Database (http://drought.unl.edu/droughtmanagement) provide examples of strategies that have been implemented to reduce drought risk and are good sources of information for use by planners. Similarly, there are several similar guides that have been developed to assist planners in carrying out an entire drought planning process (e.g. WMO/GWP, 2014; FAO/NDMC, 2008). A risk assessment, including an investigation of vulnerability, is an essential component of any drought planning process.

During the presentation, Rachael McDonnell (ICBA) thanked Cody Knutson for bringing satellites and data mining to the ground, which explains why FAO and USAID perceive RDMS as a ten-year program that aims to capture the knowledge but also to assess vulnerability.

Discussion

The presentation triggered a discussion about when a status of drought can be declared, and when it is needed to take action and instruct that steps be taken to address the situation. In this respect, it was indicated that drought planning has to take place at the local level as there is a need to understand what is happening (the impacts) on the ground for different sectors/areas. In addition, there is a need to identify triggers and decide when to take action. It should be also noted that there are different stages for drought including: drought alert, drought warning and the full crisis. Accordingly, several triggers are needed within a country's plan to avoid delay leading to the crisis mode.

The Arab League raised the question about the political nature of declaring drought. The discussions confirmed that it is indeed a very political issue, underlying the benefit of having a plan which allows making the best assessment by following adequate procedures and making decisions as laid down in the plan. The role of technical advisors in declaring drought was also addressed and it was pointed out that drought management only indicates the indicators of drought and it is up to the country decision-makers to declare drought or not. Appropriate triggers to cover the various sectors can be developed only through a process of learning and experience including implementation, monitoring and early warning systems. The learning process will lead to the selection of the proper indicators and triggers for decision-making.

In Morocco, drought is a natural hazard and coping capacity is linked to external factors. At present, most of the work that has been undertaken was more of a qualitative nature, focused on assessing existing capacities. Quantitative approaches are more recent, and most models have not taken into consideration local capacities vs. external inputs.

As for Jordan, this workshop is very important since it will assist decision-makers in identifying which indicators should be used to declare a drought. Models don't usually declare a drought situation, and decision-makers often need to make the decision to do so. Accordingly, it is important to develop a monitoring system to help identify the indicators that should lead the decision-making process of declaring a drought situation.

The issue of drought is very important for Jordan. Most definitions are mainly related to the meteorological drought and the political link is still missing; that is, in some situations declaring droughts may cause turbulence. Developing a monitoring portal, which includes triggers, as part of a preparedness plan is the best way to take appropriate measures and only declare drought when it is absolutely necessary. It provides evidence based information but the whole monitoring process is a continuous learning approach.

Marlos de Souza (FAO HQ) added that in Victoria, Australia, after 12 years of drought, the mitigation plan was based on the volume of water available in the reservoirs around the state. As such, the plan had five different increasing levels of drought severity and there was a government action plan for each level that impacted different aspects/sectors of economic activity. (Level 5 basically shut down almost all economic activities.) The government must also take into account the economic impact.

Conclusions/key messages

Priority elements to identify risk reduction measures include:

- Drought mitigation (adaptation):
  - long-term water demand reduction;
  - long-term water supply increase;
  - best land management practices;
  - flexible, diversified systems;
  - stable financial systems.
- Drought preparedness:
  - creating monitoring and early warning systems;
  - developing conjunctive water and hazard plans.
- Drought response/recovery:
  - short-term water demand reduction;
  - short-term water supply increase;
  - short-term management adjustments;
  - enhanced relief management;
  - rehabilitation.

