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A Multicriteria Approach For Evaluating the Performances of Irrigated Perimeters in the Southern Mediterranean Countries: Case of the Mitidja Plain (Algeria).

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***Abstract*— Algeria as well as the southern Mediterranean countries (Morocco, Tunisia, Lybia, and Egypt) is confronted more and more with a serious problem of water scarcity. Making a tool of assistance for a better valorization of water by the improvement of the performances of irrigated perimeters will help decision-makers to reduce this pressure. This tool is based on the knowledge and the control of the key performances indicators used in irrigation compared to four criteria: hydraulics, agronomic, economic and environmental. The first results show in the case of Algeria that various logics of valorization of this water by the farmers are in presence for example the water consumed as irrigation water by the market gardening is more effective with a bring a fertilizer excess, whereas the water consumed as water irrigation by the arboriculture is less effective and bringing a few fertilizers. These results will have to be suitable thereafter by the policymakers or managers to lead to a rational management of the water used in these perimeters.**

Keywords — cultures, indicators, irrigation, management, performances, perimeters

I. INTRODUCTION

The Southern Mediterranean countries (Morocco, Algeria, Tunisia, Lybia and Egypt), know, in majority, situation of hydrous stress, with water resources lower than 1000 m^3/capita/year [20; 22]. This situation could worsen under the effect of the climate change. In the future, raising agricultural productivity, contribute to food safety; limit the exodus towards the cities, and save the irrigation water will be the principal's challenges facing Southern Mediterranean countries. Water becomes rare not only in the arid areas and the sectors predisposed with the dryness but also in the areas where precipitations are abundant: the shortage of water relates to the quantity of available resource and water quality, because the degraded water resource becomes inalienable for more rigorous conditions. Algeria, Tunisia and Lybia have only less 500 m^3/capita/year [12; 2; 22], and Morocco a little more than 1013 m^3/capita/year [11]. The sector irrigated in these countries strongly contributes to the agricultural production and the maintenance of a food security level whose current conditions of the market show the importance [1; 23]. The average yield of the majority of the basic commodities is lower by (40 to 50) % compared to the world means. The differences between the potential and current yield are about (50 to 60) %. [10]. We find inside the same perimeter different levels of agricultural yields. This wants to say that there exist very important potentialities which are not exploited, in other words, one can by the optimization of the factors of production, to move the mean level of the yield towards definitely higher values [6]. Development of agriculture in these countries can be achieved only through a better management of water in the irrigated zones, these last strongly contributing to the agricultural production (40 to 50% of the agricultural added-value in Morocco).

Competition obliges the producers in addition to seek cultures with high added value often demanding out of water and frequently unsuited to the rigidity of the collective systems of existing resource allocation. Thus heightening the individualistic steps to reach water with a race with private pumping's.

In these countries, irrigated agriculture consumes today approximately 70% of the total volume of fresh water. A more effective application of the integrated management of the water resources and a better governorship would be desirable to face competition growing for the access to water between agriculture, the other uses (city and industry) and the satisfaction of the environmental needs. Almost the whole of the water resources is practically mobilized in this zone, except in Algeria, where approximately 40% of the dam reservoirs program remains to be realized. In Egypt, having water in abundance, the farmers pay less attention to the consumed quantities of irrigation water. That could be dangerous for the future. The silt fertilisator is retained by Aswan dam reservoir, which involves its sedimentation as well as the abusive recourse of the farmers to the artificial fertilizers. The aggravation of the deficits of the agricultural trade balance of these countries is explained by the weak performances

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carried out by agriculture and a relatively strong population growth in spite of a fall of the birthrate observed in the last few years. The whole of these reports and in particular the fact that all projections consider a reduction of the volumes of water allotted to agriculture thus impose on the one hand an increase in the production of the agricultural sector (effectiveness) and on the other hand a better use of the available resources (efficiency).

