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SUSTAINABILITY AND OPTIMISATION OF TREATMENTS AND REUSE OF WASTEWATER IN AGRICULTURE: CASE OF MOROCCO

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SUMMURY

Wastewater reuse represents a potentially important additional source of water in arid and semi-arid regions. The interest in the reuse of treated wastewater has increased significantly in southern part of morocco due to water deficit (over 260 millions m^3 per year) and increase demand for water supply. Several local experiments have shown the benefit of using treated wastewater on plant growth and yield (Ouarzane, 1996; Aissi, 1997; Skouri, 1998; Lahkim, 1999; Majidi, 2000). However, the high nitrogen content of treated wastewater represents a treat to ground water contamination under irrigation and sandy soils, because mobile contaminate such as nitrates are more easily leached. To reduce nitrate loading to groundwater and controlling this pollution requires an ability to measure and predict pollution loading by specific wastewater treatment technology and agro-management, including identification of timing and application method to provide nutrients rates necessary to achieve realistic crop yield and prevent pollutents' loss to the environment.

Nutrient management is a pollution prevention achieved by developing a nutrient budget for the crop, applying nutrient at the proper time, applying the amount of nutrient necessary to produce a crop and considering the environmental hazard of the site. The response to the need to control leaching of nutrients and contamination of soil and water recommended several steps to reduce the risks of nitrogen pollution practices as well as reducing cost of supplied water. Within this framework, we are testing different water regime as well as alternation between saline water and treated wastewater to optimize nitrogen application and reduce the risk of groundwater nitrate pollution. As well as to determine the feasibility of supplemental irrigation to stabilize the bread wheat yield.

The conclusions resulting from these studies demonstrate the height value of the reuse of treated wastewater when appropriate practices are adopted, in fact:

1- Treated wastewater resulted in similar to better growth and yield as well as the same quality of crop irrigated with reclaimed waste water in comparison to the control.
2- The use of drip irrigation and plastic mulch eliminated the risk of coliforms contamination of the harvested products.
3- The nitrogen mass balance for the tested crops receiving treated wastewater indicates the high risk of nitrate ground water table. In fact the texture, the high infiltration rate and the high nitrate concentration in the treated effluent contribute to high nitrate leaching potential the amount of nitrogen lost to the underground water are 346 and 343 kg of N/ha respectively for eggplant and chrysanthemum, considering all the components related to nitrogen budget.

Additional experiments for selected crops showed that water application of 100% ETM during the two first stages characterized by low water requirement and 120% ETM during the last stage of the crop growth reduce the nitrate leaching by 67% and increased the soil salinity by only 25%.
The studies on cereals crops demonstrate that supplemental irrigation stabilizes bread wheat yield under arid condition of morocco. There is an increase of grain yield of wheat crop from 9.5 qx /ha to 32 qx/hat, when the amount of water increase from 100 mm to 300 mm. Plants growing under rainfed condition yielded almost zero production.

Our findings demonstrate that flowering stage is the most critical growth stage, in fact, the units that received the highest amounts of water at flowering stage produce the largest yield (48.1q/ha with dose 363 mm and 34.9 q/ha with dose 230 mm).

In other investigation, when denitrification process and tertiary treated wastewater is applied (using reed bed), the quantities of NO_3 and P levels were low and did not meet the plant nutrition requirement with dose (200mm), and induced soil nitrate reduction.

INTRODUCTION

Since the sixties, Morocco has emphasis all his effort on maximizing the capture of the country's surface water and encouraging for their optimal use in irrigated agriculture. In Morocco, there are approximately 7.7 millions of arable lands of which one million ha are actually irrigated and the rest is under rainfed irrigation. High cash crops are the major crops cultivated under irrigation and wheat dominant the crops grown under rainfed conditions. Wheat production in arid regions of morocco is very dependent on rainfall. Frequent droughts took place during the spring that corresponds to flowering or grain filling stage depending on the planting date. Rational use of irrigation water, by adopting adequate drip irrigation for high value cash crops and the use of supplemental irrigation is widely recommended to stabilize and to improve crop yield. However with the scarcity of high quality water resources, the use of marginal waters (saline water and treated wastewater) is not only a necessity, but also an inevitable option to alleviate the water crisis in these regions.