3.5 Climate change and droughts

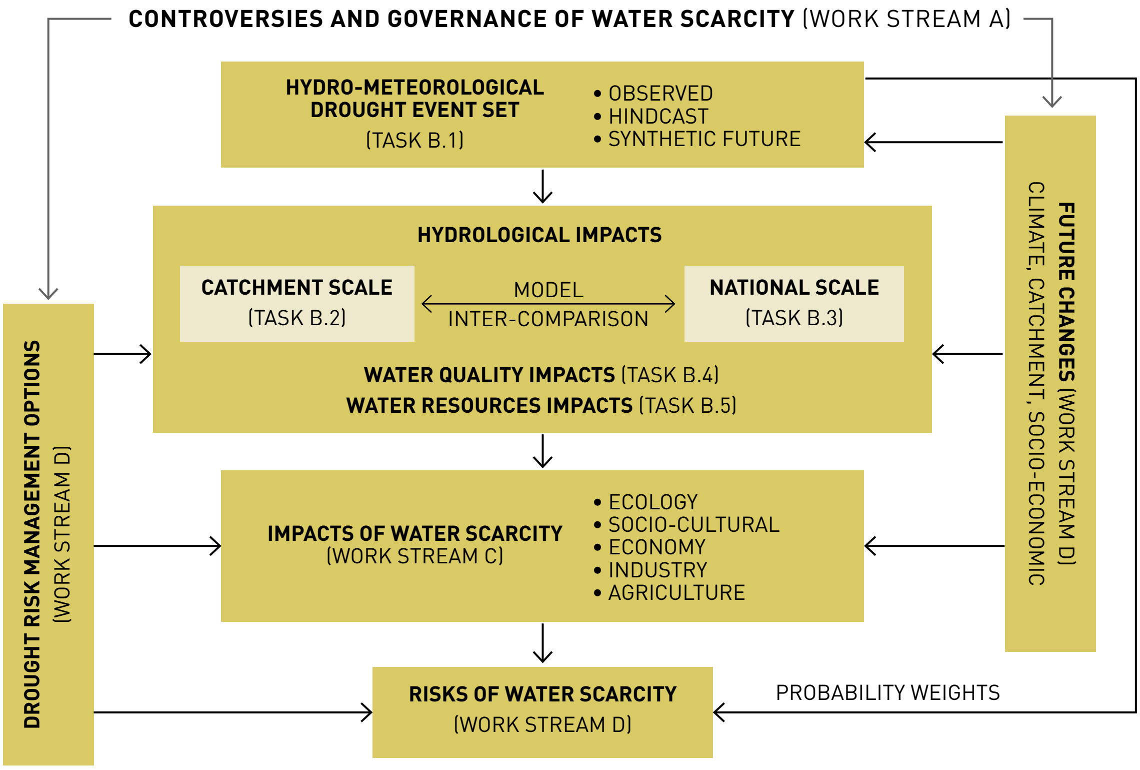
Dann Mitchell, Oxford University

Abstract

While the extent to which the 2007-08 drought in the Levant region destabilized the Syrian government continues to be debated, there is no questioning the enormous toll on humans of this extreme event. The movement of refugees from both the drought and war affected regions into Jordan and Lebanon ensured that the anomalously low precipitation of the winter of 2013-14 would have amplified impacts on already complex water and food provisions.

It is hypothesized that droughts over the Levant can be linked to three types of synoptic regimes (Saaroni *et al.*, 2014). The regimes include: a) an expansion of the subtropical high over the majority of the Mediterranean Basin, b) a pronounced stagnant ridge/block and c) an intrusion of lower-level continental polar air. The 2014 drought, affecting parts of Jordan, Lebanon, Palestine and Israel, was characterized by extremes in low rainfall, the extent of the long dry periods and three exceptional rainfall events that interspersed these. The drought itself was thought to be due to a large-scale winter blocking event that prevented weather systems from reaching the region (Udasin, 2014). A combined modeling and observational study shows that the 2014 southern Levant persistent rainfall deficit during the rainy season was made more likely due to anthropogenic climate change.

Figure 11. **Controversies and governance of water scarcity**



The presentation also shed light on the relevant projects ECI/Oxford is currently implementing, including the following:

- ACE – Africa: Attributing Climate Extremes in Africa to external causes. The project is implemented in collaboration with ICBA (focus on Africa). Experience from the project shows that each event is different. Therefore, statements are made for each individual event. The project provides the likeliness of the human induced effect of the event (or if purely natural), highlighting that no studies were undertaken in the region before 2014 until ACE came on board. Next steps for this project include measuring its impact, for instance in relation to climate suitability of, for instance, a malaria outbreak.
- MaRIUS: Managing the Risks, Impacts and Uncertainties of droughts and water scarcity. The project starts with hydro and meteorological droughts and their impact on water quality and water resources. It also provides a probabilistic analysis of droughts and water scarcity. One of the key advantages is that it provides a more precise probability of event through voluntary computing run by individuals all across the world that allows simulating climate thousands of times.

Discussion

During the discussion, the question was raised regarding how to apply extreme event attribution to the context of the NENA region. "Attribution" in this respect refers to the human impact in long-term optimal fingerprinting and long-term climate change. Discussions also addressed regional climate models (Weather@home: global circulation model), indicating that few individuals in the NENA and Africa regions are familiar with them.

Another question was raised by Pasquale Steduto (FAO) on how to approach the validation of results.

In this respect it was indicated that a key step is to validate climatology in addition to the simulation, as well as undertaking a comparison over a period of 30 years.

Hammou Laamrani (GIZ) also noted that there is a need to look into the projected impact on tropical diseases and the relationship between climate change and agriculture. Discussions revealed that positive impacts are possible, but countries need to know how to benefit from this knowledge and change the crops accordingly.

Conclusions/key messages

- At present the capacity exists to simulate climate thousands of times over the MENA region.
- This makes it possible to study very extreme events, such as droughts or heavy downpours.
- At present there are active projects linking meteorological outputs to hydrological models, as well as health impact assessment models.
- More users are welcome to apply this model in the MENA region.

3.6 Conclusions, Day 3

Drought has more than 100 definitions and all the countries are facing droughts within their own contexts and developing their own experiences. Drought declaration depends on a set of rainfall data gathered before the end of the rainy season. There is a need to learn from the countries, which are in line with the outcomes of the FAO and UN water partner institutions (UNCCD). Last November, the UNCCD conference called for a change in the paradigm towards a more proactive approach.

Desertification is a global phenomenon, while drought is local in terms of hazards. Thus, the two are not directly related. Desertification deals mainly with the loss of green cover. Drought is completely different than desertification and is considered to be better understood.

Others disagreed, indicating that in accordance with the UNCCD, desertification, drought and land degradation are all considered under the same component. However, it was noted that, under drought management, desertification is not always considered a priority.

Fawzi Karajeh (FAO RNE) indicated that nobody knows exactly what drought is, but it is a common concern. Depending on each country context, there is a need to consider different types of drought. For example, in Egypt, the focus is on hydrological drought. In Morocco, the focus is on meteorological drought. As such, there is no ONE definition that describes drought in the MENA region. We have to consider several definitions.

Hammou Laamrani (GIZ) highlighted that an important issue in the region is examining the nexus with decision-makers who are supportive of the principle but not sure how to implement it and put it into action. He also highlighted that Nexus will help to identify different ways to improve the efficiency of resources management. Nexus is more about institutional effectiveness than natural resources management.

Following up on this comment, Iran answered by indicating that we are living in a competitive world with limited national capacities. As such, institutionalizing the nexus approach at the national level will not succeed, as it needs a mechanism of regional collaboration similar to trade mechanisms between developed countries.

