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Dahan R.

in

Rana G. (ed.), Mastrorilli M. (ed.), Albrizio R. (ed.).
WEMED workshop: how to advance the knowledge on water use efficiency in the Mediterranean region ?

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 72

2007
pages 63-70

CASE STUDY: TECHNICAL APPROACHES TO THE WATER USE EFFICIENCY INDICATORS, AND SOCIO-ECONOMIC AND POLICY CONSTRAINTS TO THEIR OPERATIVE USE IN MOROCCO

R. Dahan
INRA-CRRA Settat, P.O. Box 589, Settat, Morocco

SUMMARY - With growing population and water scarcity, and increasing competition across water-using sectors, the need for water savings and improvement in water use efficiency has increased in importance in water resources management. In Morocco and in the Mediterranean region, in general, water is the major factor limiting agricultural development under both rain-fed and irrigated conditions. This paper is a case study of Morocco with regard to water use efficiency indicators. It analyzes the water resources, their mobilization, affectation and evolution; the climate context characterized by erratic and unpredictable rainfall amount and distribution both inter and intra-annually; the technical approaches developed to improve water use efficiency, mainly proven soil and crop management practices; and the socio-economical factors limiting water use efficiency practical use. The challenges to improve water use efficiency in agriculture reside on the conjunctive intervention at policy, community, technology, and management levels. Based on Moroccan case study and available scientific and technical information in the region, future needs and prospects on water use efficiency improvement are discussed.

Key words: WUE indicators, Morocco

INTRODUCTION

In the Mediterranean, water is the major factor limiting agricultural development under both rain-fed and irrigated conditions. In most areas of the region, water resources development has reached near to maximum exploitation level and agriculture faces the challenges of food security for an ever-growing population, increased demand for water, and scarcity of water. There are also challenges to improve efficiencies with regard to water use due to increased competition from other non agricultural sectors.

In the following, attempts are made through a case study of Morocco, to describe the situation on water use efficiency indicators, and especially, the technical approaches to the WUE indicators and the socio-economic and policy constraints to the WUE operative use.

AGRICULTURE IN MOROCCO

Morocco totals an area near 71 million hectares. About 13% of the area, i.e., 9.2 million ha, is arable land of which 17% is irrigated and 83% is rain-fed. The rest of the total area is split between bare and non productive land (44%), pasture (30%), forest (8%), and native alfalfa (5%).

Agriculture contributes by 13 to 20% to Gross Domestic Product depending on the growing season. It employs 80% of the population in the rural areas and 40% nationwide.

The cropping systems are cereal-based systems. Nearly 60% of the arable land is devoted to cereal crops; 7% to fruit trees; 5% to food legume crops; 3% to industrial crops; 2% to forage crops; 2% to horticultural crops; and the remaining 21% is kept as fallow.

WATER RESOURCES

The total annual precipitation in Morocco (Table 1) approaches 150 billions cubic meters (BCM); around 80% is lost by evapotranspiration. Only 20% of the total amount, i.e., 30 BCM, comprising infiltration and runoff, is considered to be potentially useful rainfall (Benazzou, 1994). The total amount of water potentially divertible is estimated at 20 BCM (Agoumi and Debbagh, 2006).

The hydraulic infrastructure allows approximately 14 BCM of available water. The potential irrigated land is 1.664 million ha, of which, 1.364 million ha are fully irrigated with 880000 ha in large scale irrigation perimeters; 484000 ha in small and medium scale irrigation; and 300000 ha for seasonal irrigation. Irrigated land represents 45% of agricultural PIB and 75% in droughty season. It plays a major role in buffering the effects of drought nationwide.

Table 1. Agro-climatic zones of Morocco with respect to annual rainfall.

Agro-climatic zones	Rainfall (mm)	Area (million ha)	% arable land
Favorable	>400	2.61	30
Intermediate	300-400	2.09	24
Defavorable	200-300	2.09	24
Mountains	400-1000	1.31	15
Pre-sahara & oasis	<200	0.61	7

WATER RESOURCES AFFECTATION

Agriculture utilizes the most important part of mobilized water (Table 2). This tendency is, however, decreasing due diversification of national economy and the demand for drinking water. The % irrigation/mobilized water have decreased from 92% in 1990 to 85% in 2000, and are predicted to reach only 81% by year 2020 (Agoumi and Debbagh, 2006).