Due to the pronounced water deficit, Agadir region is using sand infiltration system to treat its wastewater to be reused in agriculture and landscaping. This technology generates high nitrate concentration in the effluent (more than 500 mg/l). This indicates the high risk of nitrate leaching and nitrogen pollution of the ground water. This risk is amplified by the soil type (sandy soils) and the hydro-geologic analysis of this studied region. Therefore a pilot project on wastewater treatment was implemented at the commune of Drarga using recycling sand filter, denitrification process, and reed bed as tertiary treatment. The acceptability of wastewater to replace conventional water resources is highly dependent whether the health risks and the environmental impacts (salinity, nitrate pollution) are within acceptable levels. The needs for improving wastewater-use efficiency (WUE) in agricultural production and sustainable reuse of treated wastewater are clearly urgent. Our objectives is to optimize the use of wastewater for maximum crop yield or profit, but taking into account the cost of the irrigation water and minimizing the risks for soil salinity and deep percolation of nitrate. Several experiments were undertaken during the last four years to develop irrigation techniques compatible with sustainable agriculture practices:

For vegetables and flower crops our objectives were to:

(i) Master the water-nitrogen interactions by increasing the water efficiency and reducing the nitrate leaching by testing different rates of water.
(ii) Evaluate the water and the nitrogen use by different crops taking into account their nitrogen and water requirement.
(iii) Evaluate the potential risk of ground water pollution and salt accumulation for the different treatments.

For wheat we adopted supplemental irrigation order to:

(i) Determine the optimum water depth under supplementary irrigation practice.
(ii) Evaluate the effects of supplementary irrigation on the crop development, flowering, and grain yield.
(iii) Determine the impacts of applying treated effluent on the soil characteristics and the plant nutrition.

Tab. 1. Physicochemical characteristics of the irrigation treated wastewater used in our experiments

Characteristics	sand infiltration (Bensergao)	sand infiltration + denitrification+ reed bed (Drarga)
CE dS/m	3	2.61
pH	7.41	7.6
NO_3^- ppm	651	49
NH_4^+ ppm	1,8	18
K^+ ppm	46,8	20.28
PO_4^{3-} ppm	42.2	2.4
Cl- ppm	603	515
Ca^{++} ppm	169	219
Na^+ ppm	228	176
Mg^{++} ppm	90	62
CO_3^{--} ppm	0	8.5
HCO_3^- ppm	-	662
SAR	-	2.69
MES mg/l	10	5
Coliformes (Nbr/100ml)	<1000	<600
Streptocoques (Nbr/100ml)	<1000	-
Œufs d'helminthes (Nbr/l)	0	0

First year experiments:

Using drip irrigation, and 120%ETM regime we compared three type of irrigation water (sand infiltration treated wastewater, epuvalisation treated wastewater, well water to which we added nutrients).we also compared two varieties of eggplants and geranium.

For cereal's crops (maize, durum wheat, bread wheat, barley) we applied increasing regime of irrigation water (100, 110, 120%ETM) and compared two type of water (sand filter treated wastewater, well water to which we added nutrients). Also we had a control treatment for which plants were irrigated at the germination stage and for the rest of the cycle they were under rainfed conditions.

Second year experiments:

Using drip irrigation, several irrigation regime were applied on chrysanthemum (60, 80, 100, 120%ETM) and on zucchini (100,120%ETM) and we also compared treated wastewater to well water to which we added nutrients.

For wheat crop we applied increasing dose of treated wastewater (100, 200, 300, 400 mm) using micro-sprinklers.

Third year experiments

Using drip irrigation system, three irrigation practices were applied; (i) treated wastewater rich in nitrate nitrogen (651 mg/l), (ii) saline well water to which we added nutrients according to crop requirements, (iii) alternating well water with treated wastewater based on the nitrogen requirements of chrysanthemum and pepper crop. During the first growing stage of these two crops, we used well water since needs for nitrogen is very limited, and during the vegetative growth and fruit development we switch to treated wastewater. The combination of these three treatments with two water regimes (100% ETM and 120% ETM) resulted in six treatments randomly distribute in a Latin scare design. Six lyzimeters of $1m^2$ corresponding to each treatment were installed to collect leachate in order to monitor water and nitrogen balance during the crop cycle. Soil samples were analyzed for nitrogen contents before planting and at the end of the harvest. Total yield for four month growing cycle was recorded for each treatment.