In summary, identified needs include an early warning system, several elements such as baseline surveys and data distribution and improving technical know-how and institutional arrangements. It was also indicated that a main challenge is poor technical support, whereby there is a need for integration among weather and water institutions and organization. In terms of meteorology and hydrology, networking is either absent or ineffective, and countries have shown very limited cooperation, as well as institutions within the country. As such, there is a growing lack of data, also due to different interests regarding measurement scales. In terms of communication and monitoring, there is no real coordination among the agencies responsible for drought information and data, which is another main challenge that needs to be addressed through the Regional Collaborative Platform (RCP).

3.7 Operational work plan – Discussion session

The Drought Task Force has two main committees, one for monitoring and another for risk assessment that could be divided into subcommittees as needed. In this respect, risk assessment tasks are related to:

- **assessing drought impact**: identifying economic, social and environmental sectoral impacts of various droughts, e.g. Jordan agricultural impact, Iraq impact assessment, UNL drought reporter in the United States, EU drought and EWS databases with applications to Syria;
- **ranking the most pressing impacts**: focusing on higher priority impacts;
- **assessing vulnerability:** There is a wide range of options from the qualitative approach to system modelling and quantitative indicators to examine causes and effects (e.g. CAC drought study, 2004-06; State of Colorado agricultural drought vulnerability rankings, 2013).
- **identifying risk reduction measures**: mitigation, preparedness, response recovery; case studies, NDMC drought management database, UN Framework Convention on Climate Change, database on local coping strategies, drought planning resources.

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Wilhite, D.A., M.J. Hayes, and C.L. Knutson (2005) "Drought Preparedness Planning: Building Institutional Capacity", In: *Drought and Water Crisis: Science, Technology, and Management Issues*, ed., D.A. Wilhite, Taylor and Francis: New York, 93-135.

World Bank (2006) Drought: Management and Mitigation Assessment for Central Asia and the Caucasus, Regional and Country Profiles and Strategies, World Bank Europe and Central Asia Region, Environmentally and Socially Sustainable Development Department (http://siteresources.worldbank.org/INTECAREGTOPRURDEV/Resources/CentralAsiaCaucasusDroughtProfiles&Strategies-Eng.pdf).

In terms of the country level operational work plans for drought management, countries have identified their needs as follows:

JORDAN

At the regional level:

- Build capacity of the governmental ministries and institutions in the field of drought early warning as a key measure to cope with water scarcity in the region. This can be achieved through training, study tours, workshops and awareness campaigns.

- Promote regional cooperation and knowledge exchange with international agencies in the field of drought early warning systems and remote sensing and introduce up-to-date tools_and technology to help calculate the crop water requirements, water consumption and water productivity. Bilateral cooperation could be also fruitful if there are common issues to be focused on.

At the country level:

- Form a national team representing the relevant governmental institutions responsible for coordinating roles and responsibilities among the relevant institutions in the field of drought early warning and remote sensing.
- Develop a training plan covering the above-mentioned topics for the staff of the relevant departments and units of each ministry/institution.
- Establish a national information system to host all data and records to be used in building future scenarios to cope with future challenges in drought management.

MOROCCO

Project data and products:

- prepare an inventory of existing products;
- accessibility and sharing;
- harmonization and standardization.

Validation of models/products:

- implement a validation method (common protocol);
- determine the data/products to be validated;
- determine which protocol to apply.

Production scale:

- determine the perimeter: local, national, regional (to be defined at the beginning of the project);
- determine the resolution: spatial, temporal, availability, long-term, etc.

TUNISIA

Drought management

- use of ALEXI ESI and CHIRPS data for early drought warning system;
- prepare a guideline for drought management in Tunisia.

IRAN

Operationalization of what has been discussed:

- The three members from MoEn, MoE and MoA will engage the participation of other relevant stakeholders in the country.
- Schedule regular meetings to discuss priorities and develop an action plan.
- Engage the participation of international agencies working in Iran.
- Moving toward regional cooperation: determine how to harmonize and unify the methodologies used by data centres and standardize methods at the regional level.
- FAO should place more emphasis on strengthening regional cooperation.

EGYPT

Drought management:

- standardize drought indicators;
- development of early warning system.
- consider differences in capacities of the countries and standardize capacity development activities in the region;
- assess and monitor the most important factors causing drought and desertification in the four agro-ecological zones of Egypt, and their indicators;
- increase awareness and build capacity to solve problems caused by drought and desertification;
- establish a national geospatial technology based system for improving rangelands for a long term monitoring research station to combat desertification and reduce its negative impact or at least keep it under control for improving the quality of life of local population
- build on existing projects and ongoing activities by surveying national remote sensing projects of different institutions and universities to avoid duplication and maximize the benefits of these efforts;
- consider a focal point in each country to facilitate regional coordination;
- conduct projects and protocols at the regional level;
- coordinate between the different institutions at the national and regional levels.

WEST BANK GAZA STRIP

Drought management:

This work should build on the initial work carried out and plans identified in the *Technical Report on the National Drought Management Plan for Palestine*, developed in consultation with the concerned ministries and other stakeholders, with support from UNDESA.

- Institutional framework and coordination: Institutionalized establishment of a national committee with high-level ministerial representation from MoA, PWA, MoPaD-MoF, MoT (Meteorological Department), EQA, MoCD and, possibly, MoLG. The national committee should create a technical committee (including relevant ministries, authorities, universities and civil society) to raise recommendations based on monitoring data.
- Set up a drought and flood monitoring and early warning system. Use of a remote sensing system on drought and flooding. Define indicators and triggers. Unify climatological system within the region, develop and adapt to local conditions.
- Assess drought and flood risk and vulnerability in the agriculture sector.
- Develop an operational drought management plan.