Table 2. Trends of mobilized water volume and affectation/use in billion m^3 (AGR, 1995; Agoumi and Debbagh, 2006)

Ressources affectation/ use	1990	2000	2020
Volume mobilized	10.90	14.11	16.77
APWI	0.85	2.04	3.66
Irrigation	10.65	12.07	13.61
%Irrigation/mobilized water	92%	85%	81%

The average annual per capita water potential felt from 2870 in 1955 to 966 m^3/inhabitant in 2004. This was mainly due to population growth and water scarcity, and this water potential per capita would reach a situation of stress threshold within few years as illustrated by projections for 2025. In fact, the annual per capita would fall to 798 m^3/inhabitant by year 2025 (Table 3).

Table 3. Water resources per capita (Agoumi and Debbagh, 2006)

Years	1955	2000	2004	2025
Water potential capital (m^3/inhabitant)	2870	1010 Near-stress situation	966	798 Stress situation
Population (millions inhabitants)	10.1	28.7	30.0	36.3

TECHNICAL APPROACHES TO THE WUE INDICATORS

Considerable amount of work has been achieved by national agricultural research systems in Morocco to develop proven soil, water, and crop management practices combined with improved cultivars to improve water use efficiency of cropping systems and thereby permitting sustainable increases in productivity. The following is a brief description of some achievements by the National Institute of Agronomic Research (INRA-Morocco).

AGRO-ECOLOGICAL CHARACTERIZATION

Agro-Ecological Characterization including a farming system typology and simulations methods which made it possible to quantify and model climatic variability over time and space and its effects on crop growth and production have been studied. Even, recently, maps on potential productivity of crops in most of Morocco area have been elaborated (Cartes de Vocation Agricole).

SOIL AND CROP MANAGEMENT

No-till system

In Morocco, arable lands are undergoing alarming rates of degradation, either due to inappropriate soil and vegetation use or to weather impacts (drought and erosion). The results from research (Bouzza, 1990) and on-farm trials in the 1990s recognized that no-tillage system could halt or reverse decreased production and land degradation, reduce costs; labor and energy use, and improve production. Figures 1 and 2 show mean grain yield over 10 years period experiment in a semi-arid area where proven principles of soil and water management have been tested (Mrabet, 2002).

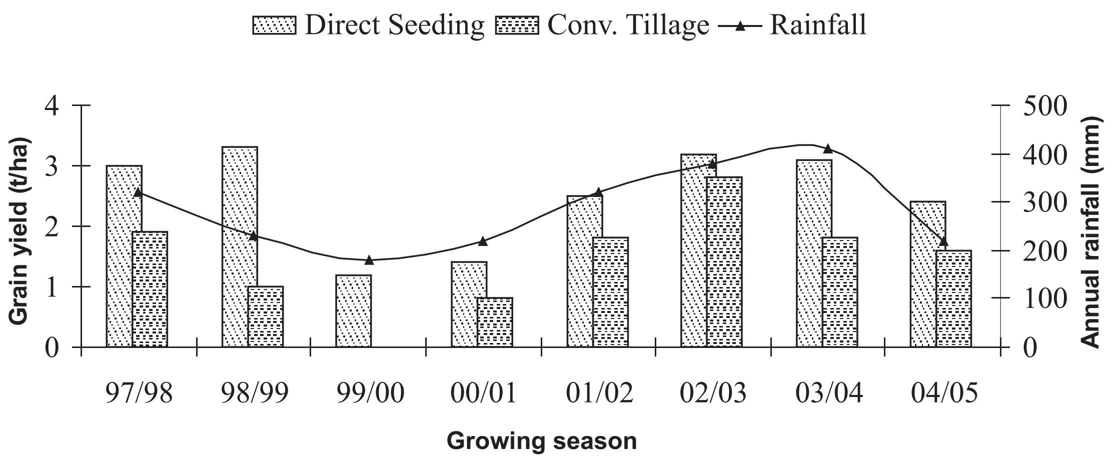

Fig. 1. Grain yield of wheat crop on farmer fields (Mrabet, 2002 modified by Elgharras)