For wheat crop we compared five irrigation doses (250, 275, 300, 350, 400 mm) to rainfed treatments

Fourth year experiments

Using drip irrigation system, two water regime (100% ETM, and 120% ETM) were applied; and two vegetable crops (green beans, tomato) were evaluated for their growth and yield responses).

Four lyzimeters of $2m^2$ corresponding to the treatment 120%were installed to collect leachate in order to monitor water and nitrogen balance during the crop cycle. The plant response evaluation, in terms of mineral content, dry matter, quality of the fruits, and total nitrogen leached from the soil solution was collected in the lyzimeters. Salts accumulation were also monitored during the whole crops cycle by mesearing the saturated paste electrical conductivity of the soil under the two water.

Soil samples were analyzed for nitrogen contents before planting and at the end of the harvest and total yield for seven months growing cycle was recorded for each treatment.

Wheat experiment was undertaken using the same treated wastewater and applied two doses of irrigation water (200, 350 mm) throughout all the crop growth stages. The entire field has received the same amount of water, which was equal to 100 mm in the vegetative stage (germination + tillering),

Starting from the flowering stage the irrigation amount is (D1-100 mm) and (D2-250 mm), was allocated according to the schedule (S1, S2, S3) between the flowering stage (F) and the grain filling stage (G) as following:
S1: 50% at (F) and 50% at (G)
S2: 70% at (F) and 30% at (G)
S3: 30% at (F) and 70% at (G)

The control plants received also the same amount of water (100mm) up to the flowering stage, after which no irrigation was added, and the plants water requirements depended on the rainfall. The experiment design adopted for our experiment was a split plot with six repetitions. The cultivars of the bread wheat used in our experiment was *Marchouch*

In this trail, we used the mini-sprinkler irrigation system which known as *micro jet sprinkler*. Its discharge ranges between 40-50 l/h, according to the water pressure, and each sprinkler covers (1 m^2).

The objectives of all these studies were to find the answers to two questions: (i) which irrigation management is optimal, considering both crop production and reduction of nitrates leaching, in the relation to the need for increasing water use efficiency? (ii) Does the use of different depth of irrigation lead to conciliate between nitrogen pollution and salt build up in the soil? (iii) Does denitrification process reduces nitrate loads?

RESULTS

Appropriate technology

There are four projects in Morocco considering the reuse of wastewater in conceiving the STEP: Ouarzazate (lagoon) Ben sergao (infiltration-Percolation), Benslimane (aerated lagoon) and Drarga (infiltration-percolation). Table 2a below represents some identification elements concerning the main projects of treatment and reuse of wastewaters in Morocco. The table includes only studies subjected to a regular follow-up by multidisciplinary teams.

Table 2a. Projects of wastewater treatment and reuse in Morocco

Plant	**Ouarzazate**	**Ben Sergao**	**Ben Slimane**	**Drarga**
Processing System	Lagoon	Infiltration Percolation	Aerated Lagons	recirculating sand filters
Implementation	ORMVAO FAO-OMS-PNUD IAVHII	DGCL RAMSA	ONEP/ MILD Canadian Contribution Municipality Ben Slimane	Project PREM/ USAID Department of Environment Commune of Drarga ERAC-Sud
Date of launch	1989	1990	1997	2000
Processing capacity	430 m^3/d (5 l/s)	750 m^3/d	5.600 m^3/d	1.000 m^3/d
Connected Population (Eq-hab.)	4 300	15 000	37 000	10 000

Concerning the treatment of wastewaters, Table 2b sums up the results of the treatment performances of some experimented processing systems.

