ON THE NEEDS FOR CONTINUED DEVELOPMENT OF AD HOC INSTRUMENTATION SYSTEMS FOR OPTIMIZING WATER RESOURCES MANAGEMENT IN DEVELOPING COUNTRIES: LOCAL ACTION IN THE GLOBAL CONTEXT

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Abstract - Over the last few decades, there has been increasing concern worldwide regarding appropriate management of water resources to achieve sustainable development. In particular, for developing countries, agriculture consumes the largest percentage of the water resources available. For instance, in México, 77% of the water available for consumptive use is used in agriculture; it is estimated that 50% is wasted by various inherent processes; thus improving irrigation practices can yield better irrigation efficiency. There are multiple issues that preclude the widespread adoption of new technologies for improving irrigation practices and planning allocation of water resources in developing countries. The authors present a summary of current policies that motivate the need for continued innovation and summarizes the results of a joint international initiative for developing ad hoc soil water content instrumentation considering final product acceptability in the Michoacán, Mexico region.

Index Terms - Irrigation efficiency, soil moisture, instrumentation, water resources management, electrical imepdance.

I. INTRODUCTION

The importance of adequate management of water resources is a key factor towards achieving sustainable development; moreover, water conservation practices play a key role in reducing climate impact. Mexico´s geographic location and extension (Fig. 1) accounts for a wide variety of climates, which in turn favor a wealth of agricultural produce [1]; Mexico´s gross domestic product (GDP) from agriculture corresponds to the 45.75% of the total GDP [2]. On the other hand, agriculture in México utilizes 77% of the water available for consumptive use. Therefore, water resources management is a key factor to ensure economic growth and social development while preserving the environment.

México`s National Development Plan 2012-2018 (Spanish: Plan Nacional de Desarrollo 2012-2018) [3] identifies the strategic importance of ensuring water resources sustainability. As a result, Mexico's National Water Program 2014-2018 [4] (Spanish: Programa Nacional Hídrico 2014-2018) outlines six objectives and actionable strategies:

Objective 1. To strengthen integral and sustainable water management.
Objective 2. To increase water security facing drought and floods.
Objective 3. To strengthen water supply and access to potable water, sewerage and sanitation services.
Objective 4. To increase the technical, scientific and technological capacity of the water management sector.

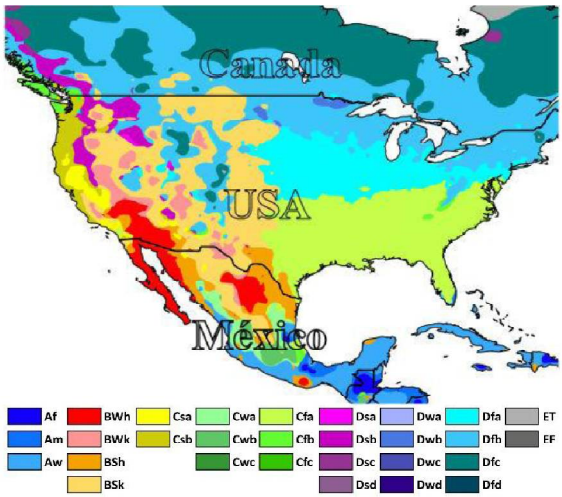

Fig. 1 North America Köppen-Geiger climate classification [1]. Image file licensed under the Creative Commons Attribution-Share Alike 4.0 International license.

Objective 5. To guarantee water for agricultural irrigation, energy, industry, tourism and other economic and financial activities in a sustainable manner.
Objective 6. To consolidate Mexico's participation in the international context of water.

Thus, there is a clear Mexican commitment to pursue strategies to improve management of water resources encompassing all aspects of social and economic development and environmental protection. However, the international commitment impose further challenges to balance the proposal and implementation of water management strategies.

II. GLOBAL CONTEXT

True sustainable development is critical for increasing economic growth and attaining social stability and well-being. The United Nations (UN) Division for Sustainable Development oversees the promotion and implementation of internationally agreed goals; the UN 2030 Agenda for sustainable development [5] states 17 Sustainable Development Goals (SDGs) and 169 targets to address critical issuesand serve as actionable guidelines[6] (Fig. 2).

In particular,the Sustainable Development Goal 6 (SDG6) is directed towards "Ensure availability and sustainable management of water and sanitation for all"[7].However, the UN Economic and Social Council recognizes that each country faces different challenges in pursuit of sustainable development [8].