In the scientific plan, many work related to the efficiency, in particular technical, exists for the agricultural parcel and also for the total perimeters [21; 7; 6; 18]. From a technical point of view a significant advance were obtained at the agricultural parcel, whereas works at the farm are less developed and often limited to the only economic aspects. The approach that we propose lies in the will to take into account simultaneously with the same tool, of the technical analyzes (hydraulic, agronomic), economic and environmental on an object: farm perceived like the relevant unit of decision. We, to this end, undertook to revisit the indicators of performances and to supplement them.

This tool should enable the establishment of reliable and relevant comparisons between various contexts of management of water in the perimeters of the same country and between the various countries. The approach implemented should make it possible to characterize the current location and to identify possible progress. The application of this tool on farms in irrigated, located in the Mitidja plain (Algeria), has made it possible to analyze through simple indicators, the current performances of the farms in irrigated system.

II. MATERIAL AND METHODS

A. The study area

The present study is performed in the Mitidja plain at the central Algerian coast. Mitidja plain covers more than 90,000 hectares. It includes the irrigated perimeter of East Mitidja (IPEM) wich covers 17,000 hectares and the irrigated perimeter of Western Mitidja (IPWM) composed of two sectors: sector 1 (IPWM S1) wich covers 8,600 ha and the sector 2 (IPWM S2) wich covers 15,600 ha (Fig 1).The farms followed for the performances indicators are located on IPWM S1. On the 456 farms which account this one, 182 were surveyed compared to: the typology of the cultures, the access and the use of water, control mode of irrigations and exploitation of the grounds [16; 17].

B. Method

The study uses census data from the crop years 2005 to 2008. A sample of 71 farms among the 182 was the subject of targeted investigations taking into account of the hydraulic, agronomic, economic, and environmental aspects. Six representative farms were followed in a detailed way (Table 1).

The indicators, for the hydraulics and agronomic performances, are defined on the plot level, according to the irrigation system and of the culture which is affected for him. The irrigation farms units are composed of the plots belonging to the own farm. The sizes measured on the plot level are defined according to the technique of irrigation used: the flow (Q), the rough amount, the agronomic yield (YL) and the dose of fertilizer The values of hydraulic application of efficiency (AE) in the absence of local standards are compared with those of the international literature; the yield obtained in arboriculture and market gardening as well as water use of efficiencies (WUE) are compared with the local standards of the TIAV (Technical Institute of Arboriculture and viticulture) and of the TITI (Technical Institute of the market gardening and Industrial crops), relatively homogeneous with those of the mediterranean southern countries, in order to locate them in an adequate socio-economic context (Table 2). The indicators used in our work tools, among the

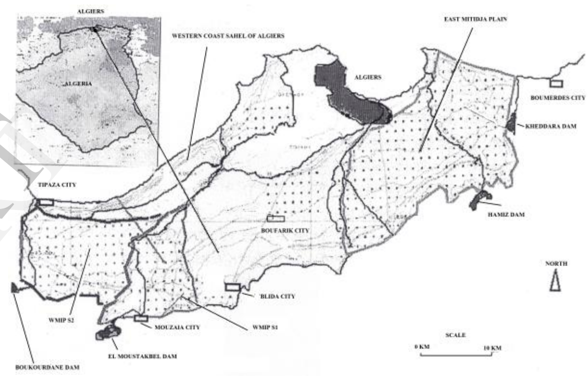

Figure 1. Status of Mitidja plain and IPWM S 1

Table 1.The six farms followed in IPWM S1.

Farms	Statute	Characteristics of farms				
		Q l/s	Cultures	Type	Plot ha	Irrigation mode
A (1 ha)	Tenant *	8.3	Sweetpepper *Lipari*	greenhouse	0.12	drip irrigation
(4 ha)	Assignee **	8.3	Citrus fruits Washington Navel	full field	1	gravity irrigation
B (1 ha)	Tenant	7	Salad *lettuce*	full field	1	sprinkling
C (6.5ha)	Assignee	7.5	Apple tree *(Royal Gala)*	full field	1	gravity irrigation
D (2.8ha)	Assignee	7.5	Citrus fruits *Washington Navel*	full field	1	gravity irrigation
E (1 ha)	Assignee	7.4	Apple tree *Royal Gala*	full field	1	gravity irrigation
F (0.5 ha)	Tenant	8.0	Sweet Pepper *Lipari*	greenhouse	0.12	drip irrigation

Legend: * Tenant: farmer who rents the ground; **Assignee: farmer owner of the ground

multitude of indicators present in the literature, were selected according to their user-friendliness, of their accessibility to measurements on ground, of their standardization. This range of indicators can be later widened with other factors being able to influence the studied performances.