Table 2b: Sewage performances: Reduction percentage

Plant	Ouarzazate		Ben Sergao	Drarga	Ben Slimane	Marrakech	Bouznika
Processing System	Lagoon	High Output Lagoon	Infiltration - percolation		Aerated Lagoon	Optional Lagoon	Lagoon
Period of Stay (Days)	25	21.9	-	-	30 – 40	30	-
DBO_5 (mg/l)	81.7	65.3	98	98.5	78	97	75
DCO (mg/l)	72	65.4	92	96	79	76	71
MES (mg/l)	28	-	100	96.6	-	69	76
NTK (mg/l)	31.5	48	85	96.8	75	71	14
Pto t(mg/l)	48.5	54	36	95.9	41	85	-
CF /100ml	99.9	99.9	99.9	99.9	100	99.4	99.9
O. Helminthes/L	100	100	100	100	100	100	100

Source: ONEP-FAO (2001)

Agro-management studies

In most cases of arid and semi-arid areas of the world, the shortage of water is increasing the interest for the recycling of treated wastewater in agriculture. Our research gives a clear picture on the use of unconventional water to get higher water use efficiency without decrease in yield.

As matter of fact, yields were higher for plants irrigated with treated wastewater (table 3). The increase of yield for plants receiving 20% more water is mainly due to more supply of nitrogen and lower salinity in the roots zone. The water use efficiency was significantly different between treated wastewater and saline well water. Water use efficiency was the highest for the plants receiving treated wastewater at 120%ETM.

Table 3. Response of several crops to treated wastewater irrigation

Treatments	Chrysanthemum	Zucchini	Egg plant	Maize	Bread wheat	Hard wheat
	Flower/plt	(Kg/plt)	(Kg/m^2)	Qx/ha	Qx/ha	Qx/ha
Control *	69	1.29	3.17	12.43	5.107	0
Treated wastewater	80	2.18	3.41	12.62	48.69	31.83

* In the case of vegetable and flower control correspond to well water with added fertilizers and for cereals control correspond to rainfed conditions.

The alternation of saline water with treated wastewater increased the water use efficiency and reduces by 50% the total nitrogen lost under treatment irrigated with treated wastewater. It appears that changes in irrigation management, as demonstrated in these studies reduce the download flux of nitrogen to the ground water, resulting in lower nitrates concentration compared to plants irrigated during the whole cycle with treated wastewater. Water and nutrients must be supplied in correspondence with their uptake to prevent the occurrence of nutrients deficiencies, salinization or pollution. As treated wastewater nutrient concentration is constant, it appears from our results that alternating saline water with treated wastewater reduce considerably nitrogen leaching and increase nitrogen efficiency.

The economic analysis of the reuse of treated wastewater allows farmers to reduce the cost of the fertilizers inputs (table 4). This could be a great incentive for the promotion on recycling treated wastewater in agriculture.

Table 4. Economic gains from treated wastewater (Euro/ha)

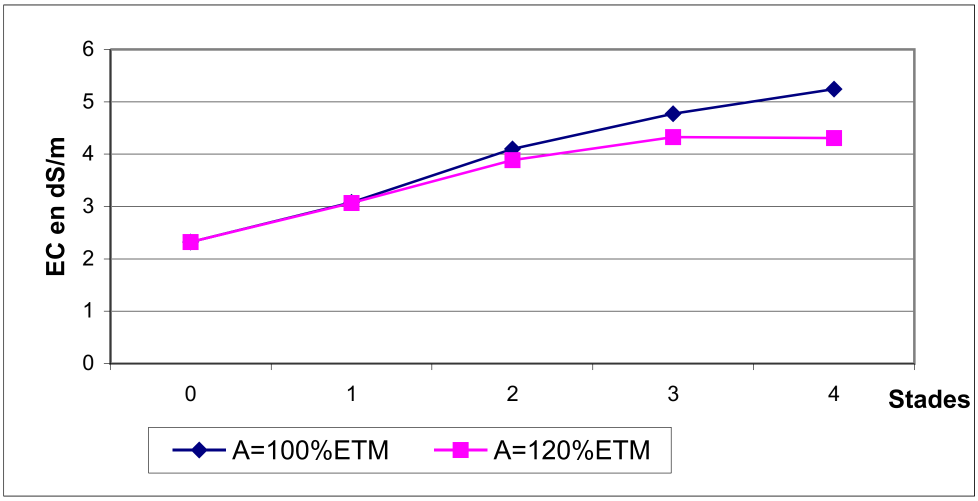
species	Geranium	Durum wheat	Bread wheat	Eggplant	Maize
Fertilizers inputs gains (Euro/ha)	456	780	680	776	350

