

Chapter 8: Potential use of treated wastewater for supplemental irrigation of cereals Algeria



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8.1 Background

Algeria has an area of 2,381,740 km²; more than 80% of which is desert. It is the second largest country on the African continent and the 11th largest country in the world in terms of total area. The coastal lowlands and mountain valleys are characterized by a Mediterranean climate, mild winters and moderate rainfall. In the Tell-Atlas area, with a high population density, temperatures average between 21 and 24°C in summer and drop to 10 to 12°C in winter. Average temperatures and precipitation are lower in the intermountain High Plateau region. The desert is hot and arid. Most of the country experiences little seasonal change but considerable diurnal variation in temperature. Rainfall is fairly abundant along the coastal part where it ranges from 400 to 670 mm annually. The amount of precipitation increases from west to east and is heaviest in the northern part of eastern Algeria. The largest river in Algeria, the Chelif, flows 725 kilometers from the Tell-Atlas into the Mediterranean Sea.

Algeria is blessed with an adequate availability of many natural resources with one notable exception – water. Being part of the Mediterranean region, Algeria is presently looking at improving water availability by adopting a new water resources policy and new alternatives addressing water scarcity. Treated wastewater represents a promising alternative that is increasingly available with the development of cities, tourism and industry. In the agricultural sector, reuse of wastewater adds to the value of water resources. However, the protection of public health and the environment are also concerns associated with the reuse of wastewater. Therefore, it is essential that the development of wastewater reuse in agriculture and other sectors be based on scientific evidence in terms of its effects on

the environment and public health. That is why there is a need for an assessment of water quality in parallel with investigating the possibility of using wastewater in cereal production in rainfed agriculture. The use of treated wastewater is an option for enhancing crop productivity in rainfed areas. This can be achieved through the application of wastewater as a source of supplemental irrigation, which is done by applying small amounts of irrigation at critical crop growth stages. Supplemental irrigation has the potential to produce several-fold increases in crop productivity per unit of applied water under rainfed conditions.

Algeria's population is estimated at 33 million. The population increases at an annual rate of 1.2%. More than 90% of the country's population is concentrated along the Mediterranean coast, which constitutes only 12% of the country's land area. Therefore, the overall population density of 14.2 people per square kilometer is deceptive. About 59% of Algeria's population is urban. Drought conditions have led to the internal migration of farmers and herders to the cities to seek alternate employment. High unemployment encourages emigration.

This report explores the different aspects of using treated wastewater as a source of supplemental irrigation for enhancing productivity under rainfed conditions in Algeria.

8.1.1 Agricultural sector

Algeria's agricultural sector, contributing about 8% of gross domestic product (GDP) and employing 14% of the workforce, is unable to meet the food needs of the population. As a result, around 45% of food is imported. The primary crops are wheat, barley and potato. Farmers also have had success growing dates for export. Cropping

is concentrated in the fertile coastal plain of the Tell.

The total area of Algeria is 238 million ha, including 200 million ha of desert, 20 million ha of steppe and 12 million ha of mountains. The area suitable for agriculture is 47 million ha with 8 million ha of arable land, including 0.6 million ha of irrigated land.

The major constraints faced by the agricultural sector are:

- Water deficit for irrigation, due to the irregular spatio-temporal distribution of rainfall and the low remobilization of the resource.
- Salinity and soil sterilization.
- Significant overgrazing.
- Erosion, etc.

A National Program for Agricultural and Rural Development (PNDAR) was implemented in 2000 to safeguard natural resources and to bring a new economic dynamics to increase farmers' incomes and fight poverty.

8.1.2 Water resources

The total annual available water resources in Algeria are 19.4 billion m³, whereas the mobilizable resources are only 12 billion m³, with 6.8 billion m³ in the north and 5.2 billion m³ in the Saharan area. These numbers correspond to an annual per capita water availability of 600 m³ by 2020. These estimates refer to conventional water resources, without taking into account the contribution of desalinated water. Thus, Algeria falls into the category of countries with low available water resources, taking the threshold of scarcity as an annual per capita water availability of 1000 m³ (Beckerman, 1992; Falkenmark and Widstrand, 1992).

Among the available scarce water resources, non-conventional ones, in particular treated wastewater, are an alternative source that can narrow the gap between freshwater demand and supply. However, the mobilization of such non-conventional water resources is rather slow and expensive. So, there is a need to make the best use of treated wastewater in agricultural production systems.

