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Life cycle assessment of cucumber irrigation: unplanned water reuse versus groundwater resources in Tipaza (Algeria)

Latifa Azeb, Tarik Hartani, Nassim Aitmouheb, Ludivine Pradeleix, Nouredddin Hajjaji and Soumaya Aribi

ABSTRACT

Effective quantitative and qualitative management of water for irrigation is crucial in many regions and the use of reclaimed water is a possible solution. Quantifying the impact of the use of such water is thus important. Using life cycle assessment methodology, this study analyzes the impact of water reuse irrigation and farmers' practices in greenhouse cucumber production. Three scenarios concerned sources of water for irrigation and agricultural practices: the first scenario used surface water including reclaimed water, the second used groundwater. The third scenario resembled the first but also accounted for fertilizer application based on theoretical cucumber requirements. The third scenario showed 35% less fertilizer is required than the quantities farmers actually use. Our results show that the higher environmental impact of irrigation using reclaimed water than using groundwater is mainly due to the over-fertilization. Comparison of the first and third scenarios also showed that the reduction in the environmental impact under the third scenario was significant. We conclude that LCA is a useful tool to compare the impacts of different water sources and farmers' irrigation/fertilization management practices, and in particular, that the quantity of nutrients in reclaimed water should be deducted from the actual amount applied by the farmers.

Key words | environmental impact, farmers' practices, groundwater, over-fertilization, reclaimed water, unplanned reuse

HIGHLIGHTS

- Evaluate the environmental impact of indirect case of reclaimed water reuse versus groundwater for agricultural irrigation using life cycle assessment (LCA).
- Our field study was conducted in the Mediterranean region of Tipaza, Algeria focusing in data from farmers work schedule.
- We compared the performance of irrigation using reclaimed water and groundwater to identify which sub-system had the most impact.
- Discuss farmers' fertilization practices in the area compared with theoretical recommendations.
- Our study could be used as basic data to farmers to respect the doses of fertilizer application with different sources water irrigation.

Latifa Azeb (corresponding author)
Agricultural Production and Sustainable
Valorization of Natural Resources (PRAVDURN),
University Djilali Bounaama of Khemis Miliana,
El Khemis Miliana, 44000 AinDefla,
Algeria
E-mail: azeb.latifa@gmail.com

Tarik Hartani
LMEA (ENSA), Tipaza University Center (CU4201),
Oued Merzoug 42000 Tipaza,
Algeria

Nassim Aitmouheb
INRAE Montpellier, UMR GEAU, University of
Montpellier,
361 Jean François Breton, 34090 Montpellier,
France

Ludivine Pradeleix
G-EAU, AgroParisTech, Cirad, IRD, Irstea,
Montpellier SupAgro, University of Montpellier,
ELSA Research Group,
Montpellier,
France

Nouredddin Hajjaji
Research Laboratory on Catalysis and Materials for
Environment and Processes LRCMEP
(LR19ES08),
National Engineering School of Gabès,
Zrig, Gabès,
Tunisia

Soumaya Aribi
PEESE, Processes, Energy, Environment and
Electrical Systems LR18ES34, National
Engineering School of Gabès,
Zrig, Gabès,
Tunisia

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INTRODUCTION

According to the threshold of scarcity established by the United Nations Development Program (UNDP), Algeria is in the category of water-poor countries (MRE 2017). The Algerian agriculture sector is the main consumer, and uses more than 64% of all water resources (MRE 2017). Reclaimed water reuse is one possible way to reduce the pressure on freshwater resources to ensure a sufficient supply of drinking water. Reclaimed water has fertilization potential as it is rich in nitrogen and/or in phosphorus (Qadir *et al.* 2007; Cirelli *et al.* 2012; Ait-Mouheeb *et al.* 2018). However, the effluent of treated reclaimed water can be reused safely without any side effects (Asano 2010; Nahed *et al.* 2017). Reclaimed water can be used for irrigation either directly from the wastewater treatment plant or indirectly after being discharged into surface water such as rivers (Ait-Mouheeb *et al.* 2020). More knowledge is needed on the impacts of reclaimed water reuse in agriculture on human health, and on different ecosystems. In the case of over-application of fertilizer, it can lead to eutrophication, acidification, and toxicity, and has other environmental impacts including nitrate pollution of groundwater (Richa *et al.* 2015). For example, long-term irrigation with reclaimed water can result in accumulation of metals such as Zn, Fe, Cu, Mn and pathogens such as helminth (parasitic worm) eggs in soil and plants that can thus be transmitted to humans or animals (Jiménez 2006; Abdel-Shafy & El-Khateeb 2019). Life Cycle Assessment (LCA) is a standard method used to quantitatively assess the environmental impacts of industrial processes at all stages, from cradle to grave. LCA is described in the ISO standards 14040 and 14044. LCA was recently applied to agricultural practices and to crops grown in greenhouses or in open fields. Romero-Gâmas (2013) analyzed the environmental impacts of lettuce and escarole crops and the effects of the different quantities of nitrogen fertilizer and concluded that the reduction of nitrogen fertilizer should be considered a priority to reduce its environmental impact. Wang *et al.* (2018) compared the environmental impact of green food-certified cucumber and conventional cucumber and also showed that fertilizer use was the largest contributor to

most impact categories. However, only a few studies have focused on reclaimed water reuse for irrigation (Muñoz *et al.* 2010; Moretti *et al.* 2019; Romeiko 2019) and have shown that replacing groundwater with reclaimed water for irrigation would reduce most environmental impact categories. Using reclaimed water also reduces the need for synthetic nitrogen and phosphorus fertilizer, thereby also minimizing the environmental impacts of the energy required for the manufacture of fertilizers. All these studies were based on experimental research and focused on direct water reuse (i.e., straight from the wastewater treatment plant).