The nitrogen mass balance for the tested crops receiving treated wastewater indicates the high risk of nitrate ground water table. In fact the texture, the high infiltration rate and the high nitrate concentration in the treated effluent contribute to high nitrate leaching potential the amount of nitrogen lost to the underground water are 346 and 343 kg of N/ha respectively for eggplant and chrysanthemum, considering all the components related to nitrogen budget.

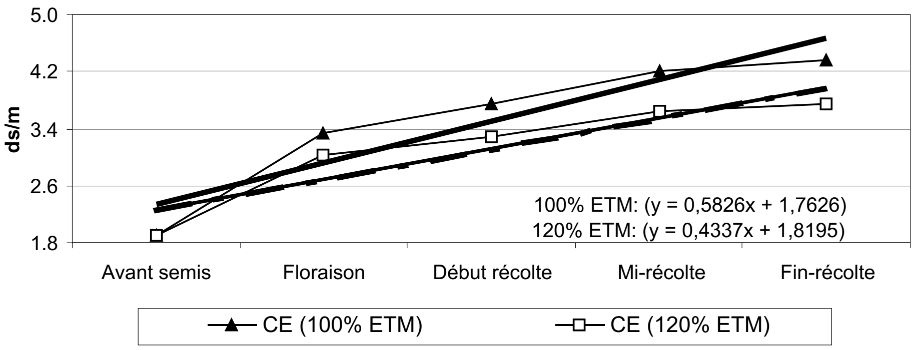
Regarding the water efficiency, the results show two mean tendencies:
The amount of water corresponding to 120% ETM induced high nitrogen leaching and reduced salt accumulation in the root zone. Eventhough, the obtained yield was significantly increased for this water regime.

The application of an equal amount of the crop requirement induces salt accumulation and reduces the nitrogen leaching and yields. Additional experiments for selected crops showed that water application of 100% ETM during the two first stages characterized by low water requirement and 120% ETM during the last stage of the crop growth reduce the nitrate leaching by 67% and increased the soil salinity by only 25%.

Salt accumulation



(a)



(b)

Fig 1. Evolution of the soil conductivity during the tomato (a) and green beans (b) crop cycle.

The studies on cereals crops demonstrate that supplemental irrigation stabilizes bread wheat yield under arid condition of morocco. There is an increase of grain yield of wheat crop from 9.5 qx /ha to 32 qx/hat, when the amount of water increase from 100 mm to 300 mm (Table 5). Plants growing under rainfed condition yielded almost zero production.

Table5. Effect of treated wastewater irrigation depth on wheat yield and its components.

Amount of water	tillers/m^2	grains/tiller	Weight of 1000 grains	Grain yield (g/m^2)	yield (Qx/ha)	Straw yield (Qx/ha)
100 mm	312	12	25	90	9.4	25.8
200 mm	328	16	22	120	11.5	32.7
300 mm	478	18	37	320	31.8	61.6
400 mm	371	26	17	160	16.4	43.5

Our findings demonstrate that flowering stage is the most critical growth stage, in fact, the units that received the highest amounts of water at flowering stage produce the largest yield (48.1q/ha with dose 363 mm and 34.9 q/ha with dose 230 mm).

One of the important observations at this trial is that the units that receive less than 50 mm at flowering stage have a critical impact on its grain yield. Furthermore, the units that received the highest amounts of water at flowering stage produce the highest number of spikes per m^2.

This high yield obtained using treated wastewater as supplementary irrigation source, compared with adjacent rainfed wheat field, which received 107 mm yielded almost zero tonnage. This result indicates the high value of the treated wastewater reuse as supplementary irrigation. If water is the limiting factor, and land is available, it appears more effective to use lower dose on large acreage.