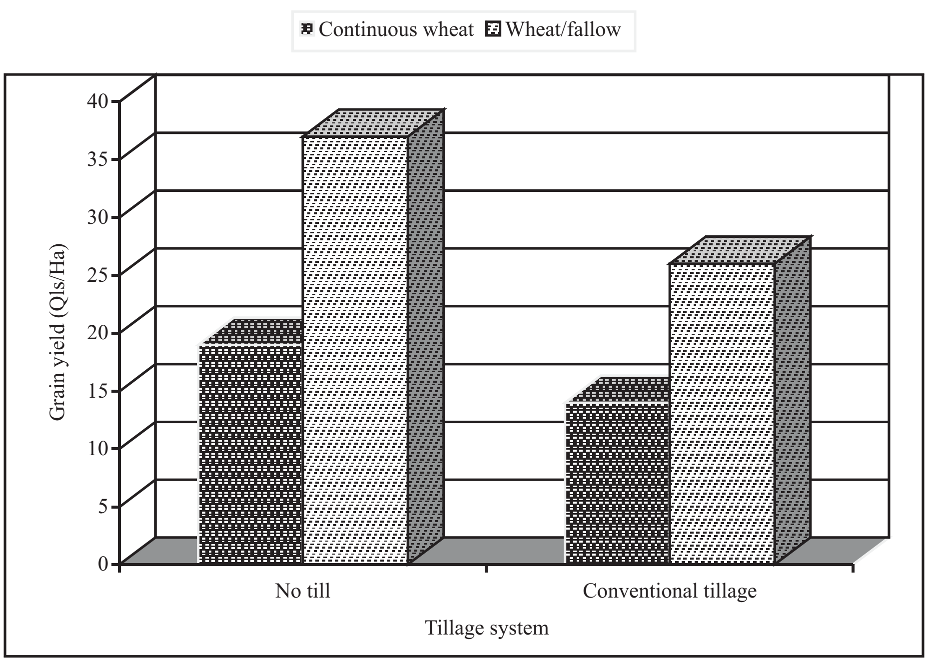

Fig. 2. Average grain yield of wheat over 10 years period in rotation under two tillage systems (Mrabet, 2002).

Cropping System Management Practices

By designing optimum planting date through shifting cropping seasons to cooler, more humid periods of the year to improve the transpiration efficiency, as is the case of winter chickpea and other crops (Kamal and Dahan, 1994); sowing to avoid probable stress periods during anthesis of the crop, or manipulating the ratio of early-season to late-season water use (Boutfirass *et al.*, 2005). Similarly, optimum seed rate and plant geometry to fully exploit the available soil water for the complete season have been investigated. Past and on-going research on fertility management has demonstrated a proven potential to make a sustainable and economic contribution to increased productivity (Elmjahed, 1993; Elmjahed *et al.*, 1998). Moreover, strategies involving tillage, herbicides, and crop rotations to control weeds and reduce competition for water have been developed.

Crop Rotations

Within variable agro-ecological settings, comparisons of different crop rotations with regard to tillage, fertilizers application, nutrients availability, weed management strategy, water storage, WUE and yields were investigated. Their role in diversifying the cropping systems, in optimizing water and nutrient use, and in managing population levels of disease pathogens and weeds have been documented (Bouzza, 1990; Elmjahed, 1993; Elmjahed *et al.*, 1998; Kacemi *et al.*, 1994, Kamal and Dahan, 1994, Masood *et al.*, 2000).

Choice of species and cultivars

Plant breeding program for major crops at INRA-Morocco has led to the development of adapted cultivars to the prevalent Mediterranean conditions. These water-use efficient cultivars (with traits such as early vigor, short duration, drought resistance, phenological plasticity…) may facilitate better use of limited and irregular rainfall. Studies on morphological and physiological mechanisms involved in drought tolerance (phenology, partitioning, plant water relations, gas-exchange parameters, spectral reflectance indices…) were conducted, and recommendations were made on adapted cultivars to be used (Dahan and Shibles, 1995a and 1995b).

Supplemental Irrigation

Substantial increases in crop yield in response to the application of relatively small amount of water as supplemental irrigation (SI) in both low and high rainfall areas have been demonstrated. The need for SI water would vary from 60 to 180mm depending on rainfall. The WUE increase due to SI varied from 30% to 96% in high and low rainfall season, respectively. SI is an efficient mean of improving and stabilizing yield of crops. A single irrigation at a critical stage near flowering and initiation of seed filling can have a profound effect on final seed yield (Boutfirass, 1997; Boutfirass *et al.*, 1999).