In this study, the LCA methodology was used to compare the impact of unplanned reclaimed water reuse (surface water mixed with reclaimed water from two wastewater treatment plants) and a reference situation in which groundwater was the source. The study was based on farmers' fertilization practices in the Tipaza region in northern Algeria. Farmers' awareness of the fertilization potential of reclaimed water is discussed in light of the local dose charts recommended by ITCMI on one hand, and in comparison with study sites facing similar scarcity and pollution issues elsewhere.

MATERIALS AND METHODS

Study area

The study area is located in the valley of Nador in the Mediterranean district of Tipaza, approximately 65 km west of the capital Algiers. Two plots were selected, each containing eight greenhouses in which cucumbers are grown using drip irrigation. Each greenhouse was 400 m² (50 × 8 m) in size with seven rows of plants, 1 m between the rows, and 40 cm between the plants. The study covered the complete life cycle of the cucumber in the region, which is seven months, and began in December 2016.

In the first case study, the water used for irrigation came from Wadi Nador, which itself is mainly supplied by the

reclaimed water discharged from two wastewater treatment plants, Chenoua and Hadjout (Tipaza district). The plants have a nominal capacity of 70,000 population equivalents; each receives 11,200 m³/day, which is treated using an extended activated sludge system at low load. Before being used for irrigation, the reclaimed water is stored in an open tank (volume approximately 18 m³) then distributed by diesel-powered pumps with a nominal discharge of 1 L/h per dripper. At points where the drippers clogged, the farmers increased the flow rate to 3 L/h to unclog them. In the second case study using groundwater, irrigation water was pumped directly from a 6-m deep well by electric pumps with a nominal flow of 0.8 L/h⁻¹ per dripper and 3,500 drippers. In this case, the farmers used 65% sulfuric acid to clean the drippers once during the agricultural season. First, the farmers irrigated for 1 hour to wet the roots and protect the roots. They then injected the acid into the tank in the same way as the fertilizer so that the pH of the water in the irrigation system probably decreased, after which the outlet valve was left open for an hour to flush the irrigation pipe. Water samples were collected monthly from the tank, the Wadi (surface water including reclaimed water), and the well to analyze nitrate, phosphorus, calcium, sodium, bicarbonate, magnesium contents, pH, and electrical conductivity. Table 1 lists the composition of the reclaimed water and the groundwater. The soil in the 0–40 cm layer in both fields is clay-loam containing 1.2% organic matter. In the scenario using reclaimed water, the amount of nitrogen in the soil was 2,856 kg/ha and in the scenario using groundwater, 2,772 kg/ha.

Table 1 | Composition of reclaimed water and groundwater

Parameters	Reclaimed water	Groundwater
pH	7.53	7.21
Electrical conductivity (mS/cm)	1.88	2.44
Nitrate NO ₃ ⁻ (mg/L)	1.46	1.76
Sodium (mg/L)	184.82	305.56
Calcium (mg/L)	206.12	232.93
Magnesium (mg/L)	67.84	67.81
Bicarbonates (mg/L)	27.75	27
Sodium adsorption ratio (SAR)	2.85	4.27

Data on the farmers' practices were collected in two stages. The first survey was of nine farmers in the Nador plain who cultivated cucumber. In the second stage, two plots were selected for the comparative LCA: one plot irrigated using reclaimed water and the other using groundwater. The survey of the farmers enabled us to obtain field data for the whole seven-month study period. The amount of fertilizer and pesticide applied and the number of applications varied depending on local practices. The fertilizers used are often soluble NPK fertilizer injected into the upstream network of the drip irrigation system 20 min before the end of each irrigation period.

The data for the third scenario, which represents the theoretical fertilization needs of cucumbers in similar soil and climate conditions in controlled greenhouse experiments, were provided by the Technical Institute of Industrial and Vegetable Crops (ITCMI).

Life cycle assessment

LCA was applied to assess the environmental impacts of different sources of irrigation water for cucumber production in accordance with ISO 14040 standards. LCA includes four steps: (1) goal and scope definition, (2) life cycle inventory, (3) life cycle impact assessment, and (4) results' interpretation (ISO 14040 2006).

Goal and scope definition

The aims of the present study were to compare the environmental performances of two irrigation water resources: (1) reclaimed water from two wastewater treatment plants mixed with surface water, (2) groundwater, and (3) to analyze the fertilization practices used by farmers in the region.