In fact, if the same amount of water (363 mm) which produced the highest yield, is applied at the rate of (230 mm), this will cover 1.58 ha which will produce 55.1 q/ha (based on the yield produced at a rate of 230 mm), and the WUE will increases from 132.4 to 151.8 g grain /m^3.

The other components that must be taken into consideration are the concentration of sodium and chloride, which are presented in high concentration in treated wastewater, as the accumulation of these salts lead to salinity problem on the long run. For example the soil chloride concentration before sowing was 0.28 g/kg, at the end of trial it became between 0.6-0.8 g/kg; the sodium was 0.3 g/kg it became between 0.5-0.6g/kg.

In other investigation, tertiary treated wastewater is applied (using reed bed), so the quantities of NO_3 and P levels were low and did not meet the plant nutrition requirement with dose (200mm), and induced soil nitrate reduction. Therefore tertiary wastewater treatment could meet the environmental goals, but didn't match the crop nutrition requirement.

The high purification level of treated wastewater, and the installation of disc-filter upstream in the field, protects the mini-sprinklers system from clogging, but the disc-filter has to be washed frequently after each three applications.

4. NITRATE LEACHING

Treated waste water used in our experiment is very rich in nitrate nitrogen (Table 6), eventhough the treatment plant used a denitrification process and reed beds as a tertiary treatment. The soil permeability of our soil is very high which presents a risk for ground water nitrate pollution and limits the reuse of treated wastewater unless best management practices are used to reduce nitrogen loading.

Tableau 6a. Quantities of leached nitrate during each stage of tomato (kg/ha)

	Stage 1	Stage 2	Stage 3	Stage 4	Total
$N\text{-}NO_3^-$	2,56	1,41	2,66	5,16	**11,87**

Table 6. Quantities of leached nitrate during each stage of green beans (kg/ha)

Stage	Floral initiation	Flowering	Initial harvest	Final harvest	Total
Quantities of leached nitrate (kg/ha)	**13,4**	**13**	**9**	**3,1**	**38,5**

The average results for the quantities of leached nitrogen nitrate during each stage of the different cropping system are presented in table 8a and 8b. The results show that there's a significant difference between the irrigation management options and the cropping system.

For the green beans the quantity of nitrogen leached in treatments irrigated with treated wastewater for 120%ETM regime varied from the initial to the last one. The last two stages contributed to 65% of the total amounts of nitrate nitrogen leached during the whole cycle of green beans (table 8b). This is the result of induced less salt accumulation in the soil and reduced the level of nitrate. These conditions allowed better symbiotic nitrogen fixation for the green beans plants irrigated with 120% ETM regime and not use the nitrate supplied by the treated wastewater irrigation. All these conditions favored the high amounts of nitrate leached during the last two stage of the crop. The water regime 100% ETM supplied the amount of water equal to the plant requirement; therefore the nitrate leaching was significantly reduced. Alternating these two regime reduce the nitrogen loading to the groundwater by 60%. This practice allows satisfying the nitrogen requirements of the crop during the early stage by using 100%ETM water regime when nitrogen requirement of the plant are very low and then irrigate plant with 120% ETM during the vegetative and the fruit development stages with treated wastewater.

For tomato crop the leached nitrates are evaluated to 11, 9 kg/ha, and represent 31,2% of the treated wastewater irrigation supply. These losses are relatively low compared to the ones cited by Benhoummane.B (2001) which represent 60% the supply and amounts to 126,8 kg/ha. Also Mojtahid.A (2001) has found 66,9% nitrate losses, which represent 74,4 kg/ha. This indicates that in our case the use of treated wastewater to irrigate tomato does not represent a nitrate pollution risk. Also the quantities leached in the average farms in the region are around 42 kg/ha which represent almost four times the amounts leached in our trial. We noticed that 50% 0f the total leached nitrate was lost during the 4th stage. This mainly due to the high water demand during this stage which forced us to add more irrigation water to satisfy the high water demand of tomato crop.