Based on these results, the Ministry of Agriculture launched a program for the development and implementation of SI. The total potential area suitable for supplemental irrigation is estimated at 1,000,000 ha: 200,000 ha are located within the large scale irrigation perimeters (non irrigated cereal cropped area); 300,000 ha are located in Central plains (reallocation of resources initially used in intensive irrigation); and 500,000 ha are identified in mainly Central plains (water can come from the excess resources that exist in some hydraulic basins (aquifers, transfer), collection of water in small dams for aquifer recharge. The amount of water needed to irrigate 1,000,000 ha was estimated to 2.1 BCM.

To implement the SI program, the Ministry of Agriculture initiated, in year 2000, a program of creating cereal production perimeters of 14,260 ha. The approach adopted to encourage farmers use SI consisted of (1) the establishment of financial aid to acquire hydro-agricultural equipments (30 % subsidies); (2) further equipment at the farm level of existing perimeters by the State. Farmers' contribution is 40 % of the cost of the operation.

In 2002, an action plan on supplemental irrigation was lunched by the Ministry of Agriculture in partnership with farmers for a period of 5 years. The agreement states that the farmers have to pay and conduct supplementary irrigation establishment projects and the government guarantees the allocation of loans and 30 % subsidies of the investment cost. The program, however, faced many problems among which: (a) Supplemental irrigation has been considered as a single technique and not as a system; (b) the effect of supplemental irrigation as a system, at the farm level, on water productivity, environment preservation and socio-economic aspects were not taken into account. This is a good case, where proven technology has been proven as an efficient mean of improving and stabilizing yield of crops, but, faced constraints which did not allow implementing.

Major contributions, then, can be anticipated from improved soil, crop, and cropping system management. The challenge is to coordinate land and water management with the use of water and nutrient-efficient cultivars in sustainable cropping system to increase biological and economic outputs while taking into account the conservation of natural resource base.

But, even with the tremendous amount of work and technology developed, still no significant impact is apparent. The main reasons reside on the fact that traditional single-disciplinary approaches for agriculture and natural resources management (NRM) resulted only in useful, but partial diagnosis; great technologies (esp. in stations and homogeneous areas),but, often poor impact.

These experiences demonstrate the need for a community based approach for the management of scarce water resources, in which the five capital assets: natural, human, physical, social and financial are to be implemented (Bebbington, 1999; Carney, 1998).

SOCIO-ECONOMICS AND POLICY: CONSTRAINTS TO THE WUE PRACTICAL USE

Land structure

The structure of land is characterized by small holdings. There are 1.5 millions of farms in Morocco. 70% of farms have an average area less than 5 ha and they represent 24% of arable land. Nearly 60% of arable land is held by 29% of farms with an average area of 5 to 50ha, whereas, 1% of farms averaging more than 50 ha hold 16% of arable land (MADRPM, 2005).

Not only the area, but also the fragmentation of land holdings is another constraint. In fact, the statistics show the existence of 9.5 millions of plots, i.e., 6.4 plots by farm with an average area of 0.92 ha/plot.

Further complexity is due to land tenure. The problem of heritage exists in 45% farms. Nearly 75% of arable land is private-owned, 18% community-owned and 7% other status (MADRPM, 2005).

Population structure, employment and income

The total population of Morocco is of 29.17 millions inhabitants; the rural population represents 12.86 millions inhabitants with 50% women. Farmers more than 55 years old represent 45%; the general unemployment rate is 12,5%.

In rural area, 81% of employment is in the agriculture sector. Poverty is widespread, and among every 10 poor Men, 7 are living in rural area. Illeteracy reaches high percentage.

Water policy

Since its conception, the water policy carried out was focused on the mobilization of resources. It wasn't until 1995 and the enactment of water law that a series of fundamental principles were introduced, among them the uniqueness of water resources, an integrated management style, decentralized by watershed, with the participation of water consumers, controlling waste and economizing resources. Since then, the principle of demand management has become the guiding principle of public water policy.

The Law on water (Law 10:95)

This law is the unique legal base of water policy. It governs the use of all water all over the country. It reiterates that all water in Morocco is public domain, except for certain sources of water on which certain traditional communities have long-established rights of use. Even for those communities however, it institutes limitations, such as the obligation to use water for agricultural purposes only.

The main objectives are to introduce innovations and integrated strategy of water management (conservation and WUE); the law is based on the principle of “pollutant-payer and spender-payer; and the law came also to solve other problems: fragmentation of responsibilities of many partners involved and to modernize the administration of water (MADRPM, 2005).