Table 2. Hydraulic performance standards (AE) [5]; and agronomic yields (YL) and water use efficiency (WUE) (TITI and TIAV Algeria).

Irrigation mode	Cultures	AE (%) *Standards	YL ($q.ha^1$) *Standards	WUE ($kg.m^{-3}$) *Standards
drip irrigation	Sweet-pepper	90 to 95	450-700	9 to 14
gravity irrigation	Citrus fruits	60	200	3.3
sprinkling	Salad	80 to 85	300 to 400	6.6 to 8.8
gravity irrigation	Apple tree	60	300	5

C. Indicators of performance

C.1. Indicators of hydraulic performance

- Plot level

There is no single indicator which makes it possible to only define in him and in a suitable way the hydraulic performance of irrigation system on a plot. Among the many indicators, one can retain most often used which are the application efficiency (AE), and the distribution of uniformity (DU) for the surface irrigation, AE and the coefficient of uniformity (CU) for drip irrigation (localized) and sprinkling (surface, sprinkler and localized irrigation).

For the surface irrigation, according to Burt [8] AE (equation 1) is defined as the ratio of the volume V_{RZ} actually stored in the root zone (rz) and the total volume applied V_T.

$$AE = 100\frac{Vrz}{Vt} \quad (1)$$

When in DU it is defined by equation 2.

$$DU = \frac{IMR}{IAR} \quad (2)$$

With IMR (infiltrated minimal rate) and IAR(infiltrated average rate)

For sprinkling in addition to AE (equation 1) the definition of CU depends on the system on irrigation, it is more frequent to use equation 3.

$$CU = 100(1 - SD/M) \quad (3)$$

With SD: standard deviation and M: average water depths measured with rain gauges placed in the centre of the mesh of a network squaring the plot or the part of the plot under study.

For the drip irrigation, the infiltration presents either an axisymmetric character in the case of a point source or bidirectional in the case of a source on line. So measurement with the field of the indicators of hydraulic performance is rather delicate. In addition to AE (equation 1), the CU used according to Burt [9] equation 4 is:

$$CU = (Qmin/Q)\ 100 \qquad (4)$$

Q: average of the values of flows of 16 drippers in the installation and Q_{min} of the 4 lowest values among the 16 drippers.

- Farm level

A distinction is made in result efficiency indicators between overall efficiency for all the irrigated plots on the farm and TPE (total plot efficiency), without allowing for conveyance efficiency. The former describes the quality of application at farm level. This must then be completed by conveyance efficiency $CE_{i,}$ leading to a second index, TPECE. This gives the aggregate values. Equation 5 and 6.

$$TPE = \frac{\Sigma(AEi \times Vti)}{Vi} \qquad (5)$$

$$TPECE = \frac{\Sigma\ (AEi \times CEi \times Vti)}{SVi} \qquad (6)$$

Where in plot i: V_{ti} ($m^3\ ha^{-1}$) is the volume at the field intake for plot I with application efficiency AE_i and conveyance efficiency CE_i.

C.2. Agricultural performance indicators

Agricultural efficiency or water use efficiency (WUE, kg m^{-3}) is generally defined as the relation between yield "YL" (kg ha^{-1}) and the amount of water required attaining this yield [24], witch is total evapotranspiration over the season, AET ($m^3\ ha^{-1}$) équation 7:

$$WUE = \frac{YL}{AET} \qquad (7)$$

Taking into account the fact that it is difficult to reach directly AET to evaluate WUE, this issue witch has been often the subject of a direct evaluation by the professionals of the irrigation, as Howell [14] indicates it, equation 8.

$$WUE = \frac{YL}{(Reff+Vi+\Delta S)} \qquad (8)$$

With R_{eff}: effective rain; V_i: irrigation; ΔS: inventory change of water of the ground corresponding to the water taken by the culture in the root zone.