Rainfall

Rainfall in Algeria is characterized by its great spatio-temporal irregularity on arable land (AL). This land is divided into three classes based on average rainfall:

1. 1.8 million ha, representing 24% of the AL, receive more than 600 mm of rain/year allowing intensive agriculture without irrigation, especially when precipitation is well distributed.
2. 3.2 million ha or 42% of AL are located in areas of 400 to 600 mm rainfall, allowing the cropping of cereals, rainfed fodder and fruit trees.
3. 2.6 million ha or 34 % of AL are located in areas where average rainfall is lower than 400 mm. In these areas, agriculture constitutes a high-risk activity.

It can be seen that 76% of the AL is located in unfavorable agro-climatic zones where water constitutes a major constraint and a limiting factor to agricultural production.

Water use

The water resources currently used are estimated at nearly 4,250 billion m³; water consumption is as follows:

- Agriculture = 2.550 billion m³
- Domestic + industry = 1.5 billion m³
- Production of electrical energy = 0.2 billion m³

Table 8.1 summarizes the distribution of water among the different sectors.

Water distribution according to the source:

- Big dams: 932 million m³ or 24% of the total;
- Small reservoirs: 28 million m³ or 1% of the total;
- Wells: 2044 million m³ or 51% of the total;
- Springs: 950 million m³ or 24% of the total.

8.1.3 Water services and tariffs

The tariff

The water tariff is stipulated by Law no. 05-12 of 4 August 2005, published in the Official

Table 8.1: Distribution of water consumption (hm³).

Type of activities	Underground water		Surface water	Total	%
	North	South			
AEP and Industry	1000	200	300	1500	35.3
Agriculture	–	–	150	150	3.5
– Large areas (GP)	900	–	200	1100	25.9
– Small areas (PMH)	–	1300	–	1300	30.6
Energy	–	–	200	200	4
Total	1900	1500	850	4250	
Percentage	44.7	35.3	20.0		100

Note: 1 hm³/year is equivalent to 1,000,000 m³/year. AEP = drinking water supply (l'alimentation en eau potable).

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The tariffs are based on:

- The type of user.
- The tariff zone.
- The volume of water provided.
- The nature and quality of the water.

Industrial and domestic water

The water tariff is based on the rate, which takes into account the cost of water in each tariff zone and the volumes used and consumed.

Domestic and industrial water users are divided into four categories:

- Households: Category I.
- Institutions, administrations, communities and publicly-owned establishments: Category II.
- Craftsmen and public sector services: Category III.
- Production facilities and tourism: Category IV.

The country is divided into 10 tariff zones, and each zone corresponds to a tariff unit.

Water services

The use, management and sustainable development of water resources aim to ensure a regular supply. The objectives are:

- Providing a water supply by mobilizing and distributing water in sufficient quantity and of the required quality, to satisfy the needs of the population and the watering of livestock and to meet the demands of agriculture, industry and other economic activities and social

users of water;

- Safeguarding public health and the protection of water resources and aquatic environments against the risks of pollution by the collection and purification of domestic and industrial used water as well as rainwater and run-off water in urban zones;
- The valorization of non-conventional water of all kinds to increase water supply possibilities.

Agricultural water

The tariffs for agricultural water use are established according to a binomial formula based on the maximum subscribed flow and the actual consumed volume. The water tariff rates applied in different regions are presented in Table 8.2.

Tariffs applied to agricultural water supply for use in irrigated areas other than those quoted above, are fixed as follows:

Table 8.2: Water tariff rates applied in the large Irrigated Perimeters (Algerian Dinar, DA).

Irrigated Perimeters	Volumetric m ³	Fixed l/s/ha
Sig	1.20 DA	250 DA
Habra	1.20 DA	250 DA
Mined	1.00 DA	250 DA
Low Chélif	1.00 DA	250 DA
Chélif medium	1.15 DA	250 DA
High Chélif	1.25 DA	400 DA
Western Mitidja	1.00 DA	400 DA
Hamiz	1.25 DA	400 DA
Saf Saf	1.00 DA	400 DA
Bou Namoussa	1.20 DA	400 DA

- Volumetric payment: 1 DA per cubic meter.
- Fixed payment subscribers: 250 DA per l/s per hectare.