Structures in charge of the concerted management of water

The law also establishes structures in charge of the concerted management of water (Bahri, 2005). At the national level, the main of these structures is the High Council for Water (HCW), which ratifies the National Water Plan (NWP)a synthesis of sub national Integrated Water Resources Management Plans (IWRMP)and which is composed for half of national government officers and of representatives of Watershed Agencies (WA) and the other agencies involved with drinking water, energy production and irrigation, and for half of representatives of water users, of local elected assemblies, of agricultural training institutions, of professional associations and of scientists and experts.

High Water and Climate Council (HWCC): for formulation of general orientations of national policies in the domains of water, the study of all aspects concerning plans of the development of water resources and the legislation of water.

Watershed Agencies (WA): they are managed by an administration council composed of all partners involved in water management and that is in charge of the organization and conduction of water management at the watershed level.

Commissions of water at the prefecture and province levels: this is to allow the participation of local collectivities and to promote the decentralization of water management.

Water Users Associations (WUA) in order to ensure better water management and sustainability of irrigation equipments and systems; to solve the problem of the farmers dues that have not been paid; to guaranty actual partnership between the ORMVAs and farmers; and to incite farmers to stop wasting too much water and hence increase WUE.

Nevertheless, the application of the Law, as reported by Bahri (2005), is still facing many difficulties due to:

(1) The multiplicity of actors in the water sector and the role given to WA at local level: although the law insists on concertation, consultation and participation, in fact the main actors remain the same (WA and even more heavily still the Regional Office for Agricultural Management (ROAM)). Water users' associations (WUA) in particular hardly start having some bearing on important decisions.
(2) Since 1995, there was no transfer of water management prerogatives to WUA. No agreement yet about the pricing of water.
(3) WUA still doesn't have the competencies necessary for accurate evaluation of costs. They are also the least motivated to cooperate since many promises that were made to them were not held: discounts on water bills, access to credit, rebates on the Value Added Tax and on energy costs, etc. The result is that although their number has grown, their effective participation is lacking and limited, in the best cases, to contributing to the maintenance of irrigation infrastructure.

FUTURE CHALLENGES AND PROSPECTS OF WATER SECTOR

Climate change and its impact on water resources

Climate projections according to IPCC methodologies predict for Morocco a trend towards an increase in average annual temperature (between 0.6 and 1.1°C in the horizon 2020), a decrease in average annual rainfall volume by about 4% in 2020 compared to 2000 levels, an increase in the frequency and intensity of frontal and convective thunderstorms in the north and the west of the Atlas Mountains, an increase in the frequency and intensity of droughts in the south and the east of the country, a disturbance in seasonal rainfall (winter rains concentrated during a short period of time), and a reduction in the period of snow cover (unfcc.int/resource/docs/natc/mornc1e.pdf).

While global warming and climate changes would be affecting agricultural production, the availability of one important resource for coping with hotter and drier conditions, irrigation water, may be adversely affected. The first quantitative estimate of possible climate change impacts on water resources in 2020 points to the fact that there would be an average and general decrease in water resources (in the order of 10 to 15 % -these figures being of the same magnitude as those advanced for two neighboring countries, Algeria Spain).

Morocco's water needs in 2020 are estimated at 16.2 billion m³, taking into account the expected increase in temperature. However, the harvesting of the 17 billion m³ that would be theoretically available in 2020 (taking into consideration climate change effects), would require great investments (dam construction, drilling of deep wells).

Needs for structural adaptation of water policy within the socio-economic and climatic contexts

These needs expressed, as reported by Moghli and Benjelloun (2000), aim at total mobilization of renewable resources and also at the development of non-conventional means of water mobilization. Other aspects, which draw attention of decisions-makers, concern maintenance of regional equilibrium for water, mastering efficient management of demand for water and protection from pollution and preservation of water quality.

There is urgent need to reinforce research and development in the field of the sustainable use of water resources in agricultural sector emphasizing technical, social, and economic and policy aspects. The development of territorialized agronomic research and mechanisms for the dissemination of knowledge and technology in rural areas has bearing in improving the WUE issues.

There are needs also to improve the institutional capacity building, human resources development and regional cooperation and exchange of experiences in the field of water resources, WUE indicators and irrigation. Finally, participation, this, in fact, has often lacked both in the conception or implementation of development program or projects. Direct implication of stakeholders through effective communication, partnership and commitment is the key for success.

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