Functional unit and system boundaries

To obtain an accurate picture of environmental performances, two functional units (FU) were chosen to compare the two systems: one hectare and one kilogram of cucumber. As shown in Figure 1, the system boundaries (SB) include the following sub-systems: fertilization, water and irrigation, pesticides. Soil preparation and the greenhouse

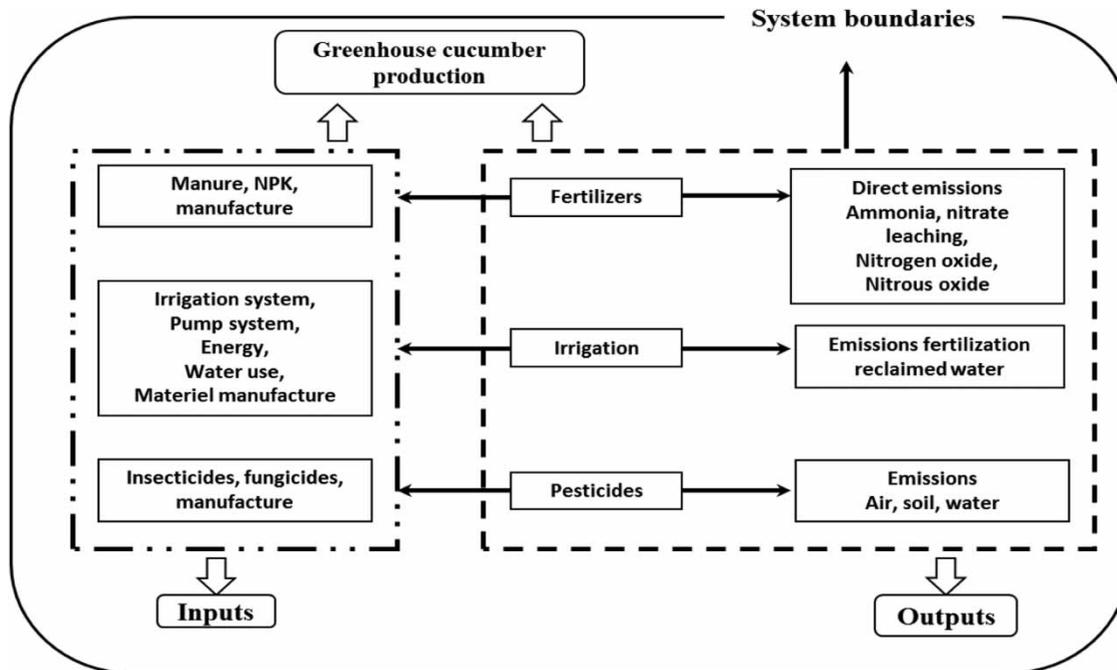


Figure 1 | System boundaries of cucumber production.

infrastructure were similar in the two cases and were thus excluded from the SB.

Fertilizer: The total quantities of N, P, and K were measured in the wide range of mineral fertilizers applied to the crop taking the nitrogen supplied by the reclaimed water into account. The crop was fertilized using water-soluble fertilizers injected into the irrigation system via the drip lines. The total amount of mineral fertilizer applied over the seven-month study period is listed in Table 2. It was divided into three applications, the first at flowering, the second application 3 weeks after flowering, and the third application at fruit development.

Table 2 | Amount of mineral fertilizer applied in the three scenarios

Mineral fertilizer input	Groundwater	Reclaimed water	Theoretical needs (ITCMI)
N-based fertilizers (kg/ha)	520	886.5	360
P-based fertilizers (kg/ha)	1,167.18	812	150
K-based fertilizers (kg/ha)	517	812	400

Direct fertilizer emissions consisted of ammonia, nitrous oxide (N₂O), N₂ and NO₂ into the air, leaching of nitrates, phosphorus, potassium, and heavy metals into the water. Several methods have been developed to estimate direct and indirect emissions of chemical fertilizers; we used those proposed by Brentrup *et al.* (2000), Nemecek & Kagi (2007), and Nemecek & Schnetzer (2012) (Table 3).

Irrigation: This includes the irrigation drip system (length 6,100 m, weight 11 g/m and length 6,096 m, weight 11 g/m under the reclaimed water and groundwater scenario, respectively). Pipes to transport the water from the Wadi to the plot were 700 m long and weighed 900 g/m in the reclaimed water scenario, and those from the well to the plot were 300 m long and weighed 695 g/m in the groundwater scenario. We included the sulfuric acid used to clean the drip irrigation nozzles in the groundwater scenario.