5. SOIL FERTILITY

Table 7 shows the major nutrients (N, P, and K) variation in the soil from initial to the final cropping cycle of green beans. It appear from this table the nitrate and potassium have been considerably lixiviated under 120% ETM treatment compared to phosphorus and the treatment receiving just the plant water requirement. The high nutrient plant uptake under 120%ETM regime did reduce the level of nitrate and potassium in the soil. This mainly due to the low concentration of these elements in the treated wastewater irrigation and could not satisfy the plant requirement, therefore the plant had to satisfy its need by pumping on the soil fertility.

Table 7a. Soil's major nutrients Variation under green beans cropping system

Elements	Water Regime	Before seeding	After harvest
NO_3^- (mg/kg)	100%ETM	115	50
	120%ETM	115	34
NH_4^+ (mg/kg)	100%ETM	14	11
	120%ETM	14	10
P_2O_5 (mg/kg)	100%ETM	121	97
	120%ETM	121	94
K_2O (mg/kg)	100%ETM	171	128
	120%ETM	171	121

In the case of tomato crop we noticed a considerable decrease of potassium and phosphorus, since it reached about 50%. There was less decrease for the nitrogen, which was reduced by 26% for the nitrate and 13% for the ammonium. This indicate that the use of reds bed as a tertiary treatment and the denitrification basin reduced tremendously the concentration level of nitrate, potassium, and phosphorus in the final effluent, which reduced the fertility value of the treated wastewater.

Using 2410 $m^{3 \text{ per}}$ hectare for wheat production can save 30-35% of the nitrogen fertilizer, 10% of P fertilizer, and 70-82% of K fertilizer, of the whole plant exported nutrients and increase the farmer income.

Table 7b. Soil's major nutrients Variation under tomato cropping system (kg/ha)

	$N\text{-}NO_3^-$		$N\text{-}NH_4^+$		P		K	
	T1	**T2**	**T1**	**T2**	**T1**	**T2**	**T1**	**T2**
initial soil fertility	70,56	70,56	25,92	25,92	84,38	84,38	403,78	403,78
After harvest	67,10	61,06	20,30	19,09	45,50	42,62	253,44	227,52
soil stock Variation	**-3,46**	**-9,50**	**-5,62**	**-6,83**	**-38,88**	**-41,76**	**-150,34**	**-176,26**

T1: treatment 100% ETM, **T2**: treatment 120% ETM

Water nutrition contribution

Since the wastewater contains nutrients, an evaluation of the contribution of irrigation water in the total nutrition requirement is determined and presented in table (8).

Table 8. the irrigation water nutrition supply

Treatment	Water dose (mm) Wastewater	Nutrient kg/ha			
		$N\text{-}NO_3$	$N\text{-}NH_4$	P	K
D1	108	12	1.5	1.1	50.7
D2	241.7	26.8	3.4	2.6	113.2

As it is presented in table (9), the treated wastewater contributes more or less to the plant-exported nutrients.

Table 9. Treated wastewater contribution to Wheat nutrients uptakes (in % of total the nutrient uptake)

Treatment	Nutrients %		
	N	P	K
D1S1	20.2	7.3	43.9
D1S2	16.2	5.3	36.5
D1S3	26	9.2	57.6
D2S1	30.8	10.4	75.8
D2S2	34.6	9.7	82.3
D2S3	32.2	9.8	71.9

Soil fertility

The difference between the soil nutrients content in the initial stage (before sowing) and the end of crop season indicates that there is a slight depression in $N\text{-}NO_3$ (negative value) in most treatments except D2S1and D2S2, an increase in $N\text{-}NH_4$ values, a high depression in P values, and an increase in K values as a result of the Potassium fertilizer application.

Water Use Efficiency (WUE)

Water use efficiency based on the yield (g/m^2) per water applied (l/ m^2) has been calculated, as presented in table (10) the highest WUE obtained by the treatment S2 and the lowest by S3 in both doses D1&D2.