8.2 Production and use of waste water

8.2.1 Introduction

In Algeria, the use of treated wastewater for irrigation is in an embryonic state and is practiced only in small areas and often on an experimental basis. In fact:

- The total area irrigated by treated wastewater is 2300 ha (MADR 2004, 2006).
- The total volume of wastewater at the national level is 731 million m³ (Source: Ministry of Water Resources).
- The total area irrigated by untreated wastewater is around 5400 ha (MADR 2004, 2006).

Most areas irrigated by this non-conventional water are concentrated in the northern provinces (*wilaya*).

The tendency to expand the use of untreated wastewater at the expense of public health can be explained by two decades of drought, which negatively influenced the behavior of some users attracted by the speculative aspects of irrigated crops. Following information follows:

- Urban population: 26 million.
- Quantity of wastewater generated: 731 hm³/year.
- Collected wastewater: 485 hm³/year.
- Intercepted wastewater: 337 hm³/year, of which.
- Wastewater intercepted but not purified: 155 hm³/year.
- Purified wastewater: 182 hm³/year.
- Volume of potentially re-usable wastewater: 510 hm³/year.
- Wastewater purification stations (STEP) to be constructed have been identified
- Total cumulative STEP until 2030: 696

8.2.2 Objectives until 2030

The government had put the following objectives:

- Continue the planning and construction of STEP.
- Guarantee a potential reuse of 52% of wastewater in the large irrigated areas and the rest in the small- and medium-scale irrigated areas.
- Develop purification systems adapted to the requirements for the success of purified wastewater projects.
- Give priority to the interception and reuse of wastewater discharged into the sea.
- Establish the methodology for feasibility studies on the success of using treated wastewater.
- Establish an inter-ministerial committee responsible for wastewater use.

8.2.3 Status treatment plants (STEP)

The number of stations for the purification of domestic wastewater in East Algeria is 45. The status of these stations:

- 10 STEP to be rehabilitated (surveys are completed).
- 11 STEP to be rehabilitated (2nd phase; study is launched).
- 03 STEP in the process of rehabilitation.
- 03 STEP under development.
- 18 STEP in operation.

The total volume of treated wastewater does not exceed 75 million m³ a year, which is nearly 12% of the total volume of wastewater.

Total potential volume of treated wastewater for use in irrigation is estimated at 39,864,000 m³/year, representing around 50% of the total volume of wastewater.

The quantity of wastewater said to be used in irrigation remains disproportionate compared to the area actually irrigated (2376 ha) by wastewater (DDAZASA 2005).

8.2.4 Wastewater reuse policy and standards of water quality

- A draft executive decree related to 'the final concession of treated wastewater uses for irrigation' is in the process of preparation for adoption.

- Law no. 05-12 of 4 August 2005 institutionalized, in articles 76 and 77, the concession of treated wastewater use for irrigation purpose.
- The articles of the decree stipulate that 'the uses of purified wastewater resources' for individual or collective agricultural use and for industrial uses, must be the authorized by the relevant administration. The procedures and the conditions of authorization are defined by the law.

8.2.5 Wastewater treatment

The treatment plants established so far are insufficient and sometimes their rehabilitation is not considered a priority. A more serious problem is that they have practically no effect on water quality, because they are not operational.

Table 8.3 lists the wastewater treatment plants managed by the National Office of Water Decontamination (ONA, Office National d'Assainissement) that can provide water for irrigating on-farm experiments.

8.2.6 Wastewater treatment potential and reuse in agriculture

The use of non-conventional water resources such as treated wastewater and desalinization is not yet common practice in Algeria.

Wastewater treatment is neglected and there is no effective reuse of treated wastewater in Algeria. The concept of the reuse of treated wastewater, which could have a tremendous impact on water supply, has not yet been applied. However, a few trial plots have been designated to explore this possibility.

Wastewater production and reuse options in the Khemisti area

A survey of the ecological, socioeconomic and agricultural aspects of wastewater use was conducted in the Khemisti region. The main findings are summarized below.

Ecological impact

- Negligible impact on the physico-chemical qualities of soils;

Table 8.3: List of wastewater purification stations.