LEBANON

Drought management:

- enhance the early warning system on LARI;
- drought forecasting;
- work on the strategies of the relevant ministries, in the following areas:
  - drought monitoring, assessment and early warning system;
  - drought forecasting, promoting the LARI early warning system;

- monitoring the effect of drought on natural resources (forest, water, land);
- aligning work with relevant, existing committees under MoA (Combating Desertification and Climate Change Committee), MoE and private sector;
- enhancing relevant research;
- building capacity.

3.8 Workshop closure: final words from convening partners

During the closing session, Pasquale Steduto (FAO) highlighted that there is a very good level of knowledge by all countries within the domain dealt with in the Workshop. Though, there is a large variability in the implementation of such knowledge. The Regional Collaborative Platform will promote the collaboration among countries to level off such a variability and support the Region to advance and accelerate its progress to cope with water scarcity.

Rachael McDonnell (ICBA) mentioned in her final comments that it was a pleasure to work with the conveners (FAO, USAID and Nebraska University) to advance the ideas presented during the workshop, indicating that ICBA's focus is on drought. The RCP of FAO, linked with USAID's Water Security Platform provides, a real opportunity in the NENA region for a long-term commitment leading to long-term results, to operationalize drought monitoring and start helping people when they are at their most vulnerable.

Chris Neale (DWFI) explained that the cooperation between FAO and DWFI began in 2012 and since then there has been a continued commitment towards the future of agriculture and water resources. He also noted that this workshop provided a good idea of what the partners are planning to undertake in the area of drought monitoring, estimating saline based ET, crop yield estimation and water productivity. In this respect, "partners" refers to FAO, DWFI, USAID, ICBA, NMDC, University of Nebraska–Lincoln, USDA, ARS and NOAA. As such, this is a fundamental difference between this workshop and previous ones; as the workshop not only served to exchange experiences and knowledge but also to set the stage for the future activities. As these actions are implemented, technologies get transferred and capacity is built. All of this cannot happen without the participation of the countries, agencies and interested parties. As such, these products need to be tested, verified and used on the ground to make this transformational difference.

John Wilson (USAID) expressed his excitement regarding the development of new partnerships and the corresponding transformational change. He indicated that country presentations identified similar issues by the end of the workshop, however these issues come from different levels, different interests and different needs. Thus, it is hoped that this workshop has set the stage to begin a process of fruitful exchange of information and capacity building and will demonstrate the value of a regional approach linked to the national actions that must follow. USAID is present to support the countries with the programs that they will design in the coming years.

Abdessalam Ould Ahmed (FAO) indicated that the process for this WSI was launched two years ago with a knowledge gap analysis. A large study was commissioned to look into the water sector in the region, identifying what the different actors had been doing to help the countries and whether FAO had any role in this effort, or any comparative advantage. The work undertaken examined, among other aspects, the evaluation report of the World Bank, the largest player in this field, spending between USD500M and USD1B in the NENA region on water issues, in addition to IFAD, AfDB and other institutions. The conclusions of the study indicated that the donors were making some progress, but that they were facing key challenges, such as scaling-up successful initiatives, primarily because institutions, governance and exchange of knowledge and information were not functioning at the country level. As such, there is a role for FAO to assist different countries. However, FAO must take the following elements into consideration: approach water scarcity in a comprehensive manner using a holistic approach; focus on demonstrating quick changes in the medium-term; work with the farmers as the ultimate end-users that can improve water productivity, conveying clear simple messages.

Concluding, we confirm the willingness to have a process that is as participatory and open as possible. It is a good sign to see this group of countries committed to designing concrete action plans supported by a large range of organizations with expertise ready to provide assistance along the way. FAO is committed for ten years, a commitment which began with the launch of the WSI. I would like to thank the delegates of the member countries for their commitment, our partners active during this workshop and those involved in the topics of evapotranspiration, water productivity and drought management, and LAS which provided us with the political forum and helped us reach out to decision-makers. I hope that for our next meeting, we will be reviewing the results achieved.

SESSION IV

OPERATIONAL WORK PLAN - SUMMARY AND RECOMMENDATIONS

This section presents the main recommendations made by each country at the end of the workshop, following the three discussion sessions regarding the operational work plan for: 1) water consumption (evapotranspiration), 2) crop water productivity and 3) drought management. The recommendations for each country are based on their priorities and needs and will constitute the basis for consultations between the relevant country institutions towards the elaboration of a comprehensive national work plan to be implemented through specific actions in the coming years.

Jordan

Muna Saba, National Center for Agricultural Research and Extension (NCARE)
Moh'd Mfadi Samawi, Jordan Meteorological department (JMD)
Jamal Al-Batsh and Suliman Sawalha, Ministry of Agriculture (MoA)
Nasim Onaizat, Ministry of Environment (MoE)
Awni Kloub, Ministry of Water and Irrigation (MoWI)

One of the key challenges the Middle East North Africa (MENA) region is facing is chronic water shortage. Agriculture constitutes by far the largest driver for water demand across the region. In light of water scarcity and its threat to the future of the agricultural sector and consequent negative impact on food security, there is an urgent need to promote regional cooperation and coordination to cope with such challenges. To this end, this workshop discussed the challenges in the agriculture sector and the need to transition from traditional practices to more economic and efficient ones.