Table 10. water use efficiency for each irrigation treatment

Treatment	Water applied (l/m^{2})	Yield (g/ m^{2})	WUE (g/l)
D1S1	230	270.1	1.18
D1S2	230	349.4	**1.53**
D1S3	230	171.7	0.75
D2S1	363.3	413.7	1.14
D2S2	360.3	480.9	1.32
D2S3	363.3	402.1	1.11

It is important to remind that the average WUE of rainfed producing wheat dry areas of WANA (West Asia and North Africa) is about 0.35 g/l, the pronounce difference between this value and that obtained from our trial (1.53 g/l) indicates the importance of supplementary irrigation schedule using wastewater as irrigation source.

8. ECONOMIC ASPECT

Using treated wastewater as irrigation source (water and fertilizer) can reduce the production cost and in turn increases the farmer net income.

8.1. Water contribution

Wastewater price is less than fresh water, so this difference constitutes increment in farm net return. Table (11) presents the gain can be saved by using wastewater.

Table 11. Treated wastewater gain as water source

Dose (m^3/ha)	Cost of fresh water (DH)	Cost of wastewater (DH)	The income gain (DH)
D1 1080	756	540	216
D1 2417	1691	1208.5	482.5

Fresh water cost: 0.7DH/m^3, Wastewater cost: 0.5DH/ m^3

Fertilizer contribution

The nutritional value of wastewater is important to the agricultural economy in developing countries, where fertilizer cost is a major constraint to improve production of irrigation agriculture. Table (12) shows the money that could be saved by using treated wastewater.

Table 12. treated wastewater gain as nutrient source

Irrigation dose Mm	Commercial fertilizer equivalent to treated wastewater fertilizer supply kg/ha			Total cost DH
	Ammonium Nitrate	Potassium Sulfate	Phosphoric acid	
D1: 108	164.3	105.4	4.9	609
D2: 241.7	367.5	235.9	14.7	1363

Ammonium nitrate (33.5%) ; 1.8 DH/kg,Potassium sulfate (48%); 2.7 DH/kg, Phosphoric acid (54%); 5.8 DH/kg
1Euro = 10 DH

In table (13), an attempt to determine the economic benefit of the reuse of treated wastewater irrigation for wheat production under the different treatments.

Table 13. Determination of the income for each treatment

Treatment	Wastewater cost (DH)	Yield q/ha	Income (Dh)	Net return (DH)
D1S1	540	27.1	8130	7590
D1S2	540	34.9	10470	9930
D1S3	540	17.2	5160	4620
D2S1	1208.5	41.4	12420	11211.5
D2S2	1208.5	**48.1**	14430	**13221.5**
D2S3	1208.5	40.2	12060	10851.5

Wastewater cost: 0.5DH/ m^3, Wheat price: 300 DH/q

CONCLUSIONS

This study was a part of comprehensive project aimed to develop wastewater best management practices for irrigation of vegetable crops, flowers, and cereal's crops grown commonly by the farmers in the Agadir region. These studies show clearly the feasibility of the reuse of treated wastewater, if certain management practices are applied. To approach this challenge will require reaching different user groups. I believe that the farmer's cooperatives and water user associations are the main clientele. We suggest developing a demonstration farm which will serve as a demonstration plots to show the farmers how to attain optimum yield and quality with minimum leaching of NO3-N below the root zone.

Other targets will be political leadership at the regional and national level, and influential people, for whom a sensitization program should established, through the organization of seminars and workshops. The results established in these studies should be presented and discussed.

The assessment of leading experiments in terms of processing and re-using waste water remains mitigated. With assistance from international organizations, Morocco launched several projects with significant results. The failure of certain processing projects because of the inadequacy of the process to the socio-economic context of the concerned regions made it possible to better understand the problem of waste water.

In spite of the acquired experience, used water processing projects achieve only a timid progress. The principal obstacle remains the financing, the awareness of the public authorities and the lack of a national policy in the field of management of the waste water with the purpose to protect water resources.

Currently, certain stations reprocess used water by maintaining the treatment performances defined in their system. The follow-up of the physicochemical and microbiological parameters is regularly assured by scientific supervision teams. Treated waste water is currently re-used in agriculture only on an experimental basis or is limited in certain cases to the farmers on grounds located near the station when this water is evacuated in nature as it is the case of the rural commune of Drarga.

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