C.3. Economic performance indicators

On the farm level, the absence of hedge accounting and a traceability of operations of work by culture in each plot, led us to rebuild the data by basing us in particular on the declarations of the farmers, corrected in the light of the data of specialized institutions (TITI and TIAV). Thus the evaluations of the economic results to the plot are generalized with the farm by not taking account of the phenomenon of economy of scale. The performances indicators on the plot level are:

The Gross margin characterized by relation 9:

$$(PC \times P) - OC \qquad (9)$$

With PC (Physical production); P (price); OP (Operational coast)

Economic efficiency or valorization of the water factor characterized by relation 10

$$\frac{GM}{QWA} \qquad (10)$$

With GM (Gross margin); QWA (quantity of water applied)

The objectives indicators are appreciated compared to a standard of output (TITI and TIAV) and allowed like objective of the pedological agro zone. They are represented by:

The Effectiveness (equation 11)

$$\frac{GMO}{NOM} \qquad (11)$$

With GMO (Gross margin obtained); NOM (Normative gross margin)

Efficiency (equation 12)

$$\frac{GMO}{NGM} \qquad (12)$$

With GMO (Gross margin obtained); NGM (Normative gross margin)

C.4. Environmental indicators

They are represented by the relationship between the quantity of nitrogen used and that applied according to equation 13:

$$C1 = \sum \frac{Nused}{Napplied} \qquad (13)$$

And the relationship between the quantity of fertilizer nitrogenizes washed and the total irrigation volume according to the equation 14:

$$C2 = \sum \frac{Nwashed}{Ntotal} \qquad (14)$$

The results obtained are based on a protocol of follow-up of the technical routes of the principal cultures. The investigations of ground made it possible to inform about the quantities and the frequencies of nitrogen application.

Measurements in laboratory inform about the use of nitrogen by the plant during the various vegetative stages.

III. RESULTS

A. Hydraulic performance indicators

The results obtained relate to the values of the hydraulic indicators (table 3) compared with the standards values reported in the literature (Table 2).

For the farms irrigating using surface irrigation, efficiencies of water application on plot level vary from (55 to 59) % and are close to the allowed standards for each technique (Tables 2 and 3). At the farm level, these efficiencies are close to those of the plot as a result of weak escapes in the water distribution network except for the farm A where the conveyance efficiency (CE) is of 70%, following the many escapes. That results in a fall of the efficiency of total application on the farm level (TPECE), reaching 39%. That shows the human factor influence on the values of efficiency. In the exploitations where the conveyance network of water is well maintained and where the escapes are controlled, it is possible to have standards of efficiency close to the recommended local standards. For the drip irrigation system, the results

Table 3.Hydraulic indicators at the plot and the farm level

			Plot level			Farm level		
*	Irrigation mode	Culture	Proportion mm/ha	AE %	CU %	TPE %	CE_i %	TPE CE%
A	Drip irrigation	Sweet pepper	28.4	70	77	70	80	56
A	Gravity irrigation	Citrus fruits	54			56	70	39
B	Sprinkling	Salad	37.8	76	76	76	90	68
C	Gravity irrigation	Apple tree	93	59		59	99	58
D	Gravity irrigation	Citrus fruits	81	55		55	99	54
E	Gravity irrigation	Apple tree	76.3	57		57	93	53
F	Drip irrigation	Sweet pepper	13.9	71	79	35	80	57

Legend: *Farm

indicate efficiencies of application on the plot level lower than the standards (Tables 2 and 3). The reason of this performance is explained by the defect of the water distribution network on the farm level (CE of 80%). One has modern means of irrigation of which the goal is to arrive to water savings, but because of this defection one loses much water by escape in the networks of the farm. For the system of irrigation by sprinkling, (farm B, Table 3) the application efficiency on the plot level is also lower than the standards, its value decreases more on the farm level scale following escapes in the water distribution network. The results obtained show that the water losses in the networks of irrigation on the farm level amount to (20, 10 and 4) % respectively in the drip irrigation system, in sprinkling and gravity irrigation. In a first stage, the performances on the plot level and the farm level can be significantly improved, while making the water distribution network as very watertight. In addition, recommendations following the results of measurements and with the observations carried out on ground can be made for a better irrigation by the increase in the frequencies of the irrigations as well as the time of irrigation, very often lower than the standards.