The importance of meeting the SDGs, has resulted on several requests from individual countries, including Mexico, to conduct voluntary national reviews to be presented at the 2018 high-level political forum on sustainable development (HLPF) to follow-up and review of the 2030 Agenda for Sustainable Development the Sustainable Development Goals (SDGs) at the global level [9].



Fig. 2 United Nations Sustainable Development Goals.

SDG6 is one of the goals to be reviewed in depth at the 2018 HLPF, and thus it is an opportunity to propose strategic plans according to national and regional needs. In particular Mexico presented a technical report of the voluntary review process as a framework to achieve the 2030 Agenda goals which involved several stakeholders including government, private sector, academia [10]. Additional ongoing international efforts are also in place to establish actionable guidelines that can lead to ensure availability and sustainable management of water. The United Nations Secretary-General and President of the World Bank convened a High Level Panel on Water (HLPW). The HLPW consists of 11 sitting Heads of State and Government (including the President of México) and one Special Adviser [9]. According to the HLPW statement, the aim is "to provide the leadership required to champion a comprehensive, inclusive and collaborative way of developing and managing water resources, and improving water and sanitation related services". Amongst their activities, the panel conducted a meeting in May 2017 (Bellagio Italy) which lead to a set of general shared principles "to motivate and encourage governments, business and civil society to consider water's multiple values and to guide the transparent incorporation of these values into their decision-making".The resulting document referred to as the "Bellagio Principles on Valuing Water" states 5 principles on valuing water, presented in a very simplified manner that can be used to convey the views of the panel [12]. Although the Bellagio draft is non-specific and lacks actionable guidelines,it is an important effort to spearhead the implementation of policies and actions in the short term. In contrast the World Water Data initiative Roadmap (WWDIR) [13]the HLPW outlines the implications of adequate water management to meet other SDGs. The WWDIR document describes actionable guidelines and scheduled deliverables. In addition, the WWDIR document highlights the importance of in situ, real-time data collection which can bring together ideas and financing through innovation and action. In addition technological developments have to consider specific and regional needs.

One fundamental enabling factor in developing appropriate measurement technology is access to funding. In an attempt to stimulate funding and investment on water innovation, a recent report to the HLPW conducted by Results for Development (R4D) [14] highlights results of interviews with experts who felt that "investing in innovation focused on developing new technologies was less urgent and less necessary relative to investing in areas that help make better use of existing technologies, such as financing, policy, and scaling up". This finding may indicate that interviewees did not fully represent the views and current needs for funding and development in particular regarding innovation directed towards obtaining in situ hard data using ad hoc instrumentation and control technologies, down to the regional level in developing countries. Thus, it may be a good idea to look at the planning and publications of individual countries in order to obtain a broader view.

For instance, México's commitment to preserve water resources in the context of national development and global climate change is reflected in the Paris Accord, where the Intended Nationally Determined Contribution (INDC) [15] technology recovery and transfer to increase capacity building. Therefore, it is important to identify key measurement technology needs that are cost-effective, and can provide information necessary for planning and allocation of water resources management considering individual regional needs.

III. LOCAL CONTEXT

Mexico´s total area is 1,972,550 km^2 and is divided in 32 states. The Michoacán state (Fig. 3) occupies a 58,599 km^2 surface in the central-west region of México. In Michoacán, the surface dedicated to agriculture is approximately 1.25 million hectare of which 400,000 hectares are irrigated lands. The climate conditions allow cultivating a wide variety of products (corn, avocado, strawberry, wheat, lemon, mango, etc.). The production value is 6.5% of Mexico`s GDP. However, Michoacán ranks 23rd in terms of land use effectiveness (99.4% harvested area/planted area), 21st place in productive efficiency (12.36 tons / ha) and 18th place in economic output per hectare (~$ 25,384 pesos/ha) [16]. On the other hand, strawberry cultivation uses a surface 10 times smaller than that used for sorghum and produces a similar economic yield. Another example is sour lemon, one of the productive chains strategic for Michoacán; due to its undeveloped external market potential, lemon is one of the most socio-economically important chains considering the number of producers, planted area, wages employed, and the dynamism of market prices and the production value. In terms of competitiveness and the environment, lemon is one of the cleanest and least contaminated agro-food chains in the use of agrochemicals. Thus, planning and allocation of water resources for irrigation districts based on hard data isessential to improve the quality and quantity of agricultural production of regional strategic crops in a sustainable manner.