Building on the efforts that have been made so far in this regard, the Jordanian delegation recommends the following actions both at the regional and country levels. These actions are perceived as the core of the future work of this platform:

- At the regional level:
  - Building capacity of the governmental ministries and institutions in the field of water consumption in agriculture, water productivity and drought monitoring and early warning is extremely important and is a key measure to cope with water scarcity in the region. This can be achieved through training, study tours, workshops and awareness campaigns.
  - Promote regional cooperation and knowledge exchange with the international agencies in the field of drought monitoring and early warning systems and remote sensing and introduce up-to-date tools and technology to help calculate the crop water requirement, water consumption and water productivity. Bilateral cooperation could be also fruitful if there are common issues to be focused on.
- At the country level:
  - Form a national team representing the relevant governmental institutions (Ministry of Water and Irrigation, Ministry of Agriculture, Ministry of Environment, Jordan

Meteorological Department, the National Centre for Agricultural Research and Extension and Royal Jordanian Geographic Center). This team will be responsible for coordinating the roles and responsibilities of the relevant institutions in the fields of water consumption, water productivity, drought monitoring and early warning and remote sensing and will follow up on results and outcomes.

- Develop a training plan covering the above-mentioned topics targeting the staff of the relevant departments and units in each ministry/institution.
- Determine the tools, equipment, programs, knowledge and capacities necessary to be able to use the advanced technology to measure the crop water requirements, water consumption, and water productivity in agriculture and be able to build scenarios to cope with drought waves. These can be then systematized and scaled up to the country level.
- Coordinate with scientific research institutions (universities, research centres, relevant NGOs) to provide governmental ministries and institutions with up-to-date research and information with regard to the various topics.
- Establish a national information system to host all data and records to be used in building future scenarios to cope with future challenges.

Morocco

Nour Eddine Bijaber and Ahmed Eraji, Royal Centre for Remote Sensing (CRTS)
Berhili Elhassan, Ministry of Water Resources and Irrigation (MWRI)
Omar Chafki. Direction de la Météorologie Nationale (National Meteorology Directorate) (DMN)

Strengthen capacity in water accounting:
- strengthen the existing capacities of partners for the control and handling of project products;
- implement project tools.

End user:
- define and analyse needs;
- participate in implementation and validation.

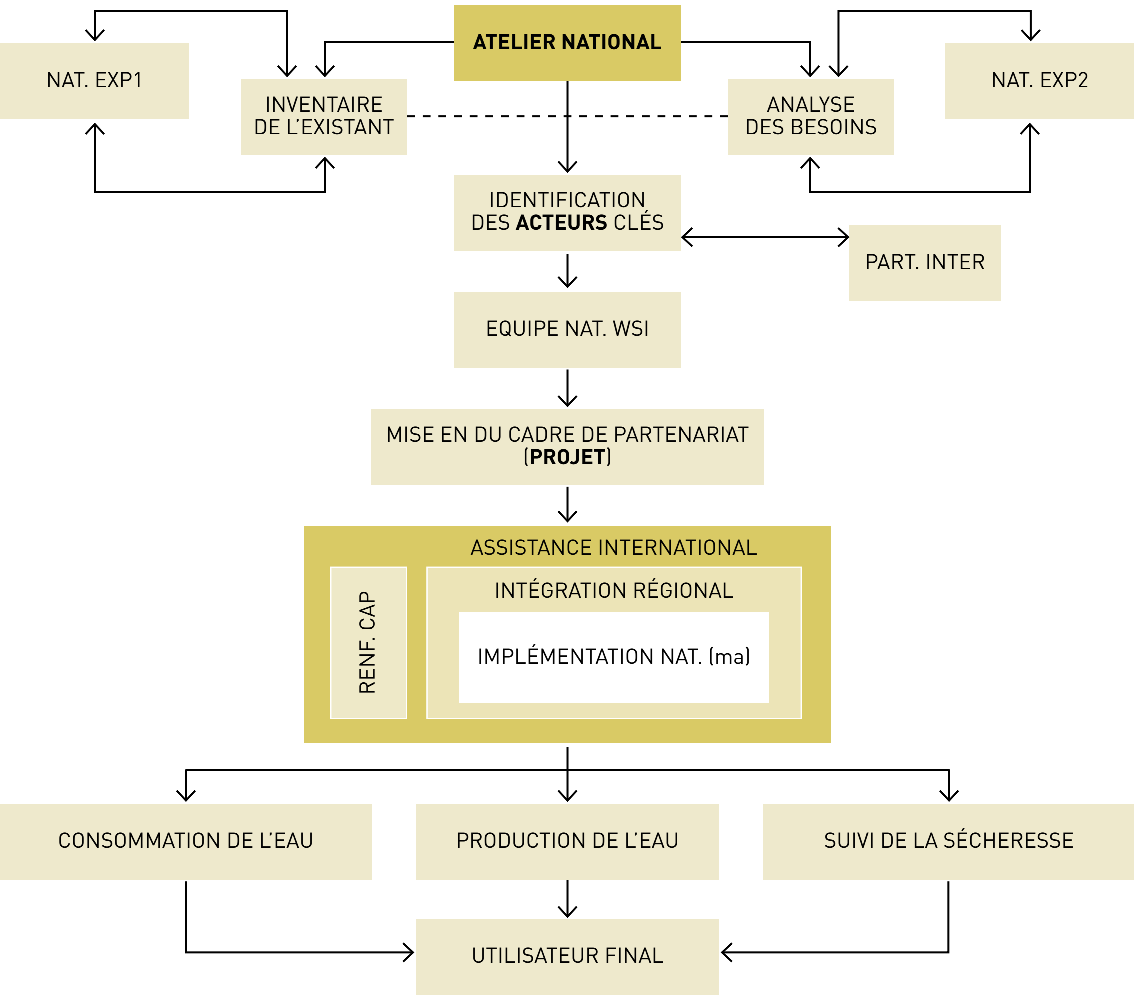
Project data and products:
- inventory existing products;
- accessibility and sharing;
- harmonization and standardization.

Validation of models/products:
- implement a validation method (common protocol);
- determine the data/products to be validated;
- determine the protocol to apply.