B. Agronomic performance indicators

The yield observed on citrus fruits and apple trees irrigated in gravity irrigation system (table 4) are lower than the local standards (table 2) with a going variation of (14 to 50) %. These median values of yield in fruit arboriculture can be explained partly by hydraulic efficiencies (table 3) and the weak contributions in fertilizer (table 6 and 7). As for WUE, it is for the whole of the farms, lower than 50%, which confirms the weak contributions out of water of irrigation on the plot level. The yields obtained on sweet pepper irrigated into drip irrigation as well as agronomic efficiencies which result from it correspond to the lower limit of the standards. The same observations apply to salad irrigated by sprinkling. The control of the market gardening in spite of the insufficiencies noted on the levels of the contributions out of water and fertilizer, allows a better valorization of water volumes used.

Table 4. Agronomic indicators at the plot level

Farm	Irrigation mode	Cultures	YL ($qx.ha^{-1}$)	WUE ($kg.m^{-3}$)
A	Drip irrigation	Sweet pepper	450	9
	Gravity irrigation	Citrus fruits	100	03
B	Sprinkling	Salad	260	3.2
C	Gravity irrigation	Apple tree	260	2.3
D	Gravity irrigation	Citrus fruits	150	1.14
E	Gravity irrigation	Apple tree	200	2.22
F	Drip irrigation	Sweet pepper	512	10.6

C. Economic performance indicators

The results of effectiveness and efficiency to the plot for the cultures show disparities for the same culture on two different farms (Table 5).

Table 5. Economic performance indicators at the plot level

Farms	Culture	Plot			
		Indicators of results		Indicators of objectives	
		Effectiveness *$AD.\ kg^{-1}$	Efficiency $AD.m^{-3}$	Effectiveness %	Efficiency $AD.\ m^{-3}$
		1	**2**	**3**	**4**
A	Citrus fruits	20.91	35.20	66	53.13
	Sweet pepper	11.83	23.44	11	212.2
C	Apple tree	7.25	20.27	57.33	35.35
D	Citrus fruits	238.	44.10	113	43.09
E	Apple tree	6.75	17.69	41	433.19
F	Sweet pepper	38.41	176.83	41	

Legend: * DA: Algerian Dinar (1 euro = 100 AD); IRE (gross margin in AD); 2: Gross margin/water dose given in cubic meters; 3: Gross margin obtained/normative gross margin in percentage; 4: normative gross margin/water dose.

This variability of the performances is accentuated in particular by the difficulty of access to water for the irrigants, phenomenon often observed in the perimeter [16]. However, one notices a better economic efficiency for citrus fruits than for the truck farming (sweet pepper). With regard to economic efficiency, it is the truck farming which develops best the cubic meter of water.

D. Environmental indicators

The units of nitrogen applied are averages by culture. The consumed units of nitrogen have summers either measured in laboratory or taken literature. The yields are the averages between the 6 exploitations for each culture. The follow-up of the nitrogenized fertilization of the principal cultures is justified by its impact proven on the high percentages of nitrates in groundwater in relation to the logics of production differentiated according to the culture considered [19]. The sweet pepper under greenhouse and the apple tree receive an excessive fertilization compared to the citrus fruits which do not receive the quantity of fertilizer necessary to reach a satisfactory yield. For the apple trees, compared to citrus fruits, the search for optimal profit seems to explain the level of intensification out of fertilizers. (Tables 6 and 7). This is explained on the one hand by the fact why the market-gardening farmers aim at an early presence on the market from where an important nitrogenized fertilization and a speculative control of their culture, whereas the agrumiculteurs whose capital is consisted their trees, generally adopt a strategy of minimal fertilization aiming maintaining their orchard and at ensuring a relatively acceptable production to guarantee their revenue.