Pesticides: A variety of pesticides was used in the plots to control pests such as aphids, red spiders, and mildew. The active ingredients used were acetamiprid, cypermethrin, lambda cyhalothrin, fenamiphos, fostylaluminum, acrinathrin, mancozeb, cymoxanyl, copper sulfate and abamictine. The quantity and dose of pesticides differed in

Table 3 | Summary of the life cycle inventory and fertilizer emissions in the scenario with reclaimed water and in the scenario with groundwater

Inputs	Reclaimed water	Groundwater	Theoretical needs (ITCMI)
N-based fertilizers (from mineral and organic fertilizer) (kg/ha)	1 055	692	360
P-based fertilizers (kg/ha)	851	1,207	150
K-based fertilizers (kg/ha)	913	620	400
N water irrigation (kg/ha)	1.42	1.21	–
Manure (ton ha ⁻¹)	31.5	32	35
Pesticides (kg)	37.50	32.24	
Diesel fuel (pumps) (L/ha)	7,812.5	–	
Electric (pumps) (kWh/ha)		1,590	–
Water for irrigation (m ³ /ha)	4,456.66	3,106.25	4,456
Outputs (yield) (ton/ha)	128	99.2	100–150
Sulfuric acid (kg/ha)	–	14	–
Air emissions (kg/ha)			
NH ₃ -N	266	135	95
N ₂ O-N	10	7	7
NO _x -N	2	1.5	1.19
N ₂ -N	75	50	41
Water emissions (kg/ha)			
NH ₃ -N	454	273	167
P	205	218	182

the two scenarios. Pesticide emissions were calculated using the model suggested by Anton *et al.* (2004).

Transport of fertilizers and pesticides was not included because the products came from a local supplier.

Life cycle inventory (LCI)

ISO 14040 (2006) defines LCI as the ‘phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.’ The foreground data for the scenario using reclaimed water and that using groundwater were

collected in interviews with the farmers concerning their practices (based on questionnaires) and by monitoring the time the farmers spent working. In the scenario on the use of reclaimed water to fulfill theoretical cucumber requirements, the amounts of fertilizer used by the farmers were replaced by the amounts recommended by the Technical Institute of Industrial and Vegetable Crops (ITCMI 2018) in the controlled site. The amount of fertilizer used by the farmers in their plots was twice the theoretical need recommended by ITCMI. The same data and amounts as in the scenario using reclaimed water were used for the irrigation and pesticide systems. The background data were taken from the Ecoinvent V3 database. The main results relating to the two plots are presented in Table 3.

Life cycle impact assessment (LCIA)

The LCIA is the stage during which the results of the analysis of the inventory are converted into potential environmental impacts. For this study, we used the ReCiPe2016 LCIA method of calculation (Huijbregts *et al.* 2017). This method analyzes midpoint and endpoint environmental impacts. In addition, 17 midpoint impact categories were determined: global warming potential (GWP), ozone depletion (ODP), ionizing radiation (IRP), photochemical oxidant formation: terrestrial ecosystems (EOFP), particulate matter formation (PMFP), terrestrial acidification (TAP), freshwater eutrophication (FEP), marine eutrophication (MEP), terrestrial ecotoxicity (TETP), freshwater ecotoxicity (FETP), marine ecotoxicity (METP), human carcinogenic toxicity (HTPc), human non-carcinogenic toxicity (HTPnc), land use (LOP), mineral resource scarcity (SOP), fossil resource scarcity (FFP), and water consumption (WCP). These impact categories are grouped in three endpoint impact categories: human health, ecosystem quality, and resource scarcity.

RESULTS AND DISCUSSION

First, we compare the environmental impacts of the two scenarios. Second, we describe the environmental impacts caused by each scenario. Our objective was to identify the

system with the highest environmental impacts. Third, we compared farmers' actual practices with the theoretical cucumber requirements based on the ITCMI charts.

Comparison of the environmental impact of irrigation with reclaimed water and groundwater

Table 4 lists the environmental impacts of cucumbers irrigated with reclaimed water and with groundwater. Considering 1 hectare as the FU, the comparison showed that irrigating cucumbers with reclaimed water had a higher impact than irrigating cucumbers with groundwater, except for IRP, FEP, METP, LOP, and SOP, which were very similar. These results can be attributed to the quantity of nutrients that was higher in reclaimed water than in the groundwater used by farmers in the region, the quantities of mineral fertilizer being based on their experience (886.5 kg N/ha, 812 kg P₂O₅/ha, and 812 kg K₂O/ha, 520 kg N/ha, 1,167.18 kg P₂O₅/ha, and 517 kg K₂O/ha,

for reclaimed groundwater, respectively). This mainly is due to NO₃ leaching, volatilized NH₃ and N₂O emitted into the air. Similar results were reported by Wang *et al.* (2018) for cucumber cultivation.

When 1 kg of cucumber was used as the FU, the impact was very similar in the two scenarios. However, cultivating cucumber with reclaimed water caused less damage to the ecosystem than using groundwater (Figure 2). The average yield of cucumbers irrigated with reclaimed water was 128 ton/ha whereas it was 99.2 ton/ha when irrigated with groundwater. The lower yield obtained with groundwater was due to the diseases that affect the crop, like mildew.