Production scale:
- determine the perimeter: local, national, regional (to be defined at the beginning of the project);
- determine the resolution: spatial, temporal, availability, long-term, etc.

URGENT ACTION: organize a workshop with national partners:

- strengthen dialogue between relevant/interested national institutions;
- assess the current situation: national and international;
- establish the partnership framework.



Tunisia

Nabil Sghaier, National Center of Cartography and Remote Sensing (CNCT)
Lotfi Laatiri. National Institute of Meteorology (NIM)
Youssef Trifa, National Agronomy Institute (INAT)

Water consumption (Evapotranspiration – ET):

- use ALEXI energy balance model to obtain daily surface ET at 375 m resolution from VIIRS;
- use the ET product for drought early warning estimates and water accounting in watersheds;
- for field scale water productivity, use DisALEXI and SEBAL to disaggregate ET;
- build capacity on different tools and models and ground flux station;

Crop water productivity:
- estimate wheat biomass and yield in the irrigated area of Bous Salem (northern Tunisia);
- crop mapping of the irrigated area of Bous Salem (northern Tunisia);
- build capacity.

Drought management:
- Use ALEXI ESI and CHIRPS data for drought early warning system;
- prepare a drought management guideline in Tunisia.

Iran

Naser Riazi, Ministry for Jihad-e-Agriculture

Masoud Bagherzadeh Karimi, Ministry of Foreign Affairs

Bahram Taheri, Ministry of Energy

Operational steps include:
- Members of the MoEn, MoE and MoA will engage the participation of other stakeholders in the country working on issues related to the key themes of the regional platform.
- Schedule regular meetings to discuss priorities and develop an action plan involving international agencies working in Iran.
- Internal integration of activities that overlap and determine where there could be gaps.
- MoFA could be a good partner to strengthen regional cooperation and collaboration. FAO can serve as the umbrella of this regional need and move the cooperation deeper and further.
- Moving toward regional cooperation. determine how to harmonize and unify the methodologies used by data centres and standardize methods at the regional level
- FAO should place more emphasis on strengthening regional cooperation.

Egypt

Heba Al-Hariry, AWC

Alaa Mohamed Zohair and Samiha Aboul Fotouh Ouda - MARL

Mohamed Abdel Monem and Mostafa AlHakim EEAA

Essam Khalifa, Mohamed Rami Mahmoud, Mohamed El-Fetyani and Eman El Saied, MWRI

Atef Nassar, MWRI

Water consumption/ET:
- there is a need for a new application for remote sensing;
- provide water consumption on daily basis;
- increase the capacity of MARL, MWRI and other institutions, as needed.

Priority areas identified by Egyptian participants:
- apply new remote sensing application (on macro level);
- water saving;
- water accounting:
- large scale drought and water scarcity evaluation;
- the importance of a monitoring and tracking system;

- the Daugherty Water for Food Institute in Nebraska will provide water consumption data on a daily basis;
- it is very relevant also to monitor groundwater through water accounting;
- there are elements that could be taken into consideration, such as what is the perspective regarding the environment and the use of remote sensing of rangelands;
- there is a need for good management practices for rangelands;
- land degradation and desertification are also important issues;
- there is a need to increase the capacity of the MALAR and MWRI staff in the use of remote sensing.

Crop water productivity

- focus on crop rotation considering the water demands;
- maximize water productivity for each crop (crop per drop) also in economic terms;
- importance to have a cropping system: assessing overall productivity and consumption;
- full farming system: taking into account multiple years since water productivity is difficult to validate/measure in a short time (requires at least 2 years);
- standardize modelling of crop water productivity.
- economic water productivity seen as part of the cropping system (intercropping system) over multiple years;
- implement a food farming system during multiple years and look at the local productivity for the whole system;
- apply a parallel approach that considers water productivity and land productivity to understand the relationship between yields and lands;

Drought management:

- standardize drought indicators;
- generalize early warning system;
- consider differences in capacities of the countries and standardize capacity development activities in the region;
- assess and monitor the most important factors causing drought and desertification in the four agro-ecological zones of Egypt, as well as their indicators;
- increase awareness and build capacity to solve problems caused by drought and desertification control via an early warning system;
- establish a national geospatial technology based system for improving rangelands for a long term monitoring research station to combat desertification and reduce its negative impact or at least keep it under control for improving the quality of life of local population
- build on existing projects and ongoing activities by surveying national remote sensing projects of different institutions and universities to avoid duplication and maximize the benefits of such efforts;
- consider a focal point for each country to facilitate coordination at the regional level;
- conduct projects and protocols at the regional level;
- coordinate between the different institutions at the national and regional levels.

West Bank Gaza Strip

Farrah Ahmed Sawaftat, Ministry of Agriculture (MoA)
Abdel Aziz Rayyan, Ministry of Agriculture (MoA)
Omar Zayed, Ministry of Agriculture (MoA)

Water accounting:

- Remote sensing data on evapotranspiration needs to be monitored:
  - identify best technique/system for ET calculation;
  - develop capacity (human and equipment) in remote sensing technique, data analysis, ground validation (human capacities within the related ministries, mainly MoA).
- Rainfall is currently monitored on a daily basis by the Meteorology Department using only rain gauges . Need to develop a technique to monitor rainfall through remote sensing.
- Need for monitoring of surface water run-off, floods, drought and groundwater recharge. Surface water run-off is not monitored at the moment. It should be monitored both on the ground and through remote sensing.

Crop water productivity:

No systematic work is being done on water productivity at the moment, but it would be useful in order to maximize the productivity per cubic meter of water, use water more efficiently and save water. To enable this:

- develop capacity of human resources in software and equipment.
- interest in piloting remote sensing operational product to calculate crop water productivity in a local context.