Table 6. Agronomic efficiency of nitrogen and yields of main irrigated crops

Culture	Units of nitrogen applied /ha/year	Units of nitrogen consumed /ha/year	*C1	Average yield q. ha^{-1}
Citrus fruits	213	250	-	125
Apple tree	219.4	120	055	230
Sweet pepper	603	200	0.33	480

Legend: * Ratio between the amount of nitrogen used and the applied one

Table 7.Hydraulic efficiency of nitrogen vemic yield.

Farms	Cultures	*V_T (m^3. ha^{-1})	**C2 (nitrogen Units /m^3. ha^{-1})
A	Sweetpepper Citrus fruits	4437 5940	0.011 no washed
B	Salad	4536	not studied
C	apple tree	5580	0.018
D	Citrus fruits	5750	no washed
E	apple tree	4580	0.022
F	Sweetpepper	4170	0.012

Legend:*****Vt: total volume income during the irrigation season; ** Ratio between the amount of the nitrogen fertilizer leaching and the total volume of irrigation.

IV. DISCUSSION AND CONCLUSION

These results do not make it possible to sit in a formal way interpretation of the performance indicators mobilized because in particular of the reduced size of the sample. The followed step was initiated starting from investigations of ground and supplemented by experimental measurements and in situ inspections between 2005 and 2008, it in addition reveals the countable absence of follow-up in the farms. The results show a valorization of the irrigation water according to several criteria (the system of irrigation, practiced culture, amounts of fertilizer) and that certain farmers develop water obviously less better than others.

Thus, for example, the tree holders, especially the agrumiculteurs for whom the orchard constitutes revenue, irrigant into gravitating seem to develop water less well than the market-gardeners irrigant into drip irrigation. The latter practice the irrigation with small equipment adapted to the configuration of their plot. The market-gardeners with an agriculture in full growth and to answer a demand for constant evolution must develop to the maximum their investments with the risk of surdoser the contributions in fertilizer and products plant health (although the latter were not the subject of evaluation) and thus to pollute the groundwater [13; 19]. This result is in coherence with those observed near the small farmer's irrigants by drip irrigation in the plain of Gharb in Morocco [4].

In addition, the passage of the plot level at farm level shows the reduction in efficiency in the case of a drip irrigation system because of failing water conveyance networks. This result, contradicts the principle even drip irrigation the purpose of which is to save water. The reasons can be multiple: the individual logic of the farmer, who consists in carrying out one more been worth important on the cultures, is not necessarily sparing out of water; the load due to the water invoice is tiny on the scale of irrigant what is not any more the case on an agricultural plain or perimeter scale [16; 17]. Within sight of this report, we make the assumption that a using accompaniment of the farmers of the installations in drip irrigation could contribute to increase the total efficiency of the system [3]. The gravity irrigation one covers 70% of the irrigated surfaces, not being able to act on the control of the irrigations which is empirical; one can improve efficiency of the water conveyance networks, by accompanying the class action suits by saving water. It would be necessary to rather encourage the class action suits than individual for the management of the water resource, to rehabilitate the irrigation networks on the level farm by improving their sealing. The methodology applied to a sample of farms in the case of Mitidja shows the importance of a good knowledge of the irrigation indicators performance to the regional scales for the management of water [15]. This step could make it possible to answer the questions put by the decision makers about the reasons for which in many cases the solutions suggested by research or installations by the developers do not function. These conclusions could help the decision makers to formulate policies which take account of the reality of the practices. It is necessary that this tool tested on the 6 farms, is it with more large scales and on a greater number of exploitations to confirm the validity of it. It opens tracks to more characterize the situation in the modes of exploitation and to identify the insufficiencies on the level of the yield and the water valorization. This step is led while proposing, the key farm level, which is not approached in the majority of work on the performances as well as a method of collection of the necessary informations to establish these indicators. It can be improved by integrating other data elements such as the level of the groundwater and work farming. This methodology could be applied to other ecosystems profiting from an integral or partial irrigation as it is the case in agriculture oasienne, Saharan and in the zones of small and average hydraulics.

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