IV. RELEVANCE OF SOIL MOISTURE ELECTROMAGNETIC MEASUREMENT METHODS

The correct characterization of soil hydraulic conductivity properties is essential for optimal water allocation and irrigation scheduling. Thus, measurement of soil moisture is a key factor to provide hard data that can be related to soil hydraulic properties. A critical component that impedes theimplementation of water management policies is the lack of hard data about soil water content down to the regional and local levels. The recent introduction of satellite soil water measurement systems appear to be a cost effective means for gathering wide are information.

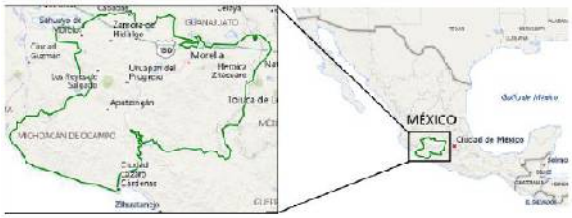

Fig. 3 Location of the Michoacán State. Image composition reproduced with permission under Esri© Master Agreement section 4.2h.

Although it have been shown that satellite soil moisture measurement systems [17-18] can yield information close to in situ data, still satellite data is restricted to the surface and is sensitive to time of day[19-21]. Another important aspect is validation of satellite data using in situ data [22]. Electromagnetic soil moisture measurement methods have been adopted for in situ measurements.One particular technique that can innovate in soil moisture measurement is electrical impedance. In a similar manner to other electromagnetic techniques, electrical impedance measurements rely on the use of a set of electrodes inserted in the soil sample; the measurement method consists of applying a fixed alternating electrical current between pairs of electrodes, while measuring the voltage to calculate the impedance in the sensing field. Water content greatly influences the soil impedance resulting in large impedance changes that can easily be detected with instrumentation electronics. However, many factors influence the soil electrical impedance: type of soil, physical and chemical content, soil management. Therefore, it is necessary to develop compensation methods so as to provide a true value of soil impedance that can be correctly correlated to soil water content. In any case there are indications that electrical impedance measurements are suitable for developing versatile and cost effective soil water content measurement systems [23] and is also a suitable technology for innovating in the water sector.

V. INTERNATIONAL INITIATIVE

Amongst the factors, that influence resistance of producers and farmers to implement instrumentation and control technologies for irrigation, are the lack of versatile devices stressing ease of use and transparent integration with knowledge based systems. In addition, it is necessary to promote practices for gathering in situ information and educate about the benefits of implementing such technologies. In order to develop instrumentation for optimizing water resources in irrigation districts an international initiative funded by the Newton Fund British Council (UK)-National Council for Science and Technology (CONACYT, Mexico)was established in early 2017.

The aim of the initiative is to develop dedicated instrumentation in accordance with Mexico´s regional agricultural development needs. The initiative identifies the advantages of electrical impedance measurements as a versatile, cost-effective water management toolcapable of providing detailed information of soil hydraulic conductivity properties.In order to convert research into a viable cost-effective commercial application it is necessary to plan a technologic road map to elevate the technology readiness level (TRL). The current work corresponds to TRL 3: prototype proof of concept.

The proposed methodology includes validating the results of the proposed measurement method with readily-available technologies and involves a commercial stakeholder to continue the development of TRL to a commercial stage. Initial results of comparing Time Domain Reflectometry and electrical impedance measurement methods can yield information close to gravimetric data (Fig. 4) and can lead to a cost effective measurement tool for implementation in water management.

CONCLUSION

Apart from the needs for building infrastructure for water management, it is also necessary to dedicate research and developments efforts to innovate in the water content measurement arena. In particular it is also necessary to develop measurement solutions that can provide in situ data for gathering hard data pertaining to particular regions. Furthermore, localized, in situ measurements are also necessary for validating remote are sensing information. In accordance with current Mexico National policies, the initiative presented is an important step to secure funding and dedicate research and development efforts according to regional needs. The collaboration of research institutions and commercial stakeholders can lead to ease the introduction of cost effective state-of-the technology according to regional needs and can have an important impact in promoting the adoption of dedicated measurement technology for optimizing water resources.The authors acknowledge the support the Newton Fund Institutional Links program British Council- CONACYT (273817194 (UK) and 277688 (México)) to spearhead the international initiative to carry out this work

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