Drought management:

This work should build on initial work carried out and plans identified in the Technical Report on the National Drought Management Plan for Palestine, developed in consultation with the concerned ministries and other stakeholders, with support from UNDESA.

- Institutional framework and coordination: Institutionalized establishment of a national committee with high-level ministerial representation from MoA, PWA, MoPaD-MoF, MoT (Meteorological Department), EQA, MoCD and possibly MoLG. The national committee should create a technical committee (including relevant ministries, authorities, universities and civil society) to raise recommendations based on monitoring data.
- Set up a flood and drought monitoring and early warning system. Use a remote sensing system on drought and flooding. Define indicators and triggers. Unify climatological system with the region, develop and adapt to local conditions.
- Assess drought and flood risk and vulnerability in the agriculture sector.
- Develop an operational drought management plan.

Lebanon

Ihab Joma, Lebanese Agricultural Research Institute (LARI)
Amin Shaban, National Council for Scientific Research
Sawsan. Bou Fakhreddine, Ministry of Agriculture (MoA)
Georges Akl, Ministry of Environment (MoE)
Wissam Kanj, Ministry of Energy and Water (MoEW)

Ihab Joma stated that, in Lebanon, water problems are considered both governance and management issues. Solutions should be sought in reforming legislation (reform the water code) as well as in modernizing water management at the field and irrigation scheme level. He suggested developing a work plan in consultation with the Committee to Combat Desertification and Climate Change, given that it already includes all important players mandated to address water and agriculture through their different representatives, including the FAO. In consultation with the Committee, a roadmap can be developed to define specific activities to build capacity at all levels to help define a strategy to improve water scarcity coping mechanisms. Key principles guiding the proposed activities may include:

- Activities related to the roadmap need to be aligned with the SDGs and UNCCD strategy for the coming ten years.
- For the next five years, at least, projects should take into account the consequences for the most vulnerable communities hosting Syrian refugees, who should benefit from project activities.
- As for the activities specifically targeting farmers, these should include awareness raising on increasing water productivity (capacity building programs, extension and training). In addition, incentives for farmers are necessary, not only in the form of subsidies, but also legislative incentives .
- Law enforcement, water metering/measuring and water charges need to be further promoted, in addition to adopting polluter pays mechanisms and ensuring environmental flows.
- The degradation of ground water quality is also of increasing importance. Absence of sewage systems negatively influences groundwater quality, which may increase the number of refugees and, thus, worsen the situation.

Water accounting:

- capacity building on data management and accuracy analysis;
- renovation of tools and equipment (for physical measurements on agro-meteorological, hydro, and water related measurements);
- modelling: management and forecasting (scenarios);
- Lebanon has many water problems at all levels. Work should be done on:
  - updating legislation (such as the water code) and law enforcement;
  - supply assessment and monitoring;
  - demand assessment, monitoring and optimization;
  - improvement of water quality (including re-use of treated wastewater);
  - enhancing relevant research on evapotranspiration and hydrology;
  - building capacity.

Crop water productivity:

- Enhance research ET per crop;
- Smart irrigation technology (LARI early warning system);
- Crop quality:
  - Promote and update research on crop water requirements (data and research is based on concepts of the 1960s);
  - Promote local action at the watershed level. Local communities are often more active than national government.
  - Increase crop quality as result of increasing crop water production.
  - Reduce different types of land degradation: soil erosion, forest fires, landslides, overgrazing, polluting, land use, etc.
  - Enhance relevant research.
  - Build capacity.

Drought management:

- enhance LARI early warning system;
- drought forecasting;
- working on the strategies of the relevant ministries:
  - drought monitoring, assessment and early warning system;
  - drought forecasting and promoting the LARI early warning system;
  - monitoring the effects of drought on natural resources (forest, water, land);
  - aligning work with relevant committees from the MoA (Committee to Combat Desertification and Climate Change), MoE and private sector;
  - enhance relevant research;
  - build capacity.

Summary: Creating a national platform to work in parallel with FAO on the three main axes of the initiative.

APPENDIX 1

Presentations

DAY 1

- Setting the Scene: Introducing the workshop objectives and its expected results
- Consumptive and non-consumptive water use: getting the right framework for sustainable water resources management
- National water accounting: setting the limits of consumptive water use in the agricultural sector
- Remote sensing methods for operational ET determinations in the NENA region
- Operational estimation of ET using the ALEXI –DisALEXI modelling framework
- Demonstration of the high-resolution ALEXI ET product for the NENA region

DAY 2

- Crop productivity assessment through remote sensing: radiation-driven and water-driven algorithms
- Monitoring cropland areas using remote sensing
- Ground validation of crop water productivity: developing a protocol

DAY 3

- Overview of drought indicators and their application in the context of a drought early warning and information system
- Drought monitoring and early warning in the MENA region: The ICBA contribution to the Regional Collaborative Platform
- Vulnerability and risk assessment
- Climate change and droughts

Presentations and photos are available at:

- https://www.dropbox.com/sh/bh6jo8nidmsk6r1/AABzKn-bvTNRTwABfISqNZt0a?dl=0
- https://www.dropbox.com/sh/kb66p6dkclury30/AABXrBltXI-SlJzeLWEqfQjMa?dl=0