Wilaya	Site location	Effective flow in m ³ /day	Proximity to arable land	Does irrigation already exist (Yes/No)
Constantine	18 km from Constantine	16,000	moderately close	No
Souk Ahras	4 km from Souk Ahras	13,000	close	No
Chelghoum El Aid	Wadi El Athmania	2,700	moderately close	No
Maghnia	2.3 km on left bank of Wadi ouedjou	7,000	moderately close	No
Ain El Hadjar	1.8 km	2,000	moderately close	No
Touggourt	Periphery of Touggourt	10,000	near palmerais	No
Sétif	Ain Sfiha	12,000	surrounded by arable land	No
Tizi Ouzou	5 km from Tizi Ouzou	15,000	surrounded by arable land	No
Boumerdes	2 km from city	5,000	surrounded by arable land	Yes, olives arboriculture
Thenia	2 km from city	3,000	surrounded by arable land	No

- Enriches soils by providing essential nutrients;
- Report of groundwater contamination risks; the station requires modification and some additional wastewater treatment processes;
- Little mobilization and exploitation of water potential.

Socioeconomic impact

- The area is characterized by a lack of knowledge of the potential of natural resources, the existence of extensive production systems with a high percentage of fallow, very strong disparities in livestock numbers, significant inadequacies in farm management, and a low level of diffusion of innovative technologies;
- Low level of technical performance, and very strong sensitivity of outputs to climatic risks, reflecting a low level of technical control;
- Low level of agricultural incomes, in particular of very small-scale farming and collective farms that do not have livestock;
- Some technical and economic progress in performance, though not very significant, due to the National Program on Agricultural Development (PNDA), which has had net impacts (diversification of farming systems, irrigation, equipment);
- Quantity of mobilizable wastewater is only enough to irrigate a limited area: 40 to 50 ha, by supplemental irrigation;
- Lack of precise knowledge of the area currently irrigated with used water, and this in spite of prohibition of the use of this resource; Consequently,
 - The current technical and socioeconomic impacts limit the use of wastewater;
 - The potential foreseeable impacts after rehabilitation of the station, collective management and control of the water resource, are relatively significant; Then, there is a need for
 - The rehabilitation of the station;
 - The installation of an organizational structure for the collective and

interdependent management of the water resource;

- Equity in access to potential wastewater for irrigation (0.5 to 1 ha/ family);
- The extra income of 26,000 to 52,000 DA per household comes from increasing wheat production from 7.5 to 15 quintals/ha, plus a considerable contribution to family food from vegetable and milk production.

Gender

Report on the situation of women who are prevented taking initiatives to access external resources – information, credit, subsidies and other State aid, employment opportunities;

- Women contribute significantly to the productive activities of the household (livestock production);
- Very strong degradation of the know-how of women (craft industries, in particular working with wool);
- High recognition of the situation of women and young people who are confronted by unemployment and difficulties of acceding to high responsibility in various State action programs.

Reuse of wastewater for supplemental irrigation project background and design

Issues

Over the last 25 years, Algeria has experienced a period of intense and persistent drought, characterized by a significant rainfall deficit of 30% over the whole country (during the year 2001/2002, this deficit was 50%).

The Algerian climate is characterized by its aridity; so the majority of the arable land is located where water is frequently scarce.

The negative impact of climate change and, in particular, the rainfall deficit recorded over recent decades has resulted in a reduction in the volume of stored water, thus limiting the amount available for irrigation. The priority in the allocation of water is given to drinking water supply. This has involved a reduction in

the quota reserved for irrigation and hence a constant reduction in irrigated areas.

The demand for water for drinking and by the industrial sector is 2.4 billion m³/year for a population of 30 million, while the availability is only 1.6 billion m³/year; and the requirement in 2010 is estimated at 3.6 billion m³/year for a population of 40 million.

The solution to this situation is to seek out and plan for other alternatives to mobilize, manage and develop as well as possible this scarce resource.

Since the mobilization of new resources is very slow and expensive for the State and for communities, the obvious, economic and fast solution consists of recovering used water for reuse in agriculture and the development of a significant hydraulic infrastructure.

As our chosen study area is known for its conventional water deficit, it was considered an interesting site to study the possibility of the reuse of wastewater in supplemental irrigation.

Choice of the site

In order to highlight the benefits of the treatment process and the reuse of water on the ecosystem, we needed to choose a suitable site in terms of environmental, technical, social and economic conditions.

For all these reasons, the choice fell upon the small rural district of Khemisti (Tissemilt Wilaya), located in the northwestern region of Algeria, where 22,812 inhabitants rely exclusively on the monoculture of cereals together with cattle and where a wastewater recovery plant was recently established.

Domestic wastewater is collected from the small town of Khemisti. This brings with it the risk of ecosystem degradation, groundwater pollution and the exposure of the population to disease. The treatment plant was set up with the specific aim of recovering and treating this water before disposal, without considering its reuse. However, wastewater treatment plants carry out only rudimentary processing, limited to simple chlorination. The

project aimed to use this treated wastewater in agriculture.

Once implemented, new production systems (expanded to other food crops and marketable commodities) will certainly involve rural women because of the development of new agricultural activities – small ruminant breeding, handicrafts and possible product diversification.

The selected area is characterized by low variable rainfall, with an annual average below 350 mm. Groundwater resources constitute most of the water reserves. However, their exploitation remains difficult and expensive for the community. To achieve this goal, it is necessary to carry out an agro-ecological survey of the study area.

Soils

The soils of the study area are calcareous with a clayey texture upstream and a loamy-clayey texture downstream of the terraces. They are suitable for growing field crops, vegetables and adapted fruit trees, except under some conditions upstream, where there is swelling clay. In these conditions, soil moisture has to be high enough to avoid soil cracking.

Water quality

The main data concerning the physico-chemical characteristics of wastewater are presented in Table 8.4.

The analysis of raw waters and water treated by decantation, at the basin level, shows no risk of toxicity due to heavy metals, chlorine and sodium on crops in the near future. There is also no soil degradation due to salinization or sodicity.

Salinity and sodicity

The SAR (sodium adsorption ratio) as low as 2.41 for raw water and 1.66 for treated water, shows there is no risk of degradation of the soil structure or porosity due to sodicity.

The electrical conductivity (EC) of water (3.9 and 2.59 dS/m) appears, on the other hand, relatively high for crops sensitive to salinity, particularly for some vegetables and fruit

Table 8.4: Physico-chemical characteristics of wastewater.

	Physico-chemical analyses		Elements (ppm)	Heavy metals	
	Raw water	Treated water		Raw water	Treated water
pH	7.45	7.81	Zn	trace	trace
EC dS/m	3.09	2.59	Cu	trace	trace
K me/l	1.52	1.19	Fe	15	10
Na me/l	14.24	10.94	Mn	5	4
NH4 me/l	129.6	144	Cd	zero	zero
Ca me/l	5.75	4.75	Pb	zero	zero
Mg me/l	74.16	80.02	Co	zero	zero
SO4 me/l	1.82	1.57	Cr	zero	zero
Cl me/l	7.29	7.65			
HCO me/l	12	10.5			
SAR	2.41	1.66			

trees in which yields can be reduced by up to 25%.

Bacteriology analyses

Studies of the indicators of fecal contamination form the basis of bacteriological water testing. The maximum level allowed for the microbiological content of irrigation water authorized by WHO is 1000 total coliforms (TC)/100 ml.

The concentration of microbes in the untreated wastewater in our study (fecal coliforms, total coliforms, activated sludge reactor and CO) is high. However, after chlorination with 2.5 g/m³ calcium chloride for 24 hours, the microbial load decreased to 1609 TC/100 ml. Measuring the load of (sulfur reducing) bacteria is preferred in this case, because their level indicates the effectiveness of disinfection in reducing the content of micro-organisms. They are also considered as indicators of fecal contamination.

The results revealed a load of anaerobic bacteria (sulfur reducing) of 300/20 ml and a concentration of fecal streptococci of 141/100 ml. It is recommended that the settling time at the reservoir level is increased to improve the bacteriological quality of used water.

8.2.7 Effect of supplemental irrigation with treated wastewater on wheat yields at the Khemisti site

The objectives of this study were to:

- Evaluate the effects of supplemental irrigation on crop development and grain yield; and
- Determine the impact of applying treated wastewater effluent on soil characteristics and plant nutrition

Materials and methods

Field experiments were conducted for two consecutive years (2006/07 and 2007/08) at two sites in Khemisti commune in Tissemsilt Wilaya (altitude: 900 m), characterized by its arid climate with hot summers and cold winters and annual rainfall ranging from 250 to 350 mm, of which about 90% is received from December to April.

In this study, three irrigation regimes of treated wastewater using sprinkler irrigation were tested. The amount of water applied in each supplemental irrigation was 50 mm. One irrigation was given in May (T2) or in March (T3) or two irrigations in March and May (T4). The check or treatment T1 was conducted under rainfed conditions.

Two varieties of durum wheat were used. The first, WAHA, is widely used by farmers and the second is a newer variety, Boussalem, selected at the Sétif ITGC (Institut Technique des Grandes Cultures) station and of ICARDA/CIMMYT origin. The experimental plot area was 1 hectare per farmer. The experiment was conducted using a completely randomized block design. Analysis of variance (ANOVA) was used to determine the effect of each treatment and their interactions. When the F ratio was significant, a multiple mean comparison was performed using Fisher's Least Significance Test ($p = 0.05$). Statistical analyses were performed using the STATITCF program.

The agronomic parameters measured were the number of spikes/m², the number of kernels/spike, 1000 seed weight and grain yield (kg/ha). In this report, only the grain yield is presented.

Results

Table 8.5 and 8.6 show the effect of supplemental irrigation at different growth stages of wheat on the yield of the two varieties, WAHA and Boussalem grown at two sites (experimental station and farmer's field). In general yields at the station are higher than those obtained at the farm level during both years of study (2006/07 and 2007/08), showing the yield gap due the poorer management used by the farmer. All irrigation treatments gave higher yields than that obtained under rainfed conditions. There was no significant difference in yield between the plot that received one irrigation in March

and the one that was irrigated in May. However, two irrigations applied in March and May significantly increased productivity. In a dry year (2007/08), the yield obtained with two irrigations (March and May) was three-fold that under the rainfed and one irrigation in March or May treatments.

8.2.8 Conclusions and recommendation

From this study we can conclude that:

- The effect of using wastewater in irrigation on the physico-chemical characteristics of the soils with a rough texture is low. More work is needed to study the effect on heavy (clayey) soils;
- Soil nutrient content (N and P) is improved when wastewater is used in irrigation;
- There is a risk of contamination of deep aquifers with wastewater;
- There is a risk of microbial contamination if treated wastewater is used by humans and livestock. In fact, it was noted that the microbiological quality of water treated by the existing purification station and non-treated water were similar.
- The availability of wastewater remains low and cannot irrigate more than 50 ha. However, its use in supplemental irrigation can significantly increase yields of cereals and farmers' incomes. From the survey, it is estimated that water can be allocated to irrigate 0.5 to 1 ha per farm in this district.

The following may be recommended:

- Because of the positive effect of supplemental irrigation and the

Table 8.5: Effect of irrigation with treated wastewater on wheat yields for WAHA variety over two years: 06/07 and 07/08.

Years	2006/2007			2007/2008		
	Grain yield (kg/ha) CA	Grain yield (kg/ha) CS	Average grain yield (kg/ha)	Grain yield (kg/ha) CA	Grain yield (kg/ha) CS	Average grain yield (kg/ha)
Rainfed T1	1423	1923	1673	528	439	510
T2	1706	1871	1788	658	681	670
T3	1740	1953	1846	715	655	685
T4	2003	4359	3181	1430	2218	1824

Note: CA: farmer's field, CS: experimental station.

Table 8.6: Effect of irrigation with treated wastewater on wheat yields for Boussalem variety over two years: 06/07 and 07/08.

Years	2006/2007			2007/2008		
Treatment	Grain yield (kg/ha) CA	Grain yield (kg/ha) CS	Average grain yield (kg/h)	Grain yield (kg/ha) CA	Grain yield (kg/ha) CS	Average grain yield (kg/ha)
Rainfed,T1	1625	1344	1485	354	729	542
T2	1738	1512	1700	576	1435	1006
T3	1673	1943	1808	665	1590	1128
T4	2254	3793	3023	1332	1964	1643

Note: CA: farmer's field, CS: experimental station.

low quality of water obtained from the existing purification station, it is recommended that the station is rehabilitated to guarantee water quality and protect the population and livestock from microbial contamination. When this is done, more experiments on supplemental irrigation are needed.

- A participatory approach to the management of the treated wastewater resource should be established.
- The community should be trained to use treated wastewater in irrigation.

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