Contribution of inputs in reclaimed water used for irrigation

The contribution of fertilization and fertilizer emission was the highest, ranging from 40% to 99% (Figure 3). The manufacture of mineral fertilizers represented a major burden in

Table 4 | Life cycle impacts under the three scenarios depending on the functional units used, 1 ha and 1 kg

Impact categories	Units	FU 1 ha			FU 1 kg		
		Groundwater	Reclaimed water	Reclaimed water Theoretical need	Groundwater	Reclaimed water	Reclaimed water Theoretical need
GWP	kg CO ₂ -eq	1.30	1.81	0.77	0.13	0.14	0.06
ODP	Kg CFC-11-eq	2.34 E-5	3.52 E-5	1.43 E-5	6.08 E-9	2.36 E-6	1.12 E-6
IRP	kBq Co-60-eq	0.031	0.033	0.010	0.003	0.002	0.0007
EOFP	kg NO _x -eq	0.0023	0.0032	0.001	0.0002	0.0002	0.0001
PMFP	kg PM _{2.5} -eq	0.005	0.007	0.003	0.0005	0.0005	0.0002
TAP	kg SO ₂ -eq	0.031	0.050	0.020	0.0031	0.0039	0.0016
FEP	kg P-eq	0.022	0.020	0.018	0.0022	0.0016	0.0014
MEP	kg N-eq	0.0019	0.0031	0.0011	0.0002	0.0002	8.84 E-5
TETP	kg 1,4-DB-eq	5.74	17.71	14.11	0.57	1.38	1.10
FETP	kg 1,4-DB-eq	0.053	0.104	0.075	0.005	0.008	0.005
FEP	kg 1,4-DB-eq	0.143	0.142	0.099	0.014	0.011	0.007
HTPc	kg 1,4-DCB-eq	0.031	0.036	0.014	0.003	0.002	0.001
HTPnc	kg 1,4-DCB-eq	1.33	1.58	0.58	0.13	0.12	0.045
LOP	m ² a crop-eq	0.031	0.032	0.009	0.003	0.002	0.0007
SOP	kg Cu-eq	0.014	0.013	0.003	0.0014	0.0010	0.0002
FFP	kg oil-eq	0.26	0.34	0.19	0.026	0.027	0.015
WCP	m ³ water-eq consumed	0.032	0.46	0.45	0.032	0.036	0.035

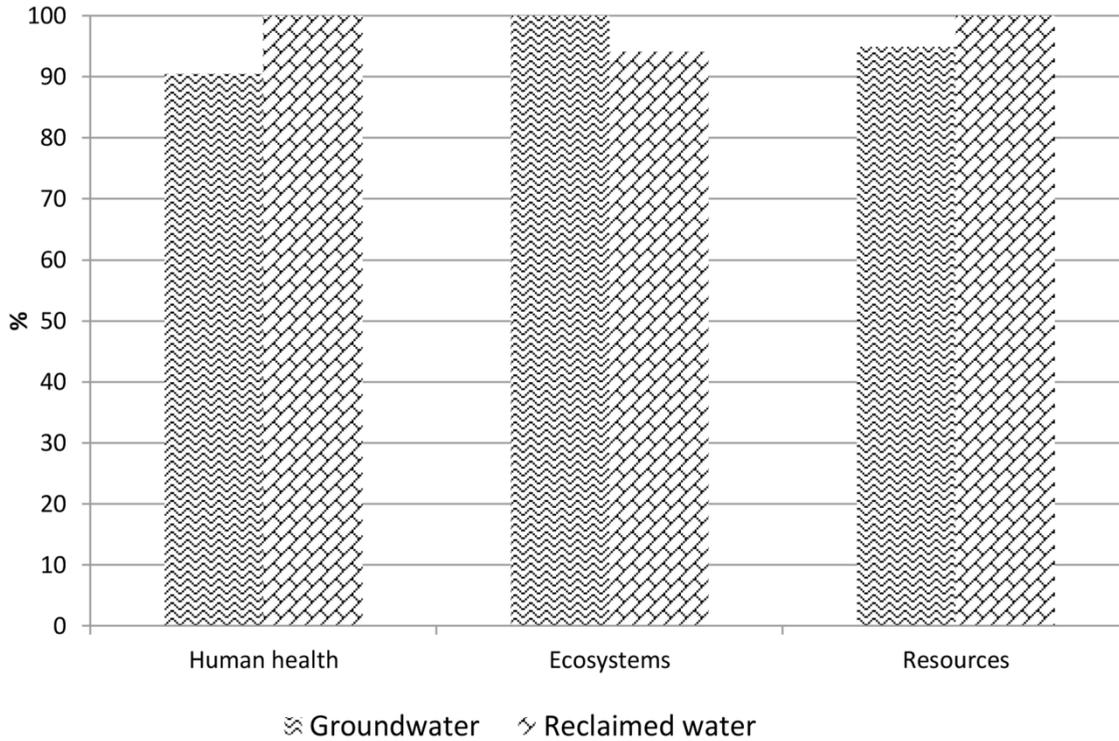


Figure 2 | Comparison of endpoint impacts for 1 kg of cucumber irrigated with reclaimed water and groundwater, ReCiPe 2016 V1.03 (H).

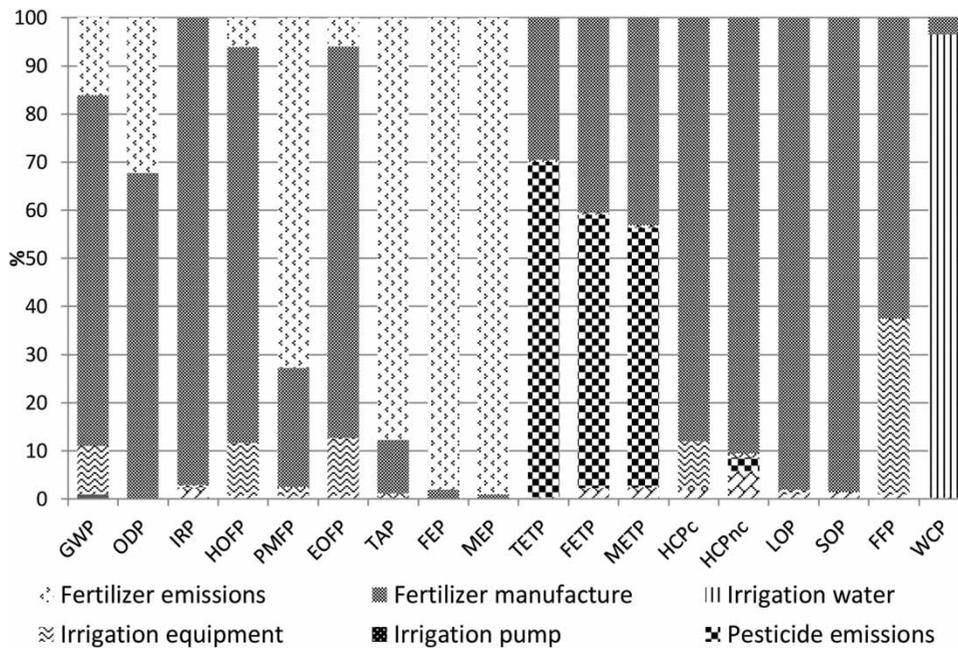


Figure 3 | Results of the analysis of midpoint impact categories for cucumbers irrigated with reclaimed water. ReCiPe 2016 1.03 (H).

LOP, IRP, HTPc, EOFP, GWP, and ODP at 98, 90, 87, 81, 72, and 67%, respectively. These results were mainly due to the unnecessarily high volumes of fertilizers applied by farmers

(886.5 kg/ha nitrogen and 812 kg/ha phosphorus). The contribution of the water was negligible due to the dilution of reclaimed water by surface water, also in comparison with

the large quantities of fertilizer used by farmers (1.42 NO₃ kg/ha). Wang *et al.* (2018) assessed the environmental impact of cucumbers grown in greenhouses and reported that the contribution to GWP of cucumber production was 204.34 kg CO₂-eq. which is considerably higher than the rates of the cucumber production systems shown in Table 4. The high GWP in their study was affected by the large quantities of fertilizer applied by the farmers (ranging from 600 to 800 kg/ha for an average yield of 50–60 ton/ha). Our average yield was higher (128 ton/ha) while the amount of fertilizer used was nearly the same.

Figure 4 shows the contribution of fertilizer to the environmental impacts due to emissions during manufacture and their application to the crop. Emissions during the manufacture of nitrogen fertilizers had the highest impact, between 47 and 71%, on all the impact categories except MEP, FEP, and TAP. Emissions due to the use of fertilizers were a major burden in MEP, contributing 99%, FEP 98%, and TAP 88%, mainly due to phosphorus emissions into water. Emissions due to the application of fertilizers were responsible for 88% of TAP and 71% of PMEP, mainly caused by emissions of N₂O, NH₃, and NO_x from N-fertilizers. These results are in agreement with those of

Romero-Gàmas (2013), who reported the highest scores for fertilizer emissions.

Pesticide emissions were responsible for 69% TETP, 56% FETP, and 54% METP. These results can be explained by the emission of active ingredients of pesticides such as Fosetyl-Al and Mancozeb. This result is in agreement with that of Muñoz *et al.* (2010). The production of pesticides (0.3% TETP, 2% FETP, and 2% METP), the manufacture of irrigation pumps and irrigation equipment had negligible effects (9% GWP, 11% EOFP).

Contribution of inputs under irrigation with groundwater

Figure 5 shows the relative contributions of inputs to the environmental impacts of irrigating cucumbers with groundwater. Fertilization was responsible for 98% of LOP, 97% of IRP, and 90% of HTPc, 90% of EOFP, 75% of GWP, 75% of TETP, 68% of FETP, and 66% of ODP. Fertilizer emissions were the second largest contributor: 98% of MEP, 98% of FEP, 83% of TAP, and 64% of PMFP. Together, fertilization was thus responsible for more than 70% of all the impact categories. The manufacture of fertilizer contributed most to all

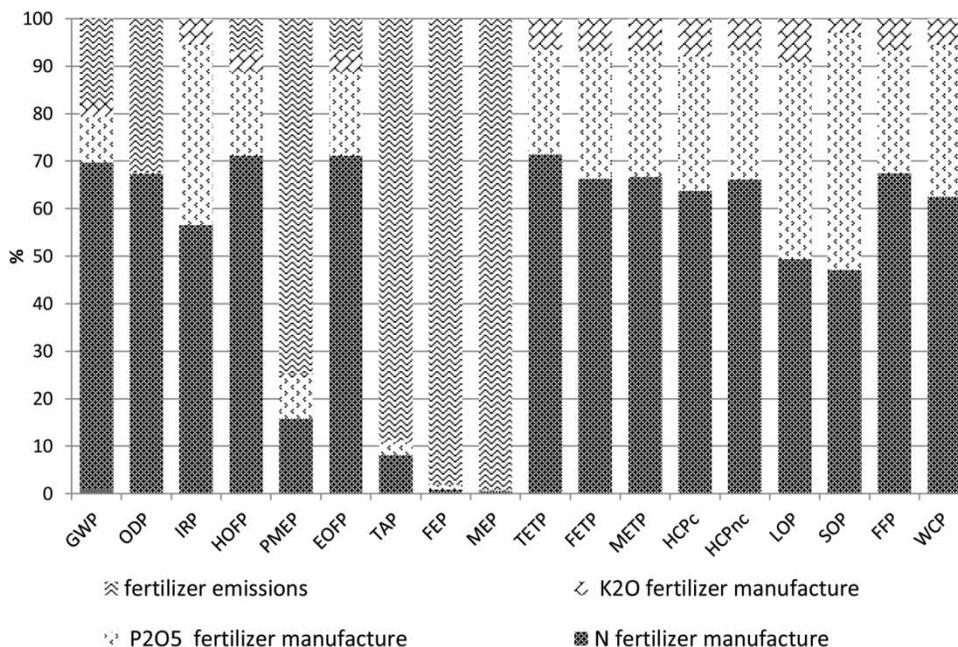


Figure 4 | Results of the analysis of midpoint impact categories of fertilizer subsystem in cucumber irrigated with reclaimed water. ReCiPe 2016 1.03 (H).

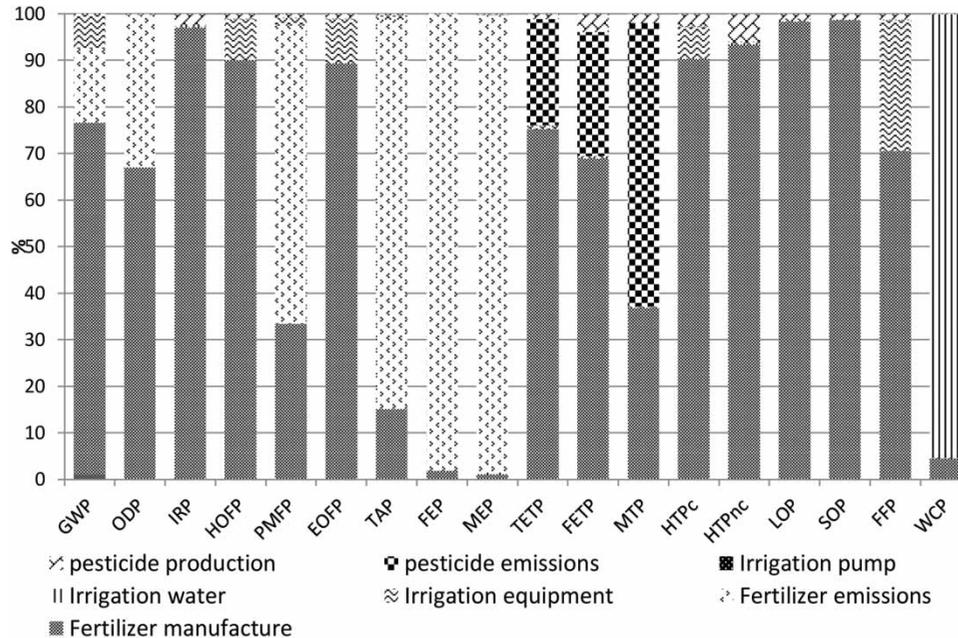


Figure 5 | Results of analyses of midpoint impact categories for cucumbers irrigated with groundwater. ReCiPe 2016 1.03 (H).

impacts categories, between 52 and 64%, while fertilizer emissions were responsible for 89% of eutrophication (Torrellas *et al.* 2012). Khoshnevisan *et al.* (2013) and Zarei *et al.* (2017) reported that the production of chemical fertilizers used for greenhouse cucumbers contributed largely to the acidification, eutrophication and GWP impact categories.

Pesticide emissions were responsible for 60% of METP and 26% of FETP due to the emission of active ingredients such as Fosetyl-Al and Mancozeb into the air, water, and soil. Irrigation water was responsible for 95% of WC, which could be explained by the fact non-renewable freshwater was used for irrigation. Results obtained in Tunisia showed that pumped water was responsible for 100% of the impact of water depletion (Pradeleix *et al.* 2015).

Using LCA, Muñoz *et al.* (2010) studied the impact of irrigation using groundwater, direct reclaimed wastewater, and desalinated water for the production of tobacco. These authors showed that irrigation with groundwater had the highest environmental impact and that irrigation with groundwater is not always the best option because groundwater is sometimes polluted by human activities and can also be affected by saltwater intrusion. The whole Tipaza region is classified as vulnerable to nitrate contamination due to the intense use of nitrogen fertilizer (Sbargoud 2013).

Comparison of the environmental impact of irrigating cucumber with reclaimed water and theoretical cucumber fertilization requirements

Figure 6 shows the results of the LCA of cucumbers irrigated with reclaimed water compared with the theoretical cucumber fertilization requirements recommended by ITCMI. Reducing fertilizer by 58% would reduce most impact categories (GWP, ODP, IRP, PMFE, EOFp, TAP, MEP, HTPc, HTPnc, LOP, SOP, FRS) by about 60% except freshwater eutrophication, for which the reduction would be about 12% due to phosphorus emissions into water. Reductions in TETp, FETp, METp ranging from 12% to 28% were affected by the manufacture of fertilizers.

According to Salhi (2013), farmers in the Mitidja region use excessive amounts of nitrogen fertilizers, and do not respect the doses of fertilizer recommended by the technical institutes for crops such as potatoes and bell peppers grown in greenhouses. The Technical Institute of Industrial and Vegetable Crops (ITCMI 2018) recommended 360 kg/ha of N fertilizer for an average yield of between 100 and 150 ton/ha. Fertilization can thus be reduced by up to 50% without negatively affecting yield, thereby reducing environmental impacts by 60%. Our results are also in agreement with those of Muñoz *et al.* (2008), who showed that a 30%

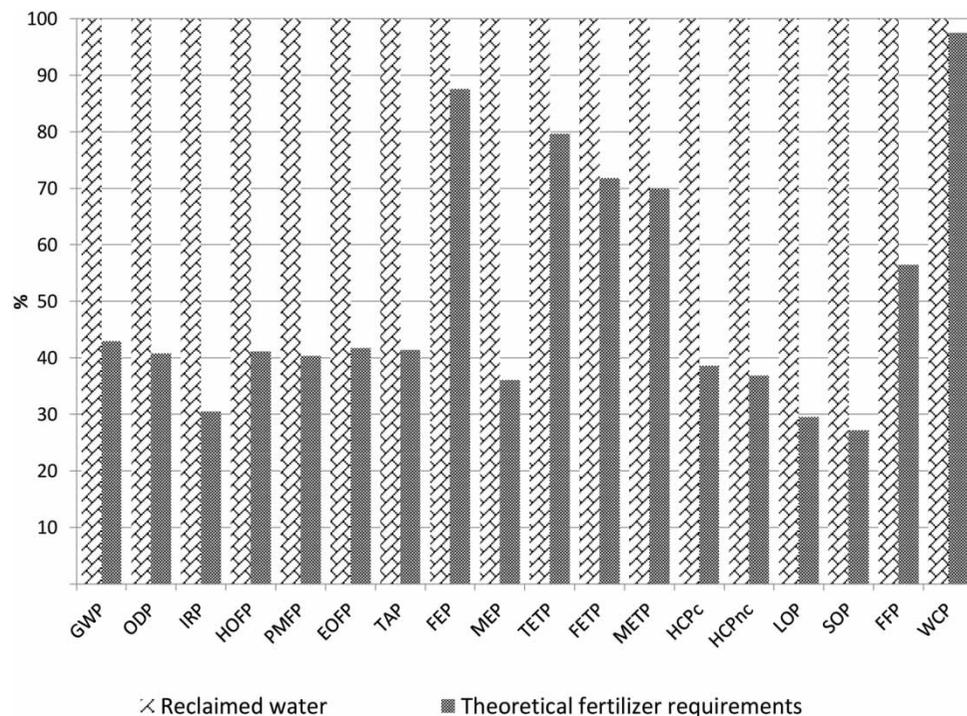


Figure 6 | Midpoint LCA results for cucumbers irrigated with reclaimed water and theoretical cucumber fertilizer requirements. ReCiPe 2016 1.03 (H).

reduction in N fertilizer would reduce the environmental impact in the categories greenhouse effect, eutrophication, photochemical oxidant formation, acidification, and abiotic resource depletion without reducing yield. In our case, the N fertilizer remaining in the soil was 2,850 kg/ha. This metric should be taken into account in the total fertilizer inputs as it could reduce the environmental impact.

CONCLUSION

This study has used current data from farmer's practices in the Tipaza region in northern Algeria to evaluate environmental impacts of the use of reclaimed water and groundwater for the irrigation of cucumbers grown in greenhouses.

Our results revealed that farmers use considerably more fertilizers than theoretically required by cucumber. Our results also show that farmers irrigate with reclaimed water without taking its nutrient potential into account. Fertilizers had the highest life cycle impacts in the case of reclaimed water. Using the LCA methodology clearly demonstrated that overuse of fertilization had negative impacts on the environment. Farmers should comply with the amounts of

fertilizers that correspond to the standard needs of the cucumber crop, which will not severely affect yield.

Our findings also provide a useful analytical framework to compare the impact of different sources of irrigation water and could be used by water managers and agricultural extension officers to propose optimum doses of fertilizer with respect to the quality of the irrigation water.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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