APPENDIX 2

Agenda

DAY 1- October 27	Sessions (facilitated by Pasquale Steduto, FAO)
9:00 - 10:30	**Opening ceremony** - Addresses by: FAO, *Abdessalam OuldAhmed* DWFI, *Christopher Neale* USAID, *John Wilson* ICBA, *Ismahane Elouafi* LAS, *Djamel Eddine Djaballah* MALR, *Dina El Khishin,-Supervisor, Foreign Agriculture Relations* MSEA, *Minister Khaled Mohamed Fahmi (tbc)* MWRI, *Minister Hossam Mohamed Moghazy*
10:30 - 11:00	*Tea/Coffee break*
11:00 - 11:30	Setting the scene: Introducing the workshop objectives and its expected results – *Pasquale Steduto (FAO)*
11:30 - 13:00	**SESSION I - Water consumption** (Evapotranspiration – ET) Consumptive and non-consumptive water use: getting the right framework for sustainable water resources management *Pasquale Steduto (FAO)* National water accounting: Setting the limits of consumptive water use in the agricultural sector *Wim Bastiaanssen (UNESCO-IHE)* Evapotranspiration and water resources reporting : country status and outlook *Country representatives (see attached list of participants)* – Part A
13:00 - 14:00	*Lunch Break*
14:00 - 15:30	Evapotranspiration and water resources reporting: country status and outlook *Country representatives (see attached list of participants)* – Part B Remote sensing methods for operational ET determinations in the NENA region *Christopher Neale (DWFI)* Operational estimation of ET using the ALEXI –DisALEXI modelling framework *Martha Anderson (USDA)*
15:30 - 16:00	*Tea/Coffee break*
16:00 - 17:30	Demonstration of the high-resolution ALEXI ET product for the NENA region *Chris Hain (NOAA)* Products and services for the NENA region: The DWFI contribution to the Regional Collaborative Platform *Christopher Neale (DWFI)* **Operational work plan – Discussion session**
17:30 - 18:00	Closing and follow-up actions

DAY 2 – October 28	Sessions (facilitated by Fawzi Karajeh, FAO)
8:30 - 10:30	**SESSION II - Crop water productivity** Crop water productivity: briefing on concepts, definitions and goals *Andrew Noble (ICARDA)* Crop productivity assessment through remote sensing: radiation-driven and water-driven algorithms *Christopher Neale (DWFI)* Monitoring cropland areas using remote sensing *Murali Krishna Gumma (ICRISAT)*
10:30 - 11:00	*Tea/Coffee break*
11:00 - 13:00	Crop water productivity: country status and outlook *Country Representatives (see attached list of participants)*
13:00 - 14:00	*Lunch Break*
14:00 – 15:30	Demonstration of SEBAL3.0 for field scale crop water productivity analysis *Wim Bastiaanssen (UNESCO-IHE)* Ground validation of crop water productivity: developing a protocol *Christopher Neale (DWFI)* **Operational work plan – Discussion session**
15:30 – 16:00	*Tea/Coffee break*
16:00 – 17:30	**Operational work plan – Discussion session (cont.)** Closing and follow-up actions
19:00 – 21:00	**Reception** (Location will be provided during the day)

DAY 3 – October 29	Sessions (facilitated by Rachael McDonnell, ICBA and Faycel Chenini, FAO)
8:30 – 10:30	**SESSION III - Drought management** Drought management: setting the framework right *Mark Svoboda (NDMC)* Overview of drought indicators and their application in the context of a drought early warning and information system *Mark Svoboda (NDMC)* Drought management: country status and outlook *Country Representatives (see attached list of participants)* – Part A
10:30 - 11:00	*Tea/Coffee break*
11:00 – 13:00	Drought management: country status and outlook *Country Representatives (see attached list of participants)* – Part B Drought monitoring and early warning in the MENA region: The ICBA contribution to the Regional Collaborative Platform *Rachael McDonnell (ICBA)* Vulnerability and risk assessment *Cody Knutson (NDMC)*
13:00 - 14:00	*Lunch Break*
14:00 - 15:30	Climate change and droughts *Dann Mitchell (Oxford University)* **Operational work plan – Discussion session**
15:30 - 16:00	*Tea/Coffee break*
16:00 - 17:30	**Operational work plan – Discussion session (cont.)** Follow-up actions
17:30 - 18:00	**Workshop Closure**

APPENDIX 3

List of participants

COUNTRIES

Institutions	Name	Title	e-mail	Phone
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The Republic of Tunisia

West Bank and Gaza Strip

AND THE SUPPORT AND PARTICIPATION OF:

The Near East and North Africa (NENA) Region has the lowest per-capita fresh water resource availability among all Regions of the world, consuming more than 85 percent of renewable fresh water resources through irrigation. Demography, food security policies, overall socio-economic development and climate change will accelerate the fast-widening gap between availability and demand for fresh water resources in the coming decades.

How can NENA countries simultaneously reduce this gap, promote sustainable water resources management and contribute effectively to food security?

Several measures are put in place. However, modernising irrigation systems remains dominant through typically converting the 'low-efficient' surface methods into the 'high-efficient' drip methods. The often underlying assumption is that increasing irrigation efficiency will allow to 'save' substantial amount of water that could be released for environment or other uses.

The evidence from research and field measurements shows that this is not the case. While the benefit at local "on-farm" scale may be dramatic, at basin scale total water consumption by irrigation tends to increase significantly.

The conclusion of this report is that restoring a balance between sustainable supply and consumption of water requires first physical control of the water resource by government or other agencies, followed by interventions to reduce allocations. Within the allocated and controlled quotas, irrigation technology will evolve and spread to the extent that it makes sense for the farmer. These conclusions have important implications for *Governments* and *Donors*.

With this report, we advocate to open up a discussion with all major stakeholders dealing with water resources management on the proper and sound framework required to address water scarcity and sustainability issues. A discussion that has been disregarded for too long.

Policy makers, water resources managers, irrigation developers and financial institutions are invited to provide their views and feedbacks to our dedicated e